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U.S. Fish and Wildlife Service

Stream Design and Reclamation Guide for Interior Alaska

Technical Report #65

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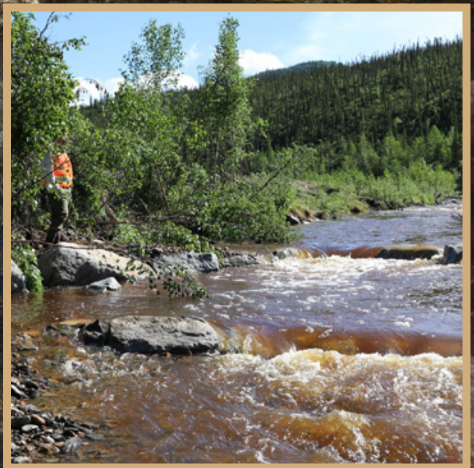

Cover Photos

Background photo: *Nome Creek.*
Inset photo left: *BLM geomorphologist surveys Little Champion Creek in Interior Alaska.*
Inset photo center: *Stream reclamation on White Creek near the Denali Highway.*
Inset photo right: *BLM Fisheries Biologist inspects reclamation work completed on Wade Creek along the Taylor Highway.*
Back cover photo: *Nome Creek.*

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Glossary of Terms

Alluvial valley – A valley with a broad width and low slope formed from overbank flooding and the deposition of fine-grained sediments. Valley widths are typically greater than seven times the channel width and valley slopes are often less than 2%. Meandering streams are commonly found in this valley type.

Alluvium – Sediment (silt, sand, gravel etc.) that is deposited in the channel or on the floodplain during flow events when the water velocity decreases.

Anastomosed Streams – A multi-thread channel pattern characterized by low stream power, low sediment supply, and high biotic controls (e.g., large wood, riparian vegetation, and beaver activity) (Castro and Thorne, 2019). These systems are often stream-wetland complexes. The channels are often separated by stable, well vegetated islands. Classified as a DA in the Rosgen Stream Classification system. Also called anabranching streams.

Anthropogenic – Environmental pollution or disturbance caused by humans.

Aufeis – The freezing of water that seeps from the ground, flows from a spring or emerges from beneath a river bed or through fractures in river ice (Woo, 2012).

Bankfull – Bankfull is a discharge that forms, maintains, and shapes the dimensions of the channel as it exists under the current climatic regime. The bankfull stage or elevation represents the break point between channel formation and floodplain processes (Wolman and Leopold, 1957). The average return interval for the bankfull discharge is 1.5 years.

Avulsion – A process where the channel location shifts abruptly. An avulsion typically occurs during bankfull or greater flow events and leads to a straightening of the stream channel.

Bankfull bench – See floodplain bench.

Braided Streams – A multi-thread channel pattern characterized by high stream power, low erosion resistance, and low biotic control (Castro and Thorne, 2019). Channels are often separated by unvegetated bars that may be inundated and mobilized during bankfull events. In Alaska, these streams are often downstream from active glaciers where sediment supply exceeds sediment transport capacity. Classified as a D in the Rosgen Stream Classification system.

Cascade – A bed feature found in steep gradient streams (slopes typically greater than 3%) and with bed material that is dominated by cobble and boulder sized material. A cascade is a steeper and coarser version of a riffle.

Catchment – Land area draining to the downstream end of the reach. Same definition as a watershed.

Colluvial valleys – Valley formed by the transport of sediment from hillslope erosion processes into the valley bottom and sometimes the stream channel. Colluvial valleys are bowl-shaped and typically confined by hillslopes. Colluvium is material that originates on the hillslopes and moves through mass wasting processes to the valley bottom where the material may interact with stream flow. These valleys are confined and support straighter, step-pool type channels (e.g., A, B, Bc, G, F). These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) less than 3.

Confined alluvial valleys – Valley formed by the deposition of sediment from fluvial processes, typically confined by terraces or hillslopes that supports transitional stream types between step-pool and meandering or where meanders intercept hillslopes. These valley types typically have a valley width ratio less than 7.0 and a meander width ratio (MWR) between 3 and 4. Stable Rosgen stream types include Bc and C.

Designer – Throughout this document, the term designer refers to the individuals who are responsible for creating and overseeing the implementation of the reclamation or restoration plan, including design of the channel and floodplain or floodplain bench. The designer can be the mine operator, government agency staff, non-profit staff, or a private consultant.

Ephemeral – Stream channels that only have flowing water during times of precipitation and runoff, including runoff from snow melt.

Exceedance probability – The probability that a certain value will be exceeded in a predefined time period. It is the reciprocal of the return interval. For example, a 100-year return interval discharge has an exceedance probability of 1%.

Floodplain – The land area adjacent to a stream channel that is normally inundated during seasonal floods. Floodplains are found in alluvial valleys and are underlain by river deposits and overbank floods (Bridge, 2003).

Floodplain bench – Also called a bankfull bench is a narrow stretch of land adjacent to the stream. It is narrower than a floodplain and exists in colluvial valleys. It is the transition zone between the channel and hillslope and is an important feature for dissipating energy in B stream types.

Functional lift – Functional lift or uplift refers to the change in stream condition or function between a pre-restoration or reclamation condition and after restoration/reclamation activities are implemented.

Incised – Incised channels have lowered their bed through the process of bed erosion. These channels carry stream flows that are greater than the bankfull discharge, thereby increasing erosive forces within the channel. Channels that have incised through human disturbances are often unstable.

Intermittent – Surface water flowing continuously during certain times of the year and more when in direct response to precipitation (e.g., seasonally when the groundwater table is elevated or when snowpack melts) (33 CFR 328.3).

Meander width ratio (MWR) – The meander width ratio of a stream channel is the belt width divided by the bankfull width. The belt width is the distance from the outside meander bend on one side of the valley to an outside meander bend on the opposite side of the valley. The measurement is made perpendicular to the fall line of the valley.

Natural Channel Design (NCD) – For this report, natural channel design refers to the Rosgen Geomorphic Channel Design method described in Part 654 Stream Restoration Design, National Engineering Handbook, published by the United States Department of Agriculture, Natural Resources Conservation Service, 2007

Perennial – Surface water flowing continuously year-round (33 CFR 328.3).

Permafrost – A thermal condition of surface earth materials that remain below 0°C for two or more years (Muller, 1945; Harris et al., 1988).

Pool – A stream feature (facet) that is deeper than the riffle and typically with a lower slope. Pools are formed from a combination of bed scour and backwater processes. They dissipate energy and provide habitat for fish and other aquatic organisms.

Project area – The geographic extent of a project. This area may include multiple reaches where there are variations in stream physical characteristics and/or differences in project design approaches.

Reach – A homogeneous stream reach within the project area, i.e., a stream segment with similar valley morphology, stream type, stability condition, riparian vegetation type, bed material composition, and level of anthropogenic influence. Multiple reaches may exist in a project area where there are variations in stream physical characteristics and/or differences in project design approaches.

Reclamation – BLM regulations define reclamation as taking measures following disturbance of public lands caused by operations to meet applicable performance standards (43 C.F.R. § 3809.420) and achieve conditions required by BLM at the conclusion of operations. Components of reclamation include, where applicable: (1) Isolation, control, or removal of acid-forming, toxic, or deleterious substances; (2) Regrading and reshaping to conform with adjacent landforms, facilitate revegetation, control drainage, and minimize erosion; (3) Rehabilitation of fisheries or wildlife habitat; (4) Placement of growth medium and establishment of self-sustaining revegetation; (5) Removal or stabilization of buildings, structures, or other support facilities; (6) Plugging of drill holes and closure of underground workings; and (7) Providing for post-mining monitoring, maintenance, or treatment.

Restoration – Manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former or degraded aquatic resource. 33 C.F.R. § 332/40 C.F.R. § 230

Restoration potential – Restoration potential is the highest level of restoration that can be achieved based on an assessment of the contributing catchment, reach-scale constraints, and the results of the reach-scale function-based assessment (Harman et al., 2012).

Riffle – Riffles are shallow, steep-gradient channel segments typically located between pools. Riffles are the river’s natural grade control feature (Knighton, 1998) and are sometimes referred to as fast-water channel units (Hawkins et al., 1993; Montgomery and Buffington, 1998). For assessment purposes, in meandering streams riffles broadly represent the section between meander bends known as a crossover, regardless of bed material size. For this report, the term riffle also refers to the crossover in sand bed streams and the cascade section of steep mountain streams.

Ripple – Ripples are small-scale bed forms in sand bed channels. As sand accumulates and the size of the ripple grows, it becomes a dune. Other sand-bed forms include plane beds and anti-dunes (Knighton 1998).

Riparian extent – The percentage of the historic or expected riparian area that currently contains riparian vegetation and is free from utility-related, urban, or otherwise soil disturbing land uses, fill, and development.

Riparian vegetation – Plant communities contiguous to and affected by shallow water tables and fluvial processes.

Significant pools – All pools, including geomorphic pools, that meet the following criteria (adapted from BLM, 2017): Contained within the main channel; contain the thalweg; laterally and longitudinally concave; and span at least 50% of the wetted channel at any location within the pool.

Stream Functions Pyramid – A hierarchical framework developed by Harman et al. (2012) that illustrates the relative relationship of stream functions and parameters that can be used to describe those functions

Stream Evolution Triangle – A conceptual model developed by Castro and Thorne (2019) that can help a designer visualize and think through how process drivers of hydrology, geology, and biology produce various channel forms, e.g., straight, meandering, braided, or anastomosed.

Unconfined alluvial valleys – Wide, low gradient (typically less than 2% slope) valleys that support meandering and anastomosed stream types (e.g., C, E, DA). In alluvial valleys, rivers adjust pattern without intercepting hillslopes. These valleys typically have a valley width ratio greater than 7.0 (Carlson, 2009) or a stream meander width ratio (MWR) greater than 4.0 (Rosgen, 2014).

Thalweg – The line of lowest elevation in the stream channel; the deepest part of the stream and the primary flow path at baseflow.

Unnecessary or undue degradation (UUD) – conditions, activities, or practices that:

(1) Fail to comply with one or more of the following: the performance standards in 43 CFR § 3809.420, the terms and conditions of an approved plan of operations, operations described in a complete notice, and other Federal and state laws related to environmental protection and protection of cultural resources;

(2) Are not “reasonably incident” to prospecting, mining, or processing operations as defined in 43 CFR § 3715.0-5 ; or

(3) Fail to attain a stated level of protection or reclamation required by specific laws in areas such as the California Desert Conservation Area, Wild and Scenic Rivers, BLM-administered portions of the National Wilderness System, and BLM-administered National Monuments and National Conservation Areas.

List of Symbols and Equations

Symbol / Acronym	Description	Equation	Section of Technical Report
A_{bkf}	Riffle Cross Sectional Area	$A_{bkf} = W_{bkf} \times d_{bkf}$	10.1 Riffle and Pool Dimension Design Criteria
CL	Channel Length	Channel measurement from station 0 to the end station (ft), measured along one side of the channel, the top of the bank, or bottom edge of the channel, or the channel centerline.	8.2 Valley/Channel Slope and Cross Section, 10.2 Channel Pattern/Alignment Design
DA	Drainage Area		6.2.1 Drainage Area Calculation
d_{bkf}	Riffle Mean Depth at Bankfull Stage	$d_{bkf} = A_{bkf} / W_{bkf}$	10.1 Riffle and Pool Dimension Design Criteria
d_{max}	Riffle Maximum Depth at Bankfull Stage		10.1 Riffle and Pool Dimension Design Criteria
d_{mbkfp}	Pool Maximum Depth at Bankfull Stage		10.1 Riffle and Pool Dimension Design Criteria
D_{50}	Median particle size		8.3 Bed Material Characterization 8.4 Stream Classification
D_{84}	84^{th} percentile from grain-size distribution.		8.3 Bed Material Characterization 10.3 Vertical Stability Assessment of the Design Dimension
γ	Specific or unit weight of water	Held as a constant 62.4 lbs/ft^3	10.3 Vertical Stability Assessment of the Design Dimension
ER	Entrenchment Ratio	$ER = W_{fpa} / W_{bkf}$	8.4 Stream Classification, 10.4 Floodprone Area Design and Stability Assessment
k	Sinuosity	k= CL / VL or VS / S	8.4 Stream Classification, 10.2 Channel Pattern/Alignment Design
L_p	Pool Length		11.4 Riffle/cascade, step, and pool lengths
L_r	Riffle Length		11.4 Riffle/cascade, step, and pool lengths
P_s	Pool Spacing	Distance between the d_{maxp} of sequential pools.	11.1 Pool Spacing
S or CS	Average Water Surface Slope, where elevation is preferably measured at the water surface from	S or CS = Δ Elevation from Upstream to Downstream end of Reach (ft) / CL (ft)	8.4 Stream Classification, 10.3 Vertical Stability Assessment

Symbol / Acronym	Description	Equation	Section of Technical Report
	the beginning of riffle features		
τ	Shear Stress	$\tau = \gamma RS$ OR $\tau = (\gamma)(d_{bkf})(CS)$	10.3 Vertical Stability Assessment of the Design Dimension and Slope
VL	Valley Length	Straight-line measurement from station 0 to the end station (ft), parallel to the valley fall line.	8.2 Valley/Channel Slope and Cross Section, 10.2 Channel pattern/alignment design, 10.3 Vertical Stability Assessment of the Design Dimension and Slope
VS	Valley Slope	VS = Δ Elevation from Upstream to Downstream end of Reach (ft) / VL (ft)	8.2 Valley/Channel Slope and Cross Section, 10.3 Vertical Stability Assessment of the Design Dimension and Slope
VW	Valley Width	Width of valley, measured perpendicular to the fall-line of the valley (ft).	8.2.2 Valley and Channel Cross Sections
VWR	Valley Width Ratio	$VWR = VW / W_{bkf}$	8.2.2 Valley and Channel Cross Sections
W_{bkf}	Riffle Bankfull Width	Design calculation. $\sqrt{\frac{W}{D} * A}$	10.1 Riffle and Pool Dimension Design Criteria
W_{bkfp}	Pool Bankfull Width		10.1 Riffle and Pool Dimension Design Criteria
W/D	Width/Depth Ratio	Bankfull width of the riffle / Mean depth of the riffle	8.4 Stream Classification, 10.1 Riffle and Pool Design
W_{fpa}	Flood-Prone Area Width	W_{fpa} = Width at Elevation determined by 2 x D_{max}	8.2.2 Valley and Channel Cross Sections

1.0 Introduction and Background

The Bureau of Land Management (BLM) is responsible for permitting and inspecting placer mine operations on BLM managed lands throughout Alaska. Authorized mining operations on unpatented federal mining claims must adhere to a variety of requirements, including the development and implementation of mining and reclamation plans. Specifically, the 43 CFR 3809 (1981 and 2001) regulations require miners to complete reclamation consistent with general and specific performance standards. The standards require the use of equipment, devices, and practices that will satisfy the reclamation requirements outlined in 43 CFR 3809.420, which include but are not limited to measures to control erosion and water runoff, reshaping the area disturbed, revegetation, and the rehabilitation of fisheries and wildlife habitat.

Environmental impact statements developed in the late 1980s described impacts to fisheries habitat from placer mining in Alaska. These documents also provided insight regarding fish habitat recovery and channel stability goals after reclamation based on BLM requirements to rehabilitate fisheries habitat (BLM, 1998a, b, c,). Recent national BLM policies further refined the definition of fisheries habitat rehabilitation as a stable channel form with adequate vegetation to reduce erosion, dissipate energy, and promote the recovery of instream habitats (BLM H-3809-1, 2012). In 2014, BLM Alaska issued its first specific policy for stream reclamation effectiveness monitoring based on quantitative measures and current science (BLM AK IM 2015-004). This policy established the link between hydraulic and geomorphic functions and the rehabilitation of fisheries habitat. The specific methods used to assess stream reclamation have been refined since 2014 in an effort to simplify monitoring and assessment procedures, but the foundational aspects of the 2014 policy are still reflected in the current policy (BLM AK IM 2021-010). All of these documents and policies focus the reclamation phase on channel stability since it is the basis for habitat rehabilitation and recovery.

A review of available literature found that stream reclamation practices in Alaska commonly fall short of the requirements and intentions stated above (Tidwell et al., 2000; Arnett, 2005; Carlson et al., 1998, Milner and Piorkowski, 2004; BLM, 1998a, b, c, and Brady et al., 2018). A typical reclamation approach has been to grade a pilot channel and re-contour valley bottoms as shown in Figure 1 without the use of hydrology, hydraulics, or geomorphology design criteria. The lack of attention to a design process, combined with the harsh Alaskan climate has led to extensive channel and sometimes valley wide erosion. As a result of the reliance on natural recovery process and faulty assumptions about recovery trajectories, channels often remain unstable and aquatic habitats remain degraded (Brady et al., 2018). Common reclamation results are shown in Figure 2.

Figure 1. Placer mine near Central, Alaska. Photo taken during the reclamation phase.

Figure 2. Common outcome of typical stream reclamation approaches. This photo shows extensive bank erosion, homogenous instream habitat, and overall channel and floodplain instability after 20 years of "natural recovery."

A study completed by the BLM in 2018 quantified the observations described above. Brady et al., (2018) assessed 40 natural streams (used to determine reference condition) and 10 reclaimed placer-mined streams in the sub-arctic region of Interior Alaska. The placer-mined sites ranged from 1 to 50 years post reclamation. The assessment method included over 50 instream and riparian indicators of channel stability and habitat; however, three indicators were considered in greater detail: channel incision, bank cover and stability, and riparian vegetation complexity. Results showed that 60% of sites (6 out of 10) had channel incision values that were rated as "functioning-at-risk" based on a moderate departure from reference condition. Eight of the reclaimed sites had bank cover and stability values and riparian vegetation complexity that were "not functioning" based on a major departure from reference condition. The results were attributed to the fact that rehabilitation efforts primarily relied on natural recovery processes rather than a quantitative assessment and design process that was followed by construction practices that installed properly sized channels, pool habitats, and robust vegetation.

Miner-led reclamation is not the only approach to instream and riparian rehabilitation that has not performed well. Engineers, geomorphologists, and other disciplines have experienced problems too. Densmore and Karle (2009) evaluated a reclamation project initiated in 1991 in Denali National Park that had been placer mined for over 80 years. Mining resulted in channel incision, bank erosion, and the removal of riparian vegetation. The rehabilitation approach included a hydraulic design assessment with a new channel dimension sized to carry flows slightly larger than the bankfull discharge, with the floodplain carrying the 100-year discharge. Shear stress analysis was used to guide the design of a stable channel and a variety of bioengineering methods were used to provide bank and floodplain re-vegetation, including brush bars, willow cuttings, and brush layering. Monitoring results showed that significant channel and floodplain erosion occurred during moderate to large flood events; however, there were a variety of lessons learned from the post-flood monitoring.

First, the authors noted that the channel had been improperly sized due to poor data quality and improper assumptions about channel forming discharge theory. Second, due to mining, the average size of the bed material was decreased by 50% (as estimated by the authors), resulting in much finer grained materials for the rehabilitation project than the prior condition. The bed armor layer was also removed and the project design did not include reintroducing an armor layer that was resistant to bed erosion.

Finally, the lack of streambank and floodplain vegetation contributed significantly to streambank and floodplain erosion. The brush bars and layers did perform well where installed. The authors conclude that "future projects in similarly disturbed watersheds will require a better understanding of the available sediment and its source, channel forming discharge, sediment transport characteristics, and natural re-vegetation." The authors did not call out icing as a specific cause of reclamation damage; however, BLM field reports and staff observations have often noted excessive icing on reclaimed mine sites resulting in channel avulsions, bank erosion, and floodplain erosion (personal communication with BLM hydrologists and fish biologists).

A recent demonstration and applied research project implemented by BLM experienced similar problems. The project, known as Demo 1, was constructed in 2015 in the Wade Creek Watershed near Chicken, Alaska (located at Milepost 85 on the Taylor Highway). The project used hydrology, hydraulic, and geomorphology principles and a design approach called Natural Channel Design (NCD). During the design process, the decision was made to construct a meandering channel to create pool habitat for Arctic grayling (*Thymallus arcticus*), which is a recreationally important fish species in the drainage. The design sought to create pools along the outside of each meander bend. Constructed riffles and log sills were used to provide grade control. And, for possibly the first time in Alaska, vegetation transplants with toe wood were used to provide lateral stability in each meander bend and at critical locations along the floodplain. The project was stable through numerous bankfull and near-bankfull events but had major adjustments during the first floodplain event. Several meander bends migrated down valley, the riffles widened, and many of the transplants were destroyed. The primary failure mechanism seemed to be the undermining of transplants along the lower third of the upstream-most meander bend. Once the transplants were undermined, they collapsed into the channel. This allowed the stream to quickly migrate across and down-valley because the floodplain sediments were unconsolidated cobble and gravel with high proportion of sand. Since grains of sand act as ball bearings that accelerates sediment transport (Wilcock et al., 2009), the floodplain sediments were quickly mobilized. If the stream bank foundation or toe had held, the transplants would likely have remained in place, and the channel would not have migrated down valley. Some floodplain erosion would likely still have occurred, but not down-valley migration of the meander bends. This failure mechanism underscores the importance of designing, installing, and maintaining robust stream bank toe protection anytime a curve or meander bend is included in a design. The lessons learned from this project and others in the region are being used to formulate a new design for this site. The most likely solution will be to replace the meandering design with a straighter channel (step-pool approach), which has proven effective at other demonstration projects in Interior Alaska.

Fortunately, successful rehabilitation projects have been completed in Alaska. The U.S. Forest Service has completed several placer mine reclamation projects on the Kenai Peninsula (Bair et al., 2008). The BLM has completed several additional demonstration projects in Alaska using step-pool (straight channel) approaches and is actively working with miners to develop stream reclamation designs that are in various stages of implementation. Descriptions of these projects are provided in Appendix A. Early monitoring results show that these projects are remaining stable and have improved aquatic habitat. However, adaptive management (i.e., maintenance) has been necessary to maintain channel stability and habitat. The lessons learned from what has and has not worked are incorporated into this planning and design guide to create resilient reclamation projects that meet BLM performance standards. More emphasis will be placed on successful Interior projects because the Kenai Peninsula has a different climate. The Interior sites often have more severe icing events, less large wood, and less precipitation (Shulski and Wendler, 2007).

2.0 Purpose of this Document

The primary purpose of this document is to provide a planning and design guide for stream designers involved with placer mine reclamation in Interior Alaska. The document provides step-by-step instruction on how to assess watershed and reach stability conditions, evaluate risk of project failure, and design Rosgen B channels that have a higher probability of meeting BLM reclamation performance standards (Section 4.0) than currently used methods. The focus is on Rosgen B stream types (including Ba and Bc) since that is the most common condition for placer mines. However, guidance is provided on selecting the correct stream type for a given project site, recognizing that it could be a stream type that is not a B. If other stream types are appropriate for a given site, references are provided to other design manuals.

This detailed guide is intended to result in stream reclamation plans with sufficient detail to allow for timely processing by agency staff and, if implemented properly, result in stable stream channels and rehabilitated habitats. However, in-stream mining and associated stream reclamation pose unique challenges based on numerous factors. The risk assessment portion of this guide (Section 9.3) acknowledges that some site and watershed conditions pose a high risk of reclamation failure. This information should be considered during the plan review and National Environmental Policy Act (NEPA) processes to minimize impacts to the environment and ensure that the BLM performance standards are met during reclamation.

A map of the Interior region of Alaska (Figure 3) is based on the same region defined in the Alaska Interior Stream Quantification Tool (AKSQTint) User Manual (v1.0) (Steering Committee, 2021). The regional boundaries are the same to provide consistency between the Stream Quantification Tool (SQT) study area and the applicability of this technical report. However, the design process provided in this document could be followed for other regions of Alaska, but the regional curves and reference data / design criteria data would need to be updated based on regionally specific information.

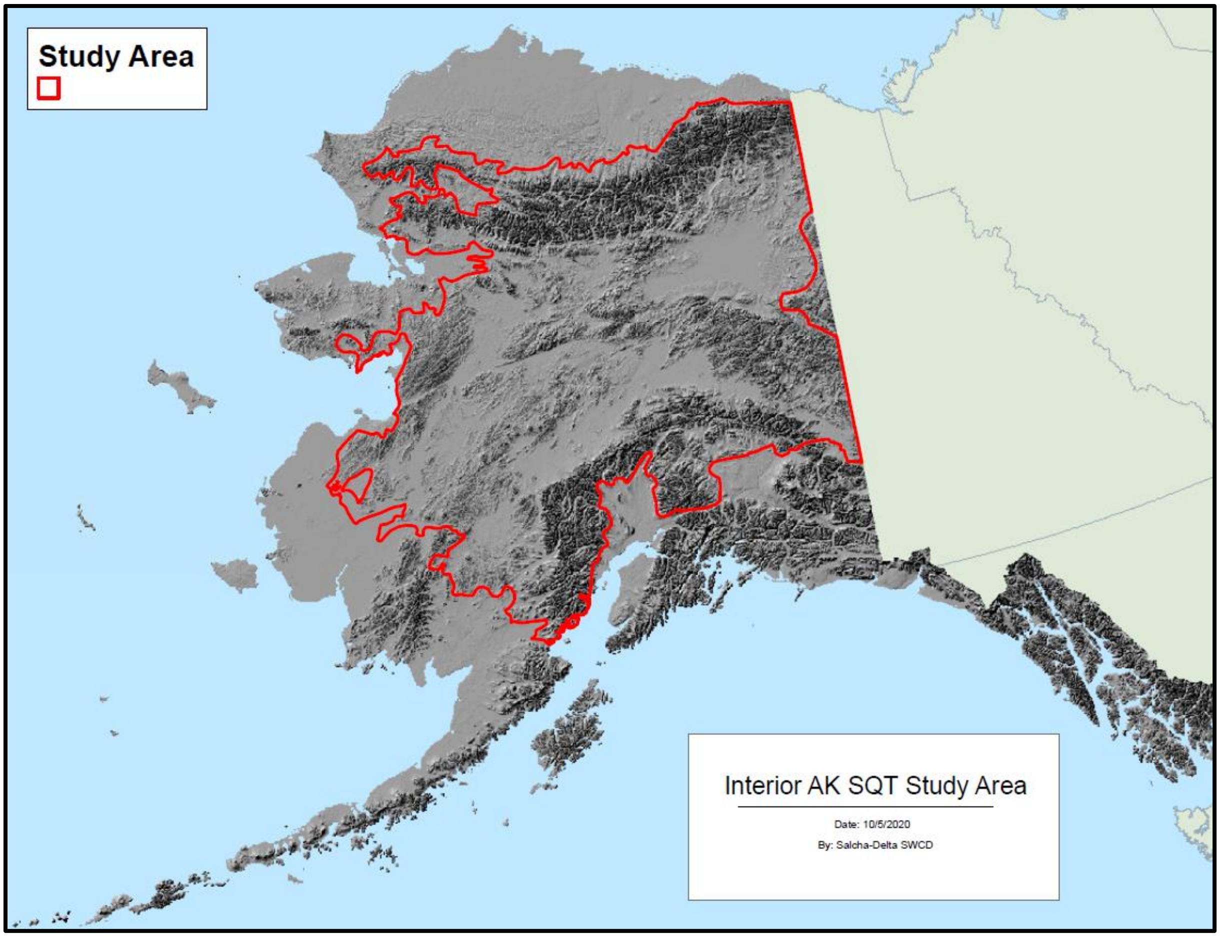


Figure 3. Interior Alaska boundary used in the AKSQTint and this technical report.

In addition to being used by stream designers involved in placer mine reclamation associated with BLM requirements, this document could be used for reclamation planning administered by other organizations, such as state agencies. In addition, other federal and state agencies, non-profit organizations, and private entities could benefit from this technical report if their programs focus on reclaiming stream corridors that have been impacted by mining or even other activities. This document could also be used to assist in stream designs within compensatory stream mitigation programs, stream restoration projects, and more. For stream compensatory mitigation projects, this design manual compliments the use of the Alaska Stream Quantification Tool (Steering Committee, 2021).

This document is the sequel to *Application of Natural Channel Design Techniques in Sub-Arctic Alaska* (Harman, 2018). That document provides background information on permafrost hydrology, icing processes, the Stream Functions Pyramid Framework, the Natural Channel Design process, and common issues related to placer mining in Alaska. The bulk of that document provides the applied science of developing bankfull regional curves, reference data sets, and design criteria needed to complete the design steps included in this document. It is recommended that stream designers read Harman (2018) before using this technical report.

3.0 Intended Audience

This document is primarily intended for stream designers who are responsible for developing or reviewing the stream and floodplain portion of placer mine reclamation plans. However, it also applies to designers developing stream restoration or compensatory stream mitigation designs. Typically, a successful stream design is completed by a team of engineers, hydrologists, geomorphologists, and biologists who have experience with the applied science and application of stream reclamation, stream mitigation, and/or restoration. The ideal team has hydrologists and geomorphologists performing watershed assessments, channel stability assessments, bankfull identification and verification, and making suggestions or recommendations to the engineer on design criteria and risk. Biologists perform vegetation assessments, identify vegetation transplant opportunities, assist with habitat assessments, and develop re-vegetation plans. The engineer takes this information and, with input from the other team members, designs the channel dimension, pattern, and profile that is most likely to meet performance standards. Note, teams often work across disciplinary boundaries, so this is just the idealized view of how experts with different academic and practical experience can work together. The important point is that this is not a simple process, and it is rare that one person can do all the assessments and design needed to create a successful project.

The document will also assist regulators and others who are responsible for reviewing reclamation or restoration projects. Appendix B in particular should be helpful in reviewing a project design – this appendix provides a form showing the results (or answers) from each design step.

4.0 Performance Standards

Mining on BLM managed public lands is governed by the 1872 Mining Law, as amended, and the Federal Land Policy and Management Act of 1976. BLM's discretion is limited to the prevention of unnecessary or undue degradation (UUD, 43 CFR 3809.5), which is tied to meeting general and specific performance standards (43 CFR 3809.420). The prevention of UUD involves every aspect of the life of a mine, but reclamation requirements are a key component outlined in the performance standards. From a stream reclamation perspective, the prevention of UUD is contingent upon using the appropriate equipment, devices, and practices to effectively control erosion and water runoff, reshape the disturbed area to compliment the surrounding drainage topography, revegetate the streambank and floodplain, and rehabilitate fisheries habitats as is outlined in 43 CFR 3809.420. Additional requirements necessary to prevent UUD include compliance with Federal and state laws, including laws related to water quality.

Over the last ten years, BLM Alaska has been working to improve consistency and communication with the mining community regarding stream reclamation through the development of policy and outreach materials. Policy guidance and training has minimized inconsistencies regarding reclamation evaluations and provided opportunities for technical assistance to miners regarding stream reclamation. BLM Alaska's stream reclamation effectiveness monitoring policy is based upon established principles of stream stability rooted in science and from experience in Alaska. Achieving the stream reclamation related performance standards outlined in 43 CFR 3809.420 is contingent on achieving stream stability, which then serves as the foundation for minimizing erosion and rehabilitating habitat. While stream stability involves a complex suite of factors, the BLM focuses on four key attributes: floodplain connectivity, bedform diversity, lateral stability, and riparian vegetation. These four key attributes not only meet the requirements of the performance standards, but they are also consistent with BLM policy that requires reclamation provide a stable channel form with adequate vegetation to reduce erosion, dissipate stream energy, and promote the recovery of in-stream habitats similar to level which were present prior to mining. These attributes are addressed in the planning, design, and construction sections of this document.

Designers using this document for compensatory stream mitigation will need to follow different guidelines for developing performance standards than BLM reclamation performance standards. Compensatory stream mitigation performance standards are defined as observable or measurable physical (including hydrological), chemical and/or biological attributes that are used to determine if a compensatory mitigation project meets its objectives (33 CFR 332.2). The designer will work with the U.S. Army Corps of Engineers and potentially other agencies to develop the performance standards. Designers working on projects other than BLM placer mine reclamation or compensatory stream mitigation should consult with the agency or entity funding or approving the work to determine if and how performance standards apply to the project.

5.0 Document Structure

The remainder of the document is the planning and design guide, which is separated into phases. The guide is a compilation of the best available science and applications that are suited for working on placer mine reclamation and other degraded stream sites within Interior Alaska. The bulk of the methods are pulled from the resources listed below, and minor additions are included from others. The planning and design methods are further guided by the lessons learned from implementing and evaluating demonstration projects in the Alaskan Interior (see a listing of demonstration projects in Appendix A).

5.1 Planning and Design Guidance Sources

Stream reclamation/restoration designers should be familiar with the following resources before applying the planning and design phases provided in this guide. The bulk of the methods in this document are pulled from the following resources, and minor additions are included from others. The full citation for these resources is included in the References section.

- United States Department of Agriculture, Natural Resources Conservation Service (USDA-NRCS) National Engineering Handbook, part 654, Stream Restoration Design. Guidance was based on Chapter 11: Rosgen Geomorphic Channel Design and Technical Supplement TS14I: Streambank Soil Bioengineering. This guidance was applied in some way to all phases, but mostly to Phases 4-6.

- *Stream and Watershed Restoration*: A Guide to Restoring Riverine Processes and Habitats. Edited by Phillip Roni and Tim Beechie. Applied to Phases 1 and 2.
- Application of Natural Channel Design Techniques in Sub-Arctic Alaska by Will Harman. This document is used to apply bankfull regional curve and reference reach information to Phases 4 and 5.
- Stream Evolution Triangle by Janine Castro and Colin Thorne. This paper is used in Phases 2 and 3.

5.2 Planning and Design Phases

There are eleven planning and design phases. Phases 1-4 are the planning phases where the watershed and stream reach are assessed, design risk is determined, and design alternatives developed. Phases 5-8 work through the design process. Phase 9 discusses permitting, followed by Phases 10-11, which cover construction through adaptive management. A list of the phases follows.

Phase 1: Project Reach Delineation, Watershed Assessment, Watershed Hydrology, and Bankfull Identification and Verification

Phase 2: Goals and Objectives

Phase 3: Existing Condition Assessment Procedures

Phase 4: Developing Design Alternatives

Phase 5: Natural Channel Design Procedure for B Stream Types

Phase 6: Channel Profile and Cross Section Design

Phase 7: In-Stream and Bankfull Bench Structure Design

Phase 8: Final Design Plan Set and Specifications

Phase 9: Permitting

Phase 10: Construction

Phase 11: Monitoring, Inspection, Maintenance, and Adaptive Management

Each result from the planning and design steps should be entered into the form provided in Appendix B.

6.0 Phase 1: Project Reach Delineation, Watershed Assessment, Watershed Hydrology, and Bankfull Identification and Verification

The data and information gathered in Phase 1 provide a foundation for decisions and calculations that will be made in later phases. Section 6.1 includes methods for delineating stream reaches within the project limits. Reach delineation creates a method for organizing assessments, data analysis, design development, monitoring, and reporting. In Section 6.2 the watershed assessment is covered and includes several components: drainage area calculations, completing a catchment assessment form, and determining watershed-scale risk factors that could affect reclamation or restoration success. Section 6.3 provides a range of methods and alternatives for quantifying watershed hydrology based on available data, type of project (reclamation versus mitigation), and the expertise of the designer. Finally, Section 6.4 provides guidance on how to identify and verify the bankfull stage, including guidance on how to use the bankfull concept on mine sites without bankfull indicators.

The results from each section should be entered on the Design Summary Form (Appendix B).

6.1 Stream Reach Delineation

A project or stream reach is a section of channel that is selected for reclamation and assigned a unique identification number and/or symbol. A mine site will have at least one stream reach but could have more depending on the variability of the site conditions and the size of the mine. Large mines that occupy multiple valleys and tributaries or varying site conditions will have multiple reaches. For example, each tributary will be its own reach and the mainstem will be its own reach. If conditions vary within the tributaries or mainstem, additional reach breaks may be needed. Reach delineation breaks should consider changes in valley type, stream type, and reclamation approach. Stream confluences should also be used as reach breaks. Figure 4 shows an example of single reach for a select mine. Figure 5 shows an example of two reaches on the same mine site due to a change in valley type. Reach 1 is in a confined-alluvial valley and Reach 2 is in an unconfined alluvial valley. Note that the channel moves away from the road in Reach 2, creating a wider valley.

Figure 4. Single reach for a select mine site.

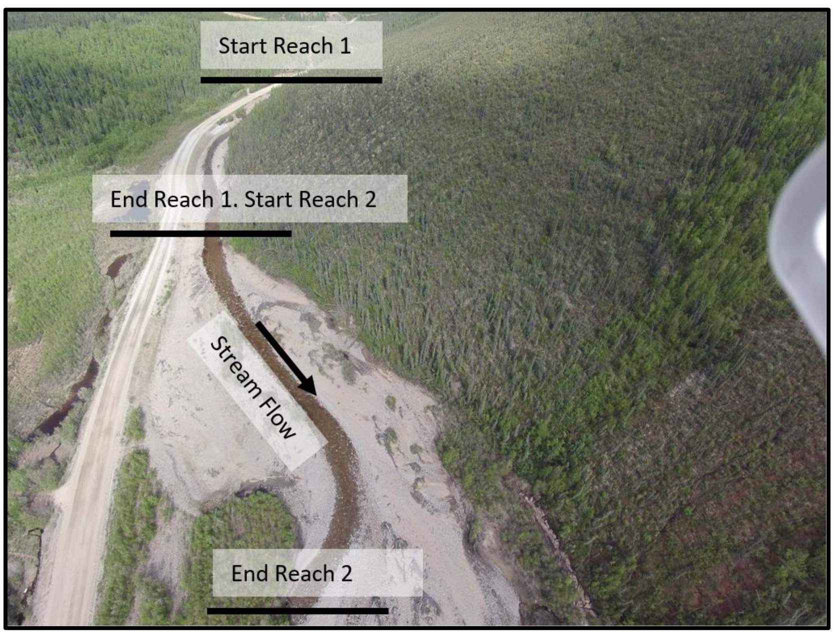


Figure 5. Multiple reaches for a select mine site due to changes in valley type.

The reach identification number and brief description should be provided on the form in Appendix B. An aerial photo or map showing the reach limits should also be provided.

6.2 Watershed Assessment

The watershed assessment includes determining the drainage area (DA), completing the catchment assessment form, and assessing the watershed-scale risk to reclaiming a stable channel with aquatic habitat features. Each task is described below.

6.2.1 Drainage Area Calculation

The watershed (also known as catchment or drainage area) is the land area in square miles that drains water to the downstream end of the project reach. Miners can use a BLM provided webservice (https://arcg.is/18iWjW) for determining the drainage area of project reaches within their claim. Alternatively, drainage area can be calculated using topographic maps, internet-based tools, and simple tools like planimeters or even grid paper. Geographic Information Systems (GIS) is a computer-based tool that can also be used if digital topographic maps are available, and the designer/miner has access to the software.

6.2.2 Catchment Assessment Form

The catchment assessment form is part of the Interior Alaska Stream Quantification Tool (AKSQTint) and is used to identify human created stressors that could jeopardize a stable channel design with aquatic habitat features (Steering Committee, 2021). The assessment form is included in Appendix C. The categories primarily address stressors that are upstream of the project reach. A detailed overview of how to complete the catchment assessment form is included in the Alaska Interior SQT user manual (Steering Committee, 2021). Once the form is completed, the designer should determine if the overall catchment condition is good, fair, or poor using their best professional judgement. A good rating means that the watershed (or catchment) is mostly free from anthropogenic (human caused) stressors. A fair rating means that there are enough stressors in the watershed to cause concern. A stable channel design is still likely, but extra precautions or additional expertise may be needed to assist with the design. A poor watershed rating could still support a stable channel design depending on which stressors are good, fair, or poor; however, it could increase the degree of difficulty of maintaining a stable channel and rehabilitating habitats. This is discussed in more depth in the next section.

6.2.3 Assessing Watershed-Scale Risk Factors

This task includes an assessment to identify anthropogenic alterations in two key watershed-scale processes that could increase the risk of implementing an unsuccessful stream reclamation design: runoff and sediment supply (erosion). Runoff processes are typically altered through: 1) vegetation change or removal, 2) interception of subsurface flow and routing to streams, 3) soil compaction and decreased infiltration, and 4) creation of impervious surfaces. Increases to sediment supply are caused by a wide range of land use changes that remove or alter vegetation. Mass wasting (e.g., landslides and hillslope erosion) processes are often increased by three disturbances: 1) over-steepening of slopes by construction practices, 2) forest/tundra/vegetation clearing and loss of root strength and soil cohesion, or 3) concentration of water through road ditches or impervious surfaces and swales (Roni and Beechie, 2013). Typically, a portion of the sediment delivered from a hillslope is stored in the valley bottom and does not make it to the stream channel. However, sediment from eroding streambanks deliver 100% of the sediment into the channel. Combined with mobilized sediment from the bed, this form of direct channel supply can deliver a large quantity of sediment to a project reach (Reid and Dunne, 1996). Figure 6 shows an example of mass wasting (landslide), where material from the hillslope was delivered to the valley bottom. None of this material made it directly to the stream channel. Figure 7 shows an example of streambank erosion where 100% of the eroded material entered the stream.

Figure 6. Hillslope erosion of colluvium that is deposited in the valley and not the stream channel.

Figure 7. Streambank erosion of sediment where 100% of the eroded material enters the stream channel.

Table 1 provides a list of reach runoff and sediment supply processes with examples of how they are altered in Interior Alaska watersheds with placer mining. The more alterations that occur in a watershed the greater the risk to reclamation success.

Table 1. Examples of how placer mining changes watershed scale processes.

Watershed-Scale Process	Alteration	Examples in Watershed with Placer Mining
Runoff	Vegetation change or removal	Placer mining removes vegetation in the floodplain and lower portions of the hillslopes. Access roads remove vegetation on floodplain, hillslopes, and ridges.
	Interception of subsurface flow and routing to streams	Vegetation removal and excavation along the edge of the floodplain and hillslope exposes sub-surface flow. This increases runoff and aufeis production.
	Soil compaction and decreased infiltration	Access roads to mine sites and transportation routes within the mine site. Mining operations and mine housing/living areas.
	Creation of impervious surfaces	Gravel roads, roof tops, mining equipment
Sediment Supply from Mass Wasting	Over-steeping of slopes by construction practices.	Mining activities along hillslopes, including the toe of the slope.
	Forest/tundra/vegetation clearing and loss of root strength and soil cohesion	Mining activities along hillslopes. Can also lead to permafrost degradation, which further increases mass wasting.
	Concentration of water through road ditches or impervious surfaces and swales	Mine drainage features and road networks
Sediment Supply from Stream Banks and Beds	Sediment supply from eroding streambanks	Active placer mining and historical mining that left unstable channels and tailing piles in the channel and floodplain.
	Sediment supply and transport of channel bed material	Active placer mining and historical mining that left unstable channels and tailing piles in the channel and floodplain.

The product from this phase is a written narrative that qualitatively describes the watershed stressors and perturbations that could increase the risk of reclamation failure. The catchment assessment form and Table 1 are provided as decision support tools that can help the designer think through the risks. Ultimately, it is the experience and judgement of the designer that will determine if the watershed-scale alterations pose too great a risk for a successful stream reclamation project.

6.3 Watershed Hydrology

The purpose of this task is to estimate the magnitude and frequency of flood events, ranging from the bankfull discharge to the 100-year (or 1% exceedance probability) flood. USGS regional regression equations (Curran et al., 2016) are used to estimate the 2- through 100-year events and bankfull regional curves are used when available to estimate the bankfull discharge. Bankfull regional curves have been developed by BLM for Interior Alaska and are under development for other regions of the state. Available regional curves are provided in Appendix D.

If bankfull regional curves are not available for the project watershed, regional curves will need to be developed or the regression equation results will need to be extrapolated to a 1.5-year event. Methods for each are provided below. Note, the methods described here are the simplest way to estimate the magnitude and frequency of events. More sophisticated methods like hydrologic modeling or long-term gaging are preferred options for designers who have the expertise, funding, and time to complete them.

The discharge values produced from this task are used later in the design process. In addition, this information can be helpful for projects that require more detailed analysis such as:

- designing and/or evaluating the hydraulic conditions over the bankfull channel and bench. For example, the shear stress over the channel and floodplain could be assessed for a 50-year discharge. This could be used instead of modeling the floodprone width as described in Section 10.4.
- performing no-rise certifications when required by local floodplain management regulations.
- designing the bankfull channel if regional curves are not available.

All three of the above examples require considerable expertise in hydrologic and hydraulic measurements and modeling. This technical report provides methods that are simpler than detailed hydrology and hydraulic modeling; this document does not discuss modeling analysis in detail. For example, most mine sites do not require a no-rise certification and bankfull regional curves are provided for most of the Interior. For the purposes of this guide, hydraulic conditions on the floodplain bench are assessed using a stage of two times the bankfull max depth and a simple single-section analyzer. Computer modeling programs may be more useful for stream mitigation or other stream restoration projects that are located in urban watersheds or watersheds that are not represented by a bankfull regional curve.

If a mine site is in a small rural watershed with bankfull regional curves that are applicable to the project reach then watershed hydrology calculations may not be necessary. Contact the BLM representative or appropriate agency staff before proceeding with the watershed hydrology calculations.

6.3.1 USGS Regional Regression Equations

Complete the tasks in this section only if watershed hydrology calculations are needed (such as if no regional curves are available). A spreadsheet tool is available from USGS to calculate the peak discharges. The report, spreadsheet tool, and a geodatabase of basin characteristics is available from https://pubs.er.usgs.gov/publication/sir20165024. The report title is *Estimating flood magnitude and frequency at gaged and ungaged sites on streams in Alaska and conterminous basins in Canada, based on data through water year 2012* (Curran et al., 2016). The spreadsheet tool filename on the above web site is “Application of Methods Tool Version

1.2 (48KB xlsx)." Users should review the report prior to using the spreadsheet tool to ensure that the project reach and contributing watershed meet the required criteria for using the tool.

Users will need to input a site name, the drainage area in square miles and the mean annual precipitation in inches from the 1971-2000 (or 1981-2010) PRISM data. The drainage area was already provided in the watershed assessment task in Section 6.2.1. The mean annual precipitation can be obtained using the same BLM provided webservice (https://arcg.is/18iWjW) or from Scenarios for Alaska and Arctic Planning (SNAP) at http://ckan.snap.uaf.edu/organization/snap. The mean annual precipitation value should be selected based on the same location used to delineate the drainage area for your project site. The below tables and figures provide example output from the tool. Table 2 is where data are input.

Table 2. Site name and data input (shaded in yellow) needed to calculate the peak discharges.

Enter a site-description name:
A test of an unregulated site in Alaska or conterminous basins in Canada

Enter the explanatory variables:

Drainage area, in square miles	DRNAREA	40	Equations are valid for DRNAREA between 0.4 and 1,000 mi^2 with PRECPRIS00 between 8 and 280 inches, and for DRNAREA greater than 1,000 and less than 31,100 mi^2 with PRECPRIS00 between 10 and 111 inches.
Mean annual precipitation from 1971-2000 PRISM data, in inches	PRECPRIS00	18	

Table 3 shows the results. The peak discharge in cubic feet per second is provided for the following exceedance probabilities (percent chance of exceedance): 50, 20, 10, 4, 2, 1, 0.5, and 0.2. Note, return interval is often used by stream designers instead of exceedance probability. Table 4 provides the conversion between exceedance probability and return interval. In addition to discharges, Figure 8 plots the lower and upper 90 percent confidence limits from the data in Table 3. Note the wide range in the confidence bands, which visually illustrates how variable the estimates are. This variability is shown quantitatively with standard error (SEP). The average error across exceedance probabilities is 69 to 82 percent.

Table 3. Discharge, 90 percent confidence limits, and standard error percentages for various exceedance probabilities.

Results:

Percent chance exceedance	Percent chance exceedance flow, in ft^3/s	Lower limit of 90 percent prediction interval flow, in ft^3/s	Upper limit of 90 percent prediction interval flow, in ft^3/s	-$SEP_{P,i}$ (percent)	+$SEP_{P,i}$ (percent)	Average $SEP_{P,i}$ (percent)
50	397	139	1,140	-47.1	89.1	70.8
20	655	234	1,840	-46.5	86.8	69.1
10	852	304	2,390	-46.5	86.8	69.1
4	1,120	391	3,210	-47.2	89.3	70.9
2	1,330	453	3,880	-47.8	91.7	72.6
1	1,540	517	4,610	-48.5	94.1	74.3
0.5	1,770	573	5,460	-49.5	98.0	77.1
0.2	2,080	640	6,750	-51.0	104.2	81.5

Table 4. Exceedance probability with corresponding return interval (Note: return interval is simply the reciprocal of the exceedance probability when expressed as a decimal).

Annual Exceedance Probability (%)	Return Interval (Years)
50	2
20	5
10	10
4	25
2	50
1	100
0.5	200
0.2	500

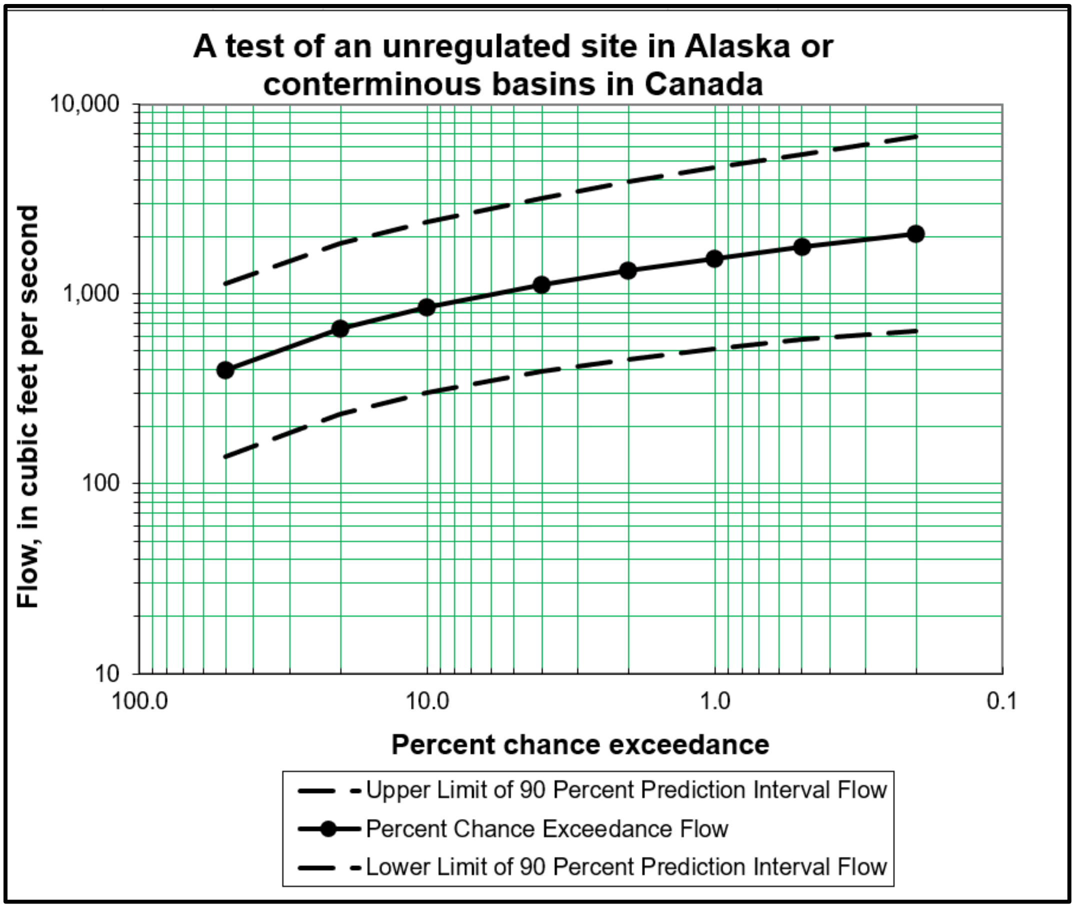


Figure 8. Graphical representation of Results. Data provided in previous tables.

6.3.2 Bankfull Discharge Estimates

The USGS spreadsheet tool does not estimate the bankfull discharge. Five options are provided for estimating the bankfull discharge. The first two options use bankfull regional or watershed-specific curves, which are the preferred methods. The other options include methods for regions that do not have regional curves.

Option 1: Using Bankfull Regional Curves

For this phase of the design process, only the bankfull discharge curve is needed. If available, designers can use the bankfull discharge versus drainage area curve to estimate the bankfull discharge. The bankfull discharge from the regional curve should be compared to the 2-year discharge calculation from the USGS spreadsheet. The bankfull discharge is generally less than the 2-year discharge and can even be lower than 1.1. The average bankfull return interval is 1.5 years (Leopold et al., 1964). Bankfull regional curves work best when the reclamation site is within the same or adjacent watershed as the data used to develop the regional curve. As the mine site gets farther away from sites used to generate the curves, uncertainty about the validity of the curve increases.

Option 2: Using a Watershed-Specific Regional Curve

If bankfull discharge regional curves are not available, the next best option is to develop a watershed-specific regional curve. If this method is selected, curves for bankfull area, width, and mean depth should be developed along with the bankfull discharge curve. These dimension curves are even more important for designing the channel than the discharge curve. It is likely that watershed-specific regional curves will include sites that do not have a gage station; therefore, the bankfull discharge that corresponds with the bankfull stage will need to be estimated. The cross section and longitudinal profile data, along with a grain size distribution (refer to Harrelson et al., 1994 for methods) can be input into the Reference Reach Spreadsheet (Mecklenburg, 2006). Once entered, the spreadsheet will calculate the bankfull discharge. The Reference Reach Spreadsheet is a free tool that was developed by the Ohio Department of Natural Resources to process channel profiles, cross sections, planform, and bed material. It can be downloaded from www.stream-mechanics.com/resources, under spreadsheet tools.

Option 3: Extrapolating from USGS Regression Equations

A third option is to extrapolate the regression line using the USGS regression equations discussed in Section 6.3.1. This option is discussed in more detail below.

Option 4: Using HEC-HMS to evaluate various discharge events

Another option is to use hydrology models such as HEC-HMS[1] to estimate the range of discharges, from bankfull through the 100-year return interval flood. This method will require a hydrologist or engineer with experience using the model and may also have increased data needs.

Option 5. Site specific quantification of stage-discharge relationships

This last option requires the installation of a gage station at the project site to develop a stage-discharge rating curve and corresponding flood frequency analysis. This method takes several years to develop.

From the methods described above, the development of watershed-specific regional curves and the extrapolation of the USGS regression equations are the most likely to be completed in placer mine reclamation projects. Therefore, more detail about these two methods is provided below.

Developing Watershed-Specific Regional Curves

If an existing regional curve is not applicable to the project site, the next preferred option is to develop a watershed-specific regional curve. This effort requires surveying 8 to 12 sites that represent the same flow regime (perennial, intermittent, ephemeral) as the project reach, and a range of drainage areas with the project drainage area near the center of the range. Care should be taken to not span too many log cycles between the smallest and largest drainage area. For

[1] https://www.hec.usace.army.mil/software/hec-hms

example, if the project site is 5 square miles, do not include data from watersheds that are a thousand square miles, or even hundreds of square miles. A range of 0.5 to 50 square miles would be more appropriate.

The specifics on how to develop regional curves is beyond the scope of this document. However, the BLM has experience developing these curves and can assist designers. In addition, there are numerous manuals and documents available that provide guidance on how to develop regional curves. One free example is Technical Supplement 5: Developing Regional Relationships for Bankfull Discharge Using Bankfull Indices from the National Engineering Handbook 654, Stream Restoration Design manual (NRCS, 2007). Another resource is the *River Stability Field Guide*, Second Edition by Rosgen (2014). Regional curve development is described in section 2.0, the Morphological Description. Note that both resources focus on developing regional curves from gaged sites. This is the preferred method, if a riffle at the gage site is stable, not incised, and free to adjust from the natural sequence of flows. Gage stations, however, often do not meet these criteria. Ungaged, reference-quality streams can be included in the development of regional curves. If the gage sites are impacted by road crossings or development, reference sites become the preferred option. If an ungaged site is used, the bankfull discharge will have to be estimated rather than recorded from stage-discharge curves/tables and a flood frequency analysis, which is the case for gaged sites.

Extrapolating USGS Regional Regression Equations

If a watershed-specific regional curve cannot be developed, the USGS regional regression equations used above to calculate various return interval floods can be used to estimate a bankfull discharge. The minimum return interval flow that is calculated with the USGS equations is a 2-year discharge. However, the average return interval for the bankfull discharge is 1.5 years (Leopold et al., 1964) with a typical range of 1 to 2 years. Therefore, the USGS data must be extrapolated to yield a 1.5-year discharge. The following procedures can be used to make the extrapolation.

Using the results from the USGS spreadsheet (refer to Table 3 for an example), plot discharge (cfs) versus exceedance probability. Plot the 50% (2-year), 20%(5-year), and 10% (10-year) exceedance probabilities as shown below in Figure 9.

1. Fit a linear regression equation to the data.
2. Use the regression equation to calculate the 67% exceedance probability (1.5-year return interval) discharge.

Using the example equation in Figure 9, the discharge associated with the 67% exceedance probability is 2,777 cfs [discharge = (-43.962 * 67) + 5,722.3].

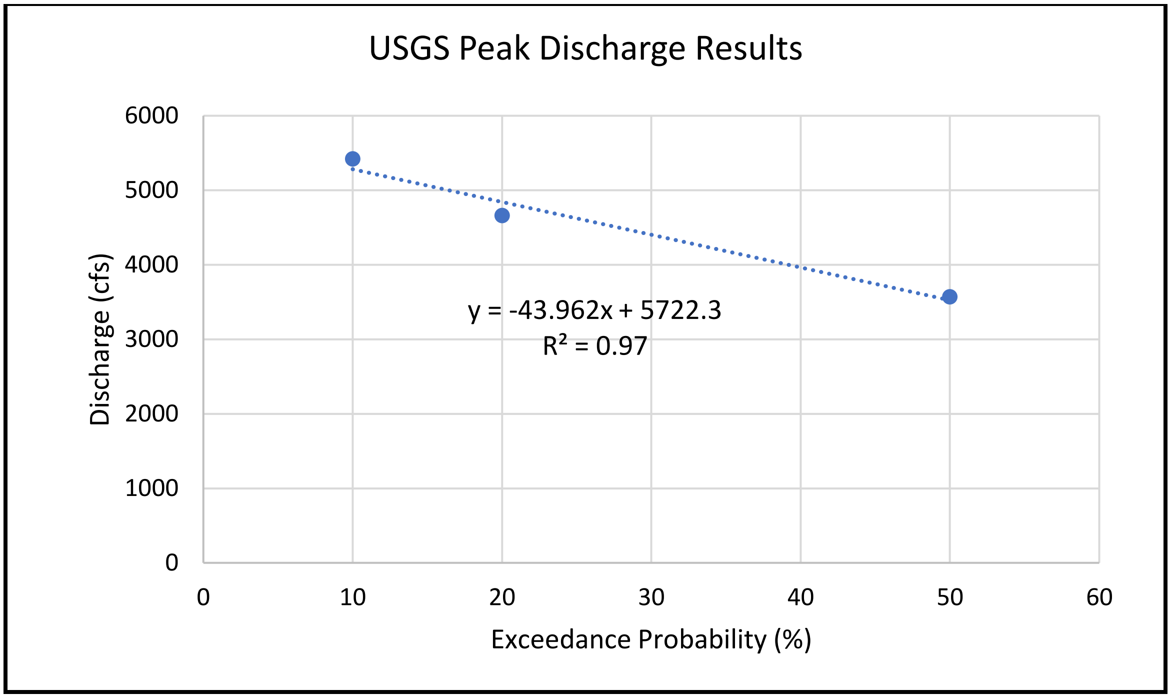


Figure 9. Using the USGS regional regression equations to estimate the bankfull discharge.

Why Watershed-Specific Regional Curves are Better than Extrapolating USGS Equations

There are several reasons why developing a watershed-specific regional curve is preferable over extrapolating the USGS regional regression equations.

- Regional curves are developed from field indicators of the bankfull stage. This field indicator represents the break between channel-forming processes and floodplain processes. To say this another way, it represents the break between water and sediment transport (channel) and water storage and sediment deposition (floodplain or bankfull bench processes).
- The 1.5-year discharge estimate does not necessarily correlate with a bankfull feature. It is simply a discharge associated with a statistical value.
- Extrapolation introduces additional error into a model that already has a lot of error. Note, the average standard error (SEP) in the example data set (Table 3) for a 50% exceedance probability flood was 71%. These are rough estimates that are not tied to geomorphic features!
- Extrapolating USGS equations only provides a rough estimate of discharge. It does not provide bankfull area, width, and mean depth values like regional curves. In the end, the goal is to design a channel not a discharge.

6.4 Bankfull Identification and Verification

Bankfull dimension data are used to help classify the stream using the Rosgen method, perform stream assessment methods like those used in the Alaska Interior Stream Quantification Tool (AKSQTint), size the new channel (reclamation channel), and perform monitoring and maintenance. Most stream restoration projects start with the identification of a bankfull feature and then verify the feature using regional curves, upstream or downstream reference reaches, and other methods. However, most placer mine reclamation projects will not have bankfull features due to the mining process. Since the channel and floodplain are excavated during mining, geomorphic features are not present. In this case, the designer should use the bankfull regional curves or upstream/downstream reference reaches (if un-mined) to determine the bankfull dimensions. The identification and verification of bankfull as described below are not needed if a regional curve is used to impose the bankfull stage onto the mine reach.

If the mine site did not disturb the channel or for other types of projects, e.g., stream mitigation, then bankfull features are likely present. In this case, the designer should identify and verify the bankfull feature. The remainder of this section provides the method for identifying and verifying the bankfull stage. Additional information is provided in the AKSQTint user manual (Steering Committee, 2021).

Identification and verification of the bankfull feature should be completed by geomorphologists, hydrologists, engineers, or biologists who have the academic training and practical experience to find field indicators that separate channel forming processes from depositional processes associated with the floodplain/floodprone area. This is not an activity for untrained or inexperienced staff.

Bankfull Identification Process

1. Look for geomorphic features recognizing that there may be more than one feature in a reach. Common geomorphic features include the inner berm, bankfull, and terrace(s). Refer to the AKSQTint user manual for more guidance on determining bankfull features (Steering Committee, 2021).
2. Measure the difference in water surface and the presumed bankfull feature at multiple locations where indicators exist. The differences should not vary by more than about 0.2 feet for the bankfull feature, unless there is a major change in the bed elevation, e.g. a headcut or waterfall.
3. Find a stable riffle within or just upstream or downstream of the reach where the bed and banks are free to adjust from the natural sequence of flows.
4. Perform a cross section survey and calculate the cross-sectional area using procedures described in the AKSQTint user manual (Steering Committee, 2021).
5. Plot the calculated bankfull area versus drainage area onto the most applicable regional curve (Appendix D). If the plotted point falls within the prediction interval limits, the regional curve can be considered as representative of the project reach. If the plotted point is above the prediction interval limit, a terrace might have been surveyed rather

than the active floodplain. If the plotted point is below the prediction interval limit, an inner berm may have been surveyed. More assessment will be needed to determine if the correct geomorphic feature was identified or if the regional curve is not representative of the project reach.

Figure 10 shows an example of the three scenarios described in number 5 (above). The orange dot plots within the prediction limits of the regional curve points (blue diamonds). This plot would confirm/verify that the bankfull regional curve is representative of the project reach, and the suite of curves could be used for assessment and design purposes. The red dot plots above the prediction limits, indicating the cross-sectional area is larger than expected. This could mean that a terrace was surveyed rather than a bankfull feature. If there is certainty that the bankfull feature was properly identified (e.g., there are no indicators below the feature), then the regional curve is not representative of the precipitation/runoff processes in the project watershed and the regional curve cannot be used. The green dot represents a plot that is below the prediction limits. This could indicate that an inner berm was surveyed rather than the geomorphic indicator. Additional field work is needed to confirm that a floodplain/bankfull geomorphic feature is not higher than what was surveyed. If there is not a higher feature, then the regional curve is not representative and cannot be used.

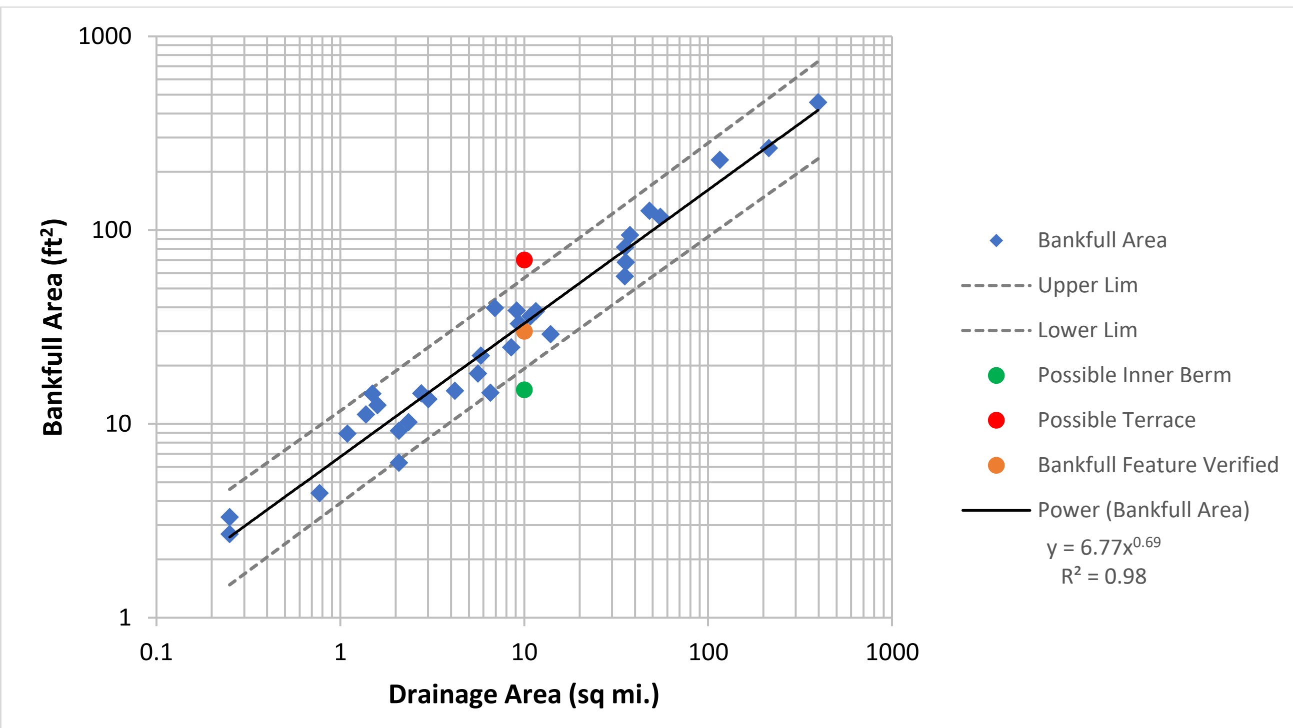


Figure 10. Regional curve showing bankfull verification example. The solid black line is the best-fit line through the bankfull area points. These points represent stable streams with obvious bankfull features. The dashed lines represent the upper and lower 95% prediction interval limits. The green dot represents a geomorphic feature that is below the lower limit and could be an inner berm feature rather than bankfull. The red dot represents a geomorphic feature that is above the upper limit and could be a terrace.

7.0 Phase 2: Goals and Objectives

Every project must have clearly developed goals and objectives. Goals can be divided into two categories: programmatic and design. Programmatic goals state why the project is being completed from a funding or regulatory perspective. Example programmatic goals include: completing a project to meet BLM reclamation standards, completing a project to generate credits as part of a compensatory stream mitigation program, or completing a project to meet grant requirements.

Projects that are associated with BLM reclamation requirements will all have the same programmatic goals, which are outlined in 43 CFR 3809.420. These regulations require measures to control erosion and water runoff, reshaping the area disturbed, revegetation, and the rehabilitation of fisheries and wildlife habitat. More simply, the programmatic goals for these projects are to meet reclamation performance standards. Projects on BLM lands will also need to ensure compliance with the relevant Resource Management Plan objectives.

Design goals and objectives should be function-based. For this document, design goals and objectives follow guidance provided in *A Function-Based Framework for Stream Assessment and Restoration Projects* (Harman et al. 2012). Goals are written in a way that explain why the project is being completed from a stream condition or stability perspective. These goals will vary based on the programmatic goal and the restoration potential. Example goals include:

Goal – *Improve channel stability and condition to support fish and wildlife habitat.* Note that this goal does not state that there will be more fish and wildlife, just that there will be more suitable habitat. This will be the standard goal for BLM reclamation projects based on the requirement for channel stability and habitat rehabilitation. This could also be a goal for a stream mitigation project if the restoration potential is less than reference condition for biological function.

Goal – *Improve channel stability and condition to return the native fish community to a reference condition.* This could be a goal for a stream mitigation or restoration project if the restoration potential supports returning the biological community to a reference condition. The restoration potential process and analysis is described in detail in the AKSQTint user manual (Steering Committee, 2021). It is not provided in this document since the focus is on BLM reclamation projects.

Design objectives are written in a way that describe which function-based parameters will be manipulated through reclamation or restoration activities to achieve functional lift. These parameters are explained in detail in the AKSQTint user manual. However, the four most important parameters, often called “the big four” are included here as an example. They comprise: floodplain connectivity, bedform diversity, riparian vegetation, and lateral migration. They should be included in all objective statements, including BLM reclamation sites. Stream restoration and mitigation projects may include others from the AKSQTint. Ideally, objective statements will be written to also communicate the amount of functional lift that will be obtained.

Example objectives using "the big four" and showing functional lift are listed below. For those not familiar with these parameters and metrics, they are described in Harman et al. (2012) and the AKSQTint user manual (Steering Committee, 2021)

- Improve floodplain connectivity by decreasing the bank height ratio from 2.0 to 1.0 and increasing the entrenchment ratio from 1.1 to 1.9 (B stream type).
- Improve bedform diversity by decreasing the pool spacing ratio from 10 to 5, increasing the pool depth ratio from 1.2 to 2.5, and decreasing the percent riffle from 90% to 60%.
- Improve riparian vegetation by transplanting vegetation along the streambank and extending the riparian vegetation to a width of 30 feet from top of bank (B stream type).
- Improve lateral migration by reducing the bank erosion hazard index (BEHI) and near bank stress (NBS) rating from high/high to low/high and reducing the percent of erosion from 70% to 5%.

These objectives will vary based on the existing condition assessment. Therefore, the design goals and objectives cannot be finalized until Phase 3 below is completed. It is prudent to start developing these goals and objectives prior to the existing condition assessment and then refine and finalize them before the design process starts.

8.0 Phase 3: Existing Condition Assessment Procedures

The existing condition assessment is the baseline that quantifies the condition of the stream channel and floodprone area before reclamation begins. The existing condition assessment also includes surveying and processing to create a topographic base map, which is used to develop the design. The procedures below are the minimum needed to create designs in a variety of valley types. Assessment procedures are similar to those required for the AKSQTint, but not exactly the same. Projects that use the AKSQTint should refer to the AKSQTint user manual for additional assessment details (Steering Committee, 2021).

8.1 Determine Valley Type

The type of existing condition assessment completed will depend on the valley type at the project location; therefore, this is the first step to complete. There are many different valley type classifications and descriptions (Rosgen, 2014). For this document, the designer should simply determine if the valley type is V-shaped, colluvial, confined alluvial, or unconfined alluvial. A description of each is provided in Table 5 and photographic examples are provided in Figure 11. Note that alluvial fans and glacial valleys are not included in the table even though they are common throughout Alaska. The reason is that these valleys are often not conducive to stream reclamation activities that have the goal of creating stable channels with adequate in-stream and riparian habitat. These valleys contain dynamic stream systems like braided stream types, which are not covered in this technical report. Therefore, if the mine is located on an alluvial fan or in a glacial valley, the designer should consult with the BLM or their appropriate agency representative to receive guidance on how to proceed.

Table 5. Description of valley types used in this technical report.

Valley Type	Description
V-shaped	Narrow valley bottom and steep valley walls. Valley is literally shaped like a V. Valley slope is typically greater than 4%. Channel pattern is straight (sinuosity is less than 1.2). Bedforms are characterized as step-pool but dominated by riffles/cascades. Bedrock or large colluvium often provide grade control. Drainage areas are typically small.
Colluvial	Bowl-shaped valley, broader valley bottom than V-shaped. Channel and valley-bottom material dominated by colluvium. Valley slope is typically between 2 and 4%. Bedforms are characterized as step/cascade/riffle-pool. Drainage areas are small to moderate.
Confined-Alluvial	Wider valley bottom than colluvial valleys with valley slope generally less than 2%. Alluvium present in valley bottom. Some stream meandering occurs with meander bends typically intersecting the hillslope toe. Bedforms are riffle-pool sequence with some riffle-step-pool sequences.
Unconfined Alluvial	Wide valley bottom with valley slope typically less than 1%. Valley material is alluvium. Meandering or anastomosed stream geometries are common, depending on sediment supply and stream power. Meanders typically do not intercept hillslopes. Single-thread meandering streams typically have more stream power and sediment supply than anastomosed channels.

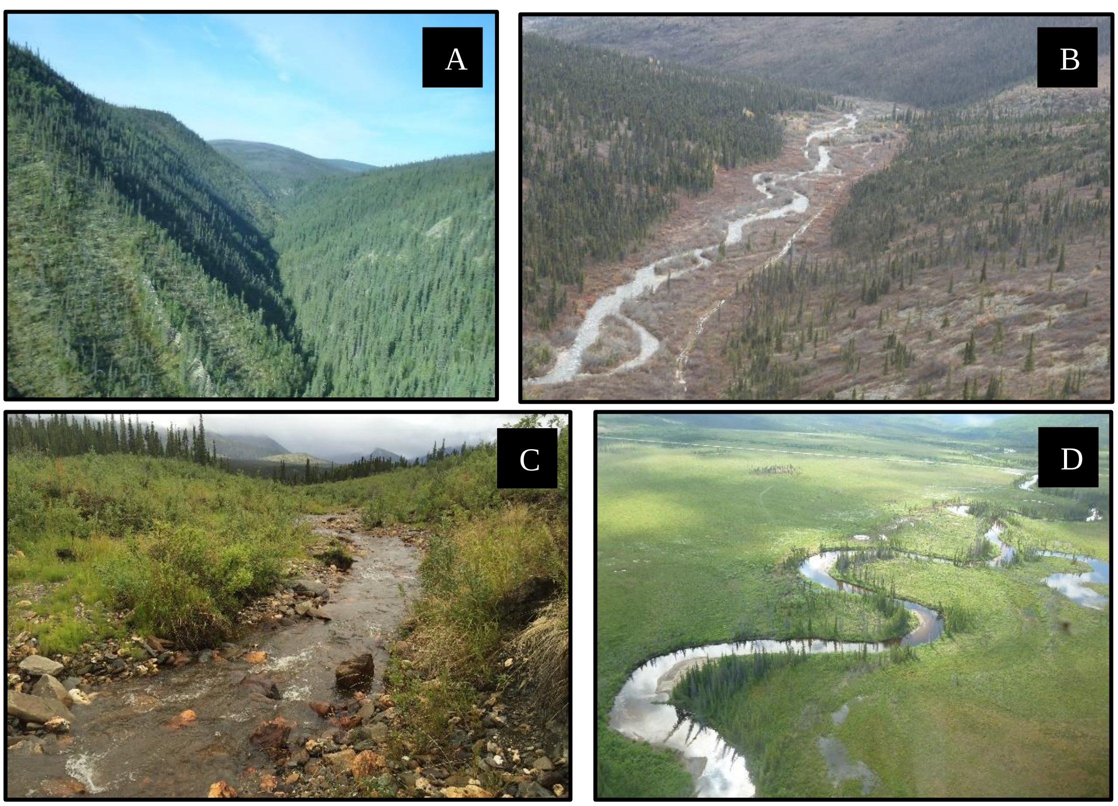


Figure 11. Example Valley Types: A) V-shaped, B) Confined Alluvial, C) Colluvial, and D) Unconfined Alluvial.

8.2 Valley/Channel Slope and Cross Section

A valley slope measurement and cross section surveys are required for all existing condition assessments, regardless of valley type. Both measurements can assist with determining the valley type and are used in other parts of the design. These measures help determine the appropriate stream type and bedform configuration that should be used in the design. Valley slope (VS) is measured as the elevation change from the upstream end of the reach to the downstream end divided by a straight-line measurement down the valley. If there are no abrupt elevation changes such as headcuts or knickpoints in the channel, the change in elevation can be made from measurements in the channel, preferably measured at the water surface from the beginning of riffle features. If abrupt elevation changes do occur in the channel, the floodplain or terrace elevation should be used. Tailing piles and other topographic abnormalities should be avoided when making the measurement. A level or laser level and tape (or other types of surveying equipment) can be used to make this measurement. Valley slope in equation form is shown below.

(*1*) Valley Slope (VS) = Change in elevation from upstream to downstream end of reach (ft)

Valley Length (ft)

In addition to calculating valley slope, the existing channel slope (CS) should be calculated. The same elevation change used in the valley slope calculation can be used; however, the valley length is replaced with channel length. Therefore, the channel slope equation is:

(*2*) Channel Slope (CS) = Change in elevation from upstream to downstream end of reach (ft)

Channel Length (ft)

The channel length (CL) is measured along the channel centerline, top of the bank or bottom edge of the channel. For edge of channel, the tape should follow one side of the channel, starting and ending at the same location where the elevation is measured. These approaches are generally better than measuring the thalweg length because assessors tend to overestimate the length; meaning, they overestimate the thalweg length by chasing scour holes that are not associated with the main flow thread of the channel.

8.2.1 Valley Slope Guidance in Determining Valley Type

Table 5 provides typical slope ranges by valley type. V-shaped valleys are the steepest, followed by colluvial valleys, confined alluvial valleys, and then unconfined alluvial valleys. Sinuosity and bedform type are tied to valley slope. Sinuosity (k) is inversely related to valley slope; it increases as valley slope decreases. This typically means that in unaltered systems meandering streams are found in unconfined alluvial valleys and non-meandering or straight streams are found in colluvial and V-shaped valleys. Confined alluvial valleys are a transitional valley type between colluvial and unconfined alluvial. They may have low to moderate sinuosity values (less than 1.3) with meandering and some step-pool features as well.

Bedform configuration is also related to valley slope. V-shaped and colluvial valleys have step-pool bedforms while alluvial valleys have meandering bed forms (Figure 12). Again, confined alluvial valleys are transitional and may contain both bedform types. Step-pool bedforms do not literally look like a staircase, with a consistent sequence of vertical steps, all with equal drops, followed by a pool. Rather, they consist of cascades, steps, cascades with steps, and then pools. Harman (2018) provides illustrations and guidance about how to measure step-pool bed forms. Meandering bedforms follow a riffle-pool sequence where riffles are the crossover section between meander bends. Major pools are found in the outside of the meander bend.

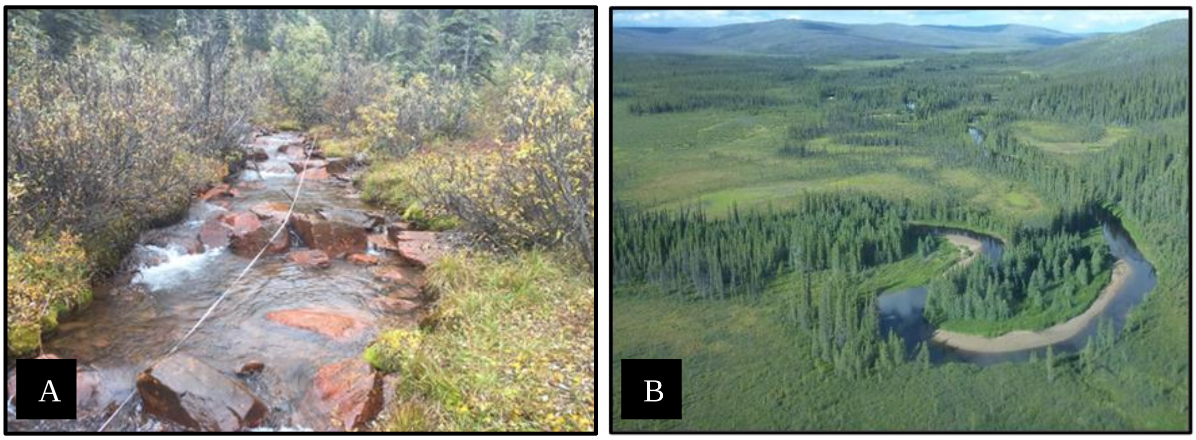


Figure 12. Valley type produces different bed forms: A) step-pool stream in colluvial valley, B) meandering stream in unconfined alluvial valley.

8.2.2 Valley and Channel Cross Sections

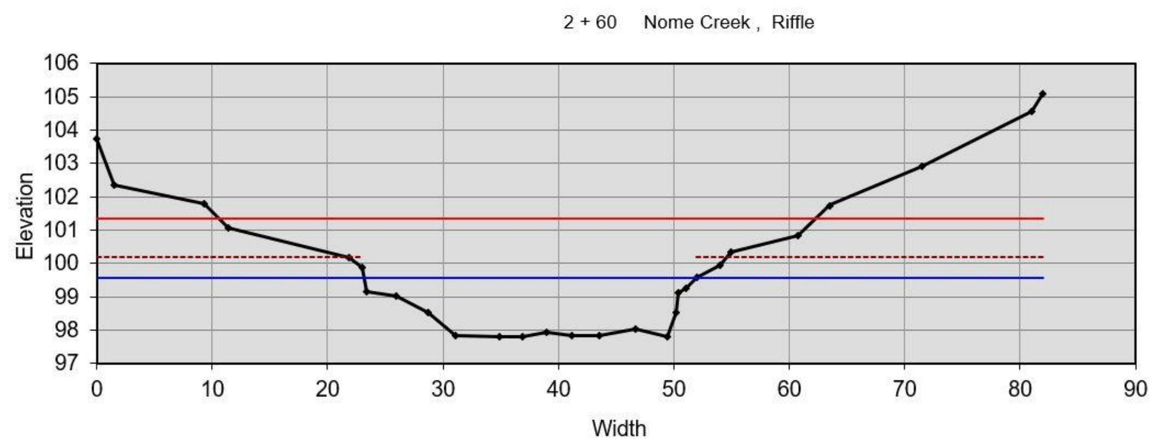
The purpose of cross sections is to characterize the width of the valley (VW) and the width and depth of the channel. When possible, the cross sections should span the entire width of the valley, starting at the left hillslope, extending across the channel, and ending at the right hillslope. The cross sections should be aligned so the survey is perpendicular to the channel. In V-shaped and colluvial valleys, the channels are relatively straight and one cross section can often be used to characterize the valley width and the channel. In alluvial valleys, the riffles are often oriented at an angle to the fall-line of the valley. In these cases, the cross section should not extend the full width of the valley. The valley width should be measured separately from the cross section and extend from the left hillslope to the right hillslope perpendicular to the fall-line of the valley. A tape, range finder, hand-held global positioning system (GPS) or other device can be used to make this measurement.

For the channel portion of the survey, the following features should be surveyed and noted: top of stream bank, bankfull feature, inner berm if present, edge of channel, water surface, and thalweg. All major breaks in slope and other topographic features should be included in the survey. The bankfull feature should be verified using the procedures outlined in Section 6.3.2. If no bankfull features exist, the regional curve should be used to estimate the bankfull stage (depth). This can be done during the cross-section analysis rather than in the field. Specific guidance for measuring cross sections can be found in Harrelson, et al. (1994) and Rosgen (2014).

The cross-section surveys can be entered into the Reference Reach Spreadsheet for analysis (Mecklenburg, 2006). Once the bankfull feature is identified, the spreadsheet will calculate the bankfull dimensions: width, mean depth, max depth, area, and width/depth ratio. Using the lower elevation of the two top of bank points, the bank height ratio is calculated. If the cross section extended for the entire width of the valley or past the elevation of two times the max bankfull depth, the floodprone width will be measured and shown on the cross-section plot. If the floodprone width is not included in the cross section, the user can manually enter the value. Like valley width, the floodprone width is measured perpendicular to the valley fall line. The floodprone width is measured as:

(*3*) W_{fpa} = Width (ft) at elevation determined by 2 * D_{max} of the riffle (Rosgen, 2014).

Figure 13 provides an example of a cross section plot in a colluvial valley that spans the valley width.



Bankfull Dimensions	
39.6	x-section area (ft.sq.)
28.8	width (ft)
1.4	mean depth (ft)
1.8	max depth (ft)
30.0	wetted parimeter (ft)
1.3	hyd radi (ft)
21.0	width-depth ratio

Flood Dimensions	
51.7	W flood prone area (ft)
1.8	entrenchment ratio
2.4	low bank height (ft)
1.4	low bank height ratio

Materials	
160	D50 Riffle (mm)
280	D84 Riffle (mm)
109	threshold grain size (mm):

Bankfull Flow	
4.3	velocity (ft/s)
170.2	discharge rate (cfs)
0.66	Froude number

Flow Resistance	
0.068	Manning's roughness
0.50	D'Arcy-Weisbach fric.
4.0	resistance factor u/u*
1.5	relative roughness

Forces & Power	
2.7	channel slope (%)
2.22	shear stress (lb/sq.ft.)
1.07	shear velocity (ft/s)
9.9	unit strm power (lb/ft/s)

Figure 13. Example cross section that spans the valley width. The blue line shows the bankfull width, the red line the floodprone width, and the brown dashed line the top of the low streambank.

The bankfull calculations from the cross section will be used in a later step to determine the Rosgen Stream Type and to aid in determining design options and risk. The valley width measurements will be used with the bankfull width measurement to calculate the valley width ratio (VWR shown below), which can be used to help distinguish an unconfined alluvial valley from a confined alluvial valley.

(*4*) Valley Width Ratio (VWR) = Valley Width (ft) / Bankfull Width (ft)

If the valley width ratio is greater than 7.0 the valley is likely an unconfined alluvial valley (Carlson, 2009). The qualitative criteria in Table 5 should also be used to help make the determination. If the ratio is less than 7.0 it is likely a confined alluvial valley; again, if the other criteria also support the determination.

8.3 Bed Material Characterization

A bed material sample is needed for bankfull discharge and sediment transport calculations. Bed material should be sampled using a pebble-count method of the riffle surface. Procedures for performing pebble counts can be found in Harrelson et al. (1994). Once the data have been collected, the results can be entered into the “Materials” worksheet within the Reference Reach Spreadsheet (Mecklenburg, 2006). The “Riffle Surface” option should be selected. The spreadsheet will produce a cumulative frequency curve and a histogram (Figure 14). A table of results is provided below the graph.

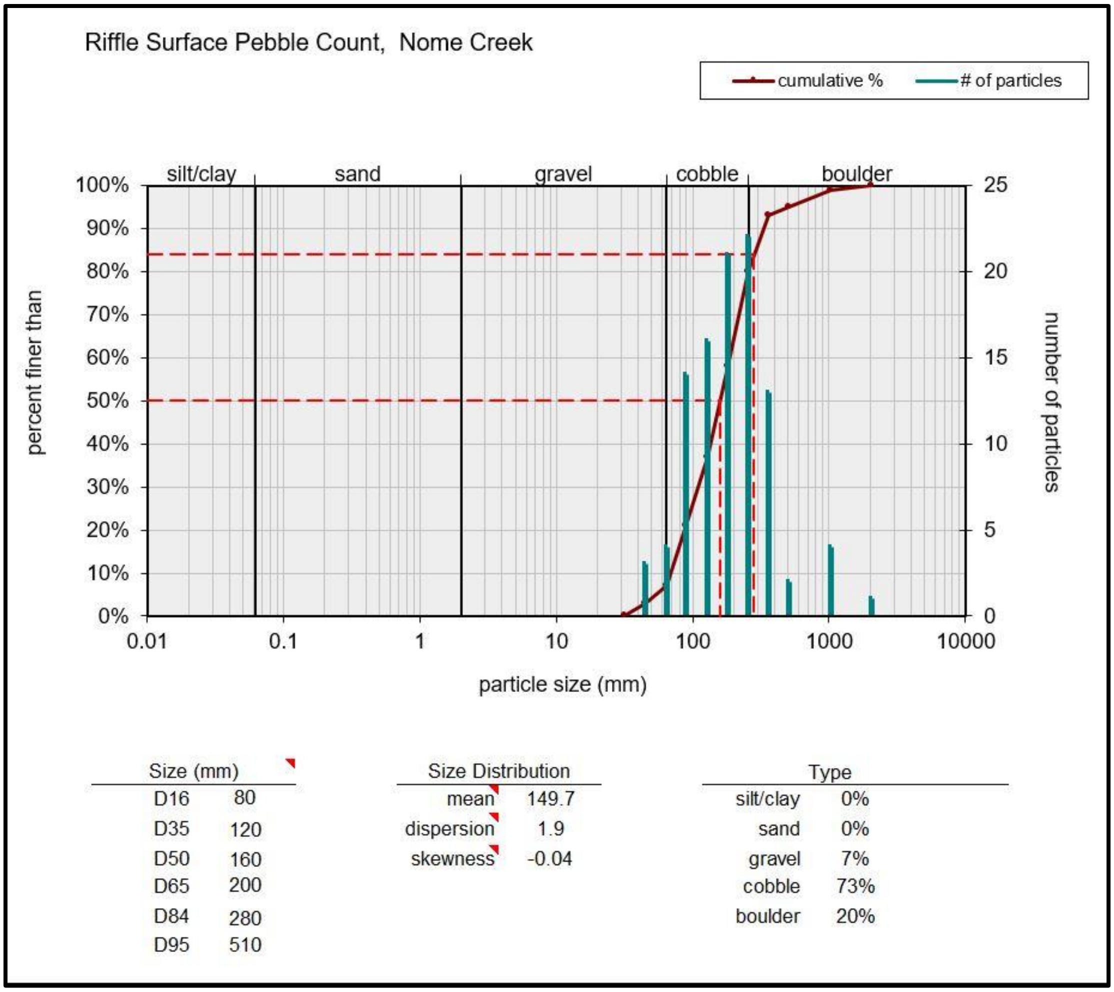


Figure 14. Cumulative frequency curve and histogram of bed material sampled using a pebble-count method. This example is from Nome Creek in the White Mountains north of Fairbanks.

If the cross section was also entered into the Reference Reach Spreadsheet and the channel slope is entered on the Dimension worksheet, the bankfull discharge will automatically be calculated. For example, the Nome Creek bankfull discharge is 170.2 cubic feet per second and the velocity is 4.3 feet per second (Figure 13). The bankfull width/depth ratio is 21.

The cross section, slope, and bed material data are also used to calculate shear stress and stream power, which are shown under Forces and Power section of the Cross Section output. For Nome Creek, these values are 1.1 pounds per square foot and 9.9 foot-pounds per second, respectively. All these calculations provide helpful information for determining risk and developing the design. The existing condition assessment simply focuses on collecting the data and making the calculations.

8.4 Stream Classification

The above information can be used to determine the Rosgen Stream Type for the existing condition. The channel slope, cross section survey, and bed material samples are used to make this determination for each assessment reach. From the cross-section data, the entrenchment ratio (ER) and bankfull width/depth ratio (W/D) are needed. The median particle size (D_{50}) from the bed material is also needed. The final parameter needed to determine the stream type is sinuosity (k), which is measured as the stream length divided by the valley length or valley slope divided by channel slope. The classification key and steps for determining the Rosgen stream classification can be found in the National Engineering Handbook, Part 654, Technical Supplement 3E (NRCS, 2007). The classification key is also included in Appendix B.

In addition to determining the existing Rosgen Stream Type, the design stream type should be determined. This is more difficult because it is answering the question: "What should the stream type be given the valley type setting and anthropogenic constraints?" This requires an understanding of valley geomorphology, stream classification, and channel evolution. As a general guide, Table 6 below provides a list of common stable stream types for the valley types listed in Table 5. In addition, unstable stream types that can be found in these valleys when human impacts have occurred are also provided. Note, it is possible to have stable and unstable C stream types in alluvial valleys. Many more examples of fluvial landscapes with stable and unstable stream types are provided in Rosgen (2014).

Table 6. Typical Stream Types for each Valley Type included in this Technical Report.

Valley Types	Typical Stable Stream Type(s)	Un-stable streams associated with human impacts
V-shaped	Aa+, A	N/A
Colluvial	B, Bc, Cb	G, Gc, F
Confined Alluvial	B, Bc, Cb, C	G, Gc, F, C, D
Alluvial	C, E, DA	C, Gc, F, D

The design stream type determination is the stream type that will be targeted in the design and then constructed. This is an extremely important step because the design criteria are stratified by stream type. Design failure can occur when the wrong stream type is designed for a given valley type and level of constraint. The most common failure occurs in the confined alluvial valley setting. Both meandering (C) and step-pool (Bc) channels exist in this valley type. However, for a C-type channel to remain stable, there must be significant riparian vegetation in place to resist the erosional forces from bankfull and floodplain flow events. It is more conservative to design a Bc channel in these valleys. This is one of the reasons for Demo 1's failure (see Introduction).

Demo 1 is located at mile-marker 85 of the Taylor Highway, between Chicken and Eagle, Alaska on Wade Creek. A C stream type was designed in a confined alluvial valley. Vegetation transplants were used extensively along streambanks and modestly on the floodplain with the rationale that the transplants could provide stability during bankfull and floodplain flows. Monitoring showed that while the transplants provided stability during bankfull flows, the combination of multiple bankfull flow events described in the Introduction slowly undermined the transplants through lower bank (toe) erosion. The floodplain flow completely undermined the transplants and the channel quickly migrated through unconsolidated floodplain sediments that were devoid of vegetation. The stream began to straighten itself through down-valley migration of the meander bends. A Bc stream-type would have been a more conservative approach because energy is dissipated through a step-pool profile design and bankfull bench. Lateral migration processes are removed from this design approach.

8.5 Base Map

Designs in many colluvial valleys and all alluvial valleys will require a large-scale base map, which is a topographic map of the stream reach. Ideally, the base map will be created using a ground survey followed by data processing and digital terrain model (DTM) development in a Computer Aided Drafting and Design (CADD) software. Technology such as Structure from Motion (SfM) mapping is an alternative to ground-based surveys and relies on stereo paired or overlapping aerial images from a drone or other aircraft using consumer-grade cameras to create a topographic map of a specific area. Another remote sensing option is LiDAR (Light Detection and Ranging). LiDAR is typically more accurate than SfM but may also be more expensive. These alternatives may be more cost effective than a ground survey; however, they are not a substitute for surveying channel dimensions since these technologies do not penetrate the water surface.

The base map should include detailed topography of the existing channel and floodplain bottom. Areas of interest, such as transplant source areas, rock stockpiles, haul roads, etc., should be located on the map. An example of a stream reclamation base map scope of work is provided in Appendix E. This scope will be helpful for designers who want to sub-contract the survey work needed to develop the base map.

For active mine sites, site preparation work will likely occur in the fall as a last step before mining operations stop for the winter. The site should be graded in a way that represents the existing condition or template for the stream design. This may include rough grading the valley, improving settling ponds, establishing drainage, etc. Interim site stabilization methods are likely needed during this phase to meet mine compliance regulations and prevent UUD. Once interim stabilization is completed, the topographic survey should be completed. This will allow for data processing and design tasks to be completed over the winter.

It may be possible to create stream designs without a base map in small V-shaped and colluvial valleys where only one channel alignment, located in the lowest elevation portion of the valley, is possible. However, it takes considerable survey and design experience to construct a channel using only the design criteria, and not tying it to a base map. This essentially means that the stream is being designed at the same time it is being constructed. Designing without a base map is generally not recommended. However, if a base map is not used, aerial imagery of the site showing the location and extent of the reclaimed channel should be provided. A drone can capture imagery if appropriate rules and regulations for flying drones are followed. A sketch of the channel alignment and extent of the riparian re-vegetation should be provided.

For alluvial valleys and meandering streams, (including C channels in confined alluvial valleys), a base map is a requirement. It is not optional. For these settings, contact the BLM or the appropriate agency for guidance.

8.6 Transplant, Large Wood, and Rock Source Areas

Vegetation transplants, large wood, and rock are key components of a successful stream reclamation project. The design and installation of these materials will be covered in Section 12 (Phase 7). For the existing condition assessment, the designer should identify areas where these materials can be harvested or obtained. The quality and characteristics of all material must be assessed to determine its suitability to meet project goals.

The best transplants are young trees and/or shrubs *with* ground cover and cohesive soils.

Transplant source areas are ideally located within areas planned for future mining or in areas that have high recovery potential such as the outer edges of the floodplain. The best transplants are young trees and/or shrubs with ground cover and cohesive soils (not from tailings). A global positioning system (GPS) or survey equipment can be used to map the transplant source area and to calculate the total area available for transplants.

Figure 15 is an example of a transplant source area on a low terrace adjacent to the stream reclamation site. Close source areas help to minimize travel times during construction and therefore minimize construction costs.

Figure 15. Transplant source area.

Fallen large wood is typically scarce in Interior Alaska, so large wood typically comes from onsite live trees. The best source areas for whole birch, spruce, cottonwood, or other tree species are future mining areas, upstream or downstream from the reclamation reach. If this is not an option, nearby terraces are a good source area. Hillslopes that will not be mined should be avoided. In some cases, it may be cost effective to transport dead trees to the reclamation site from other job sites, e.g., a nearby construction site or logging operation.

A mixture of rock sizes is needed for every project. Large, medium, and small boulders found during the mining process should be stockpiled for use during reclamation. Table 7 provides an estimate of rock quantities and sizes for stockpiling rock. Generally, all available boulder/cobble materials should be stockpiled for construction; it would be rare to have too much rock. The quantity percentages refer to the rock classification divided by the total amount of rock available. These quantities are for general planning purposes. Actual quantities may vary based on the size of the stream and risk of instability. Stockpiles should be segregated by rock classification to improve construction efficiency.

Table 7. Rock Dimensions and Quantity by Classification.

Rock Classification	Dimensions	Quantity (% of Total)
Large Boulders	6’ X 4’ X 2’ or larger	20%
Medium Boulders	4’ X 3’ X 1’ or larger	50%
Small Boulders	2’ X 2’ X 1’ or larger	15%
Cobble	1’ X 1’ X 0.5’ or larger	15%

8.7 Areas of Cut and Fill

During the existing condition assessment, it may be possible to identify areas that will need to be excavated (cut) and areas that will need fill. Example cut areas include: location of new channels and terraces or tailing piles that need to be converted into bankfull benches. Fill areas include abandoned channels, low areas in the floodplain, and mining ponds. If it is suspected that the design will need more fill than what can be generated from channel and floodplain bench excavation, then borrow areas should be identified and included on the base map. Conversely, if it is expected that the design will create excess material, then waste areas should be identified and mapped.

9.0 Phase 4: Developing Design Alternatives

The purpose of this phase is to select the design approach that provides the highest probability of reclamation success. The selection process utilizes much of the information collected above, along with a few additional approaches that will be introduced below. In addition, this process assesses the overall risk of reclamation, including a possible result that the risk is too high to successfully mine and reclaim a site. In other words, reclamation would be unlikely to avoid unnecessary and undue degradation (UUD) and meet reclamation performance standards in some scenarios.

Some design options are not supported by this technical report. These cases will be highlighted, and other design manuals will be referenced. Miners are encouraged to communicate with BLM or the appropriate agency before proceeding with these other design approaches.

9.1 Stream Evolution Triangle

The Stream Evolution Triangle (SET) is a conceptual model developed by Castro and Thorne (2019) that can help a designer visualize and think through how process drivers of hydrology, geology, and biology produce various channel forms, e.g., straight, meandering, braided, or anastomosed. Determining the proper planform and thinking through the process drivers is a way to determine if the correct design Rosgen Stream Type was selected during the existing condition assessment. Therefore, two forms of the SET are used below to help determine the proper planform, to validate the Rosgen stream type, and to set the stage for determining design risk later in this section. Designers should review Castro and Thorne (2019) before starting this phase.

Figure 16 shows the SET overlaid with various plan form geometries from Schumm (1985). The planform in the upper corner of the triangle is a type of multi-thread channel called anastomosed. The process drivers for this stream type include low stream power and high biological control (well-established riparian vegetation and possible large wood controls and beaver activity). These stream types are typically associated with unconfined alluvial valleys with low sediment supply. It is unlikely that miners in Interior Alaska would work in this type of system, but it is possible. Placer mine sites are most common in valleys with higher stream power, more sediment supply, and less biological control.

The planform in the lower left corner is also a multi-thread channel, but it is a braided stream type. The process drivers for these systems are high stream power, low erosion resistance, and low biological control from riparian vegetation, beaver, and large wood. Braided and anastomosed streams are both multi-thread; however, they function very differently. Braided streams are more dynamic, and their planforms change frequently. These systems are typically found in glacial valleys and alluvial fans. They are not good candidates for stream reclamation projects due to their dynamic nature.

The planform in the bottom right corner is a straight, single-thread channel. The process drivers are high erosion resistance, high stream power, and low biological control. These are mountain streams with step-pool bedforms and often with bedrock control. These systems are resilient. Reclamation activities in these systems have a higher potential for success than other systems because energy dissipation relies heavily on the step-pool morphology and less on floodplain/riparian function.

Straight channels can also have moderate stream power, moderate erosion resistance, and moderate to low biotic control. These channels are often in colluvial valleys and dissipate energy vertically through the profile via a step-pool bedform configuration.

The planform geometry in the center of the triangle is the classic single-thread, meandering stream type. The process drivers are evenly balanced resulting in a transport channel that is in dynamic equilibrium. These streams are typically found in unconfined alluvial valleys but can also exist in confined alluvial valleys.

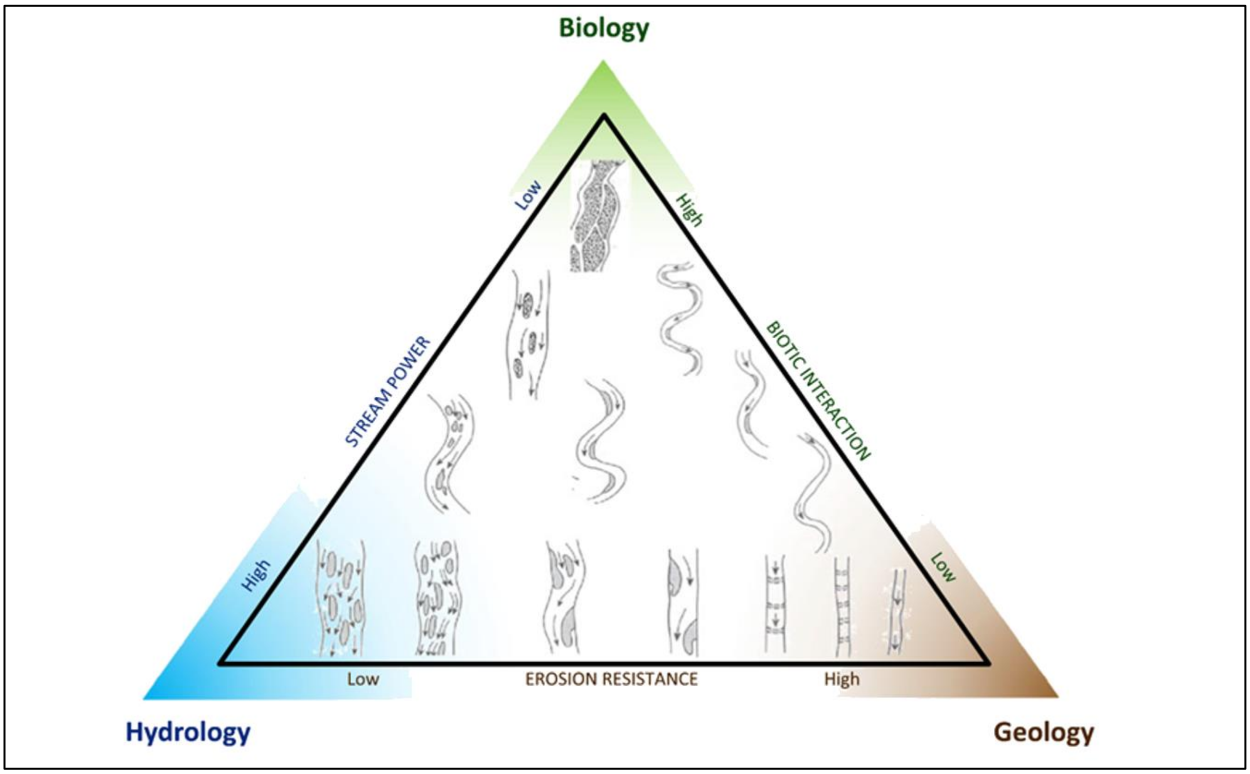


Figure 16. Stream evolution triangle from Castro and Thorne (2019) showing planform patterns (from Schumm, 1985) associated with the process drivers.

The Rosgen Stream Classification can also be overlaid with the SET (Figure 17) and therefore linked to process drivers. A comparison summary between the Schumm and Rosgen classifications and the SEP process drivers is provided in Table 8.

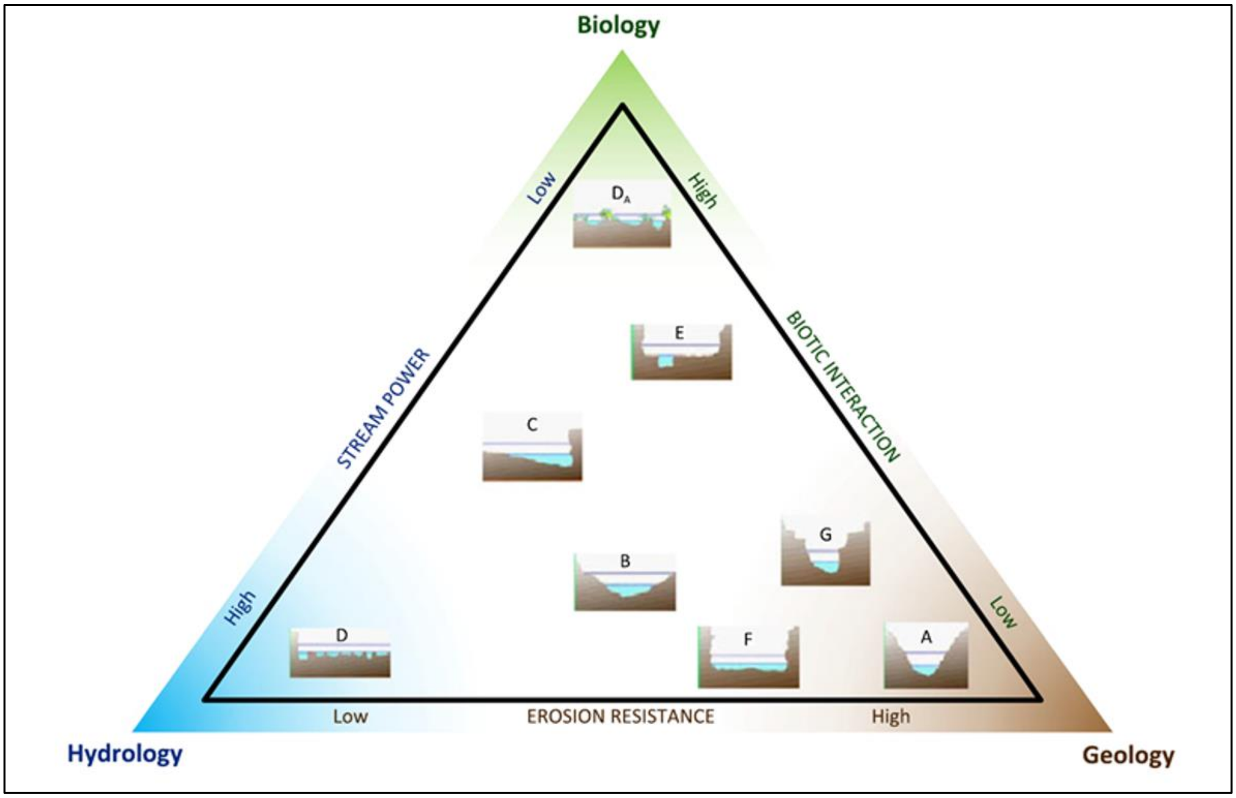


Figure 17. Stream evolution triangle with Rosgen stream types from Castro and Thorne (2019).

Table 8. Schumm (1985) and Rosgen (1996) stream types with process driver descriptions from the stream evolution triangle.

Schumm (1985) Planforms	Rosgen (1996) Classification	Process Drivers
Anastomosed	DA	Low stream power, High biologic control, Moderate erosion resistance.
Braided	D	High stream power, low biologic control, low erosion resistance.
Straight	A, G, F	High stream power, low biologic control, high erosion resistance
Straight	B	Moderate/high stream power, moderate erosion resistance, and low to moderate biotic control.
Meandering	C, E	Moderate stream power, moderate biologic control, moderate erosion resistance

The Rosgen A stream type is listed in Table 8 because the example provided in the above paragraph was for the stream in the lower-right corner. It is important to note that other stream types with low biologic control, high erosion resistance and high stream power are naturally stable F and G stream types. These F and G stream types are associated with gorge or canyon valley types and are typically not associated with placer mine sites. However, past reclamation efforts have sometimes created unstable F and G stream types in broader valleys, not canyons or gorges. These applications of unstable G and F stream types often lead to prolonged instability, UUD, and unsuccessful reclamation. Designers should avoid F and G stream types for these reasons.

The stream type in the colluvial valley with high stream power, low biotic control, and moderate erosion resistance is the B stream type. This is the most common stream type used for Interior Alaska mine sites and is a focus of this technical report. However, as the SET shows, this stream type is still dependent on some biotic influence, i.e., riparian vegetation. If the riparian vegetation cannot resist the high stream power, the stream type could evolve into an unstable G, F or even a D if the valley is wide enough, e.g., a confined alluvial valley.

Figure 18 shows an example of a mine reclamation site that inadvertently constructed a G stream type when a B stream type would have been more appropriate. The channel design resulted in a stream power that is too high for the erosion resistance, leading to a headcut. A B-type design would have reduced stream power; however, riparian vegetation and grade control would still be needed.

Figure 18. G stream type used for reclamation resulting in bed erosion (headcut).

The final step is to compare the Rosgen stream type selected in the existing condition assessment with the Rosgen stream type associated with process drivers described in the SET and make a final stream type decision. Past information such as valley type, stream power (shown on the cross section), and access to good transplants can help make the final decision for the design or target stream type. The following section provides additional guidance on how to take the above information and make a final stream type decision.

9.2 Determine Final Stream Type

Review the preliminary design stream determination from Section 8.4 and the new information provided in Section 9.1. If needed, modify the final design stream type. The following summary can be used as an aid in making the final selection.

Summary criteria for selecting Rosgen A stream types

Select this stream type when the following criteria are met:

- Located in a V-shaped valley;
- Valley-width ratio is less than 7.0;
- Valley slope is greater than 4%;
- Process drivers are high stream power, low biotic interaction, and high erosion resistance.

Material needs:

- Rock Supplies – Highly critical
- Transplant Material – Moderately critical; can be replaced with rock and bioengineering if transplant material is not available.
- Large Wood – Moderately critical; can be replaced with rock if wood is not available

Summary criteria for selecting Rosgen B stream types

Select this stream type when the following criteria are met:

- Located in colluvial valleys;
- Valley-width ratio is less than 7.0;
- Valley slope is greater than 2%;
- Process drivers are high/moderate stream power, low/moderate biotic interaction, and moderate erosion resistance.

Material needs:

- Rock Supplies – Highly critical
- Transplant Material – Moderately critical, transplants can be replaced with wood and rock if transplants are not available.
- Large Wood – Moderately critical; can be replaced with rock if wood is not available

Summary criteria for selecting Rosgen Bc stream types

Select this stream type when the following criteria are met:

- Located in a colluvial valley and confined alluvial valley;
- Valley-width ratio is less than 7.0;
- Valley slope is less than 2%;

- Process drivers are moderate/high stream power, moderate biotic interaction, and moderate erosion resistance.

Material needs:

- Rock Supplies – Highly critical
- Transplant Material – Highly critical
- Large Wood – Moderately critical

Summary criteria for selecting Rosgen C stream types

Select this stream type when the following criteria are met:

- Located in unconfined alluvial valleys;
- Valley-width ratio is greater than 7.0;
- Valley slope is less than 2% and preferably less than 1%;
- Process drivers are moderate stream power, moderate biotic interaction, and moderate erosion resistance.

Material needs:

- Rock Supplies – Highly critical
- Transplant Material – Highly critical
- Large Wood – Highly critical

Notes: This document does not provide methods for designing C stream types. Refer to the NRCS, 2007 (Rosgen Geomorphic Design Approach) manual for designing C stream types. It is recommended to contact the BLM or the appropriate agency before proceeding.

Summary criteria for selecting DA stream types

Select this stream type when the following criteria are met:

- Located in unconfined alluvial valleys;
- Valley-width ratio is greater than 7.0;
- Valley slope is less than 1%;
- Process drivers are low stream power, high biotic interaction, and moderate erosion resistance.

Notes: This document does not provide methods for designing DA stream types. Contact the BLM or other appropriate agency if you are considering working in a DA stream type.

Summary criteria for selecting D stream types

Select this stream type when the following criteria are met:

- Located in glacial valleys (glacial outwash plain and downstream of active glaciers) and alluvial fans.

- Valley-width ratio is greater than 7.0.
- Valley slope is less than 4%.
- Process drivers are high stream power, low biotic interaction, and low erosion resistance.

Note: Do not proceed. Stream reclamation is not appropriate in these stream types.

9.3 Risk Assessment

The final step before proceeding to the design phase is to determine the overall risk of stream reclamation or restoration failure. Given the harsh environment, level of valley material alteration from mining, lack of experience in natural channel design, and funding constraints, mining should not be attempted without carefully considering the cost and risk of reclamation maintenance and even failure. As the risk of failure increases, the likelihood of costly maintenance increases. Table 9 can be used to help determine if the overall risk is moderate or high. This risk should be clearly communicated in the design report.

Table 9. Criteria for determining if the risk of failure is high, medium, or low. A report section number is provided with each criterion as a reference to where that information can be obtained.

Risk Level	Criteria
High	1. Sites with unstable watersheds (e.g., high sediment supply from bed and bank erosion, hillslope failures, etc). Section 6.2. 2. Large uncertainty in discharge estimates, no regional curves. Section 6.3. 3. Few high-quality transplants. Section 8.6. 4. No availability of large trees for floodplain roughness. Section 8.6. 5. Low rock supply and not in the recommended quantities or sizes. Section 8.6 6. High stream power with low biotic interaction and low erosion resistance (high potential for stream to evolve into a G/F or D stream type). Section 9.1.
Moderate	1. Stable watershed, low sediment supply from upstream mining or other disturbances. Section 6.2. 2. Regional curves available for sizing channel. Section 6.3. 3. Good quality and quantity of transplants. Section 8.6. 4. Good quality and quantity of trees. Section 8.6. 5. Good quality and quantity of rock. Section 8.6. 6. Moderate to low stream power, moderate to high biotic interaction, and moderate to low erosion potential once reclamation activities have been installed. Section 9.1.
Low	1. Upland reclamation only (this assumes that the correct equipment and methods are used). Stream channel and floodplain are not mined and left untouched.

The table illustrates that any reclamation activity that includes the channel and adjacent floodprone area is at least of moderate risk. There is no low-risk option for working in the channel and floodprone area because the mining process removes all the riparian vegetation and often creates a finer grain size distribution, e.g. more sand and less cobble to boulder size material in the channel and floodplain. This shifts the process drivers toward less erosion resistance and biotic control, making the system more susceptible to erosion and adjustment. The moderate risk category is the best case for doing reclamation when the criteria in Table 9 are met. By implementing these criteria, the process drivers can shift towards greater biotic control and less erosion resistance. However, given the harsh Alaskan climate, there is still risk that these measures will not be sufficient during large flood events or if poor design and construction methods are used. Maintenance and adaptive management will almost always be required, so the reclamation budget should include funding for these tasks.

10.0 Phase 5: Natural Channel Design Procedure for B Stream Types

This section provides step-by-step instruction on how to develop a design for the reclaimed channel's dimension, pattern, and profile. The riffle and pool dimensions are designed first followed by the pattern. The vertical channel stability assessment follows and is completed prior to starting the profile design to ensure that the design will not lead to bed degradation or aggradation. This is often an iterative process.

The design steps have been adapted from the “Rosgen Geomorphic Channel Design” provided in the *National Engineering Handbook*, Part 654 by the Natural Resources Conservation Service (NRCS, 2007). The steps below are for designing a Rosgen B (including Bc) stream type, the most common stream type found in placer-mined valleys in Interior Alaska. Designers creating C or E stream types should follow guidance provided in the NRCS Handbook but should consult with BLM or the appropriate agency before proceeding.

Prior to completing these design steps, the designer should read *Application of Natural Channel Design Techniques in Sub-Arctic Alaska* (Harman, 2018). This report provides the results of reference reach surveys and bankfull regional curve development in Interior Alaska. The reference reach information from this report is used as design criteria in many of the steps provided below; however, more detailed information on the reference reach data collection process is provided in the Harman (2018) report.

Enter the results from each step into the summary form provided in Appendix B.

10.1 Riffle and Pool Dimension Design Criteria

Steps 1 through 7 (below) provide instructions on how to calculate the design criteria for the riffle and pool dimensions. These design criteria will be used in the final design/plan set development process to draw typical and actual riffle and pool cross sections. These sections will include more measurements than what is included here.

Step 1: Calculate Bankfull Riffle Dimensions from Regional Curve

The use of bankfull regional curves was discussed in Section 6.3 but the focus was calculating the bankfull discharge and verifying bankfull features found along the project reach. For this step, the bankfull area, width, and mean depth curves are used that fit the project site. As a reminder, bankfull regional curves are provided in Appendix D. The curves that are closest to the project site should be used. If regional curves are not close to the site, it is best to develop watershed-specific regional curves (Sections 6.3 and 6.4). However, if this is not a viable option, the broader-scale Interior Alaska regional curves can be used (the equations between curves are all quite similar). They are divided into Northern and Southern Interior regions (Appendix D).

Step 2: Select a Bankfull Riffle Width/Depth Ratio

Use the graph in Figure 19 to determine an initial bankfull W/D ratio (W/D) for the design riffle (typical riffle). The overall range of W/D ratios observed in reference streams is 11 to almost 27 with a median value of 14 and a mean of 16. The 25th percentile is 12 and the 75th percentile is approximately 19.

The selected W/D ratio may change based on results from the sediment transport analysis in step 13. Width/depth ratios near the lower end should be selected for projects trying to maximize sediment transport capacity and minimize the risk of aggradation. Higher width/depth ratios should be selected for projects concerned about high shear stress values, which can result in incision/degradation. Generally, the selected W/D ratio will range between 12 and 19, at least as a starting point. The W/D ratio may change several times through design iterations that are a result of the sediment transport analysis in Section 10.2.

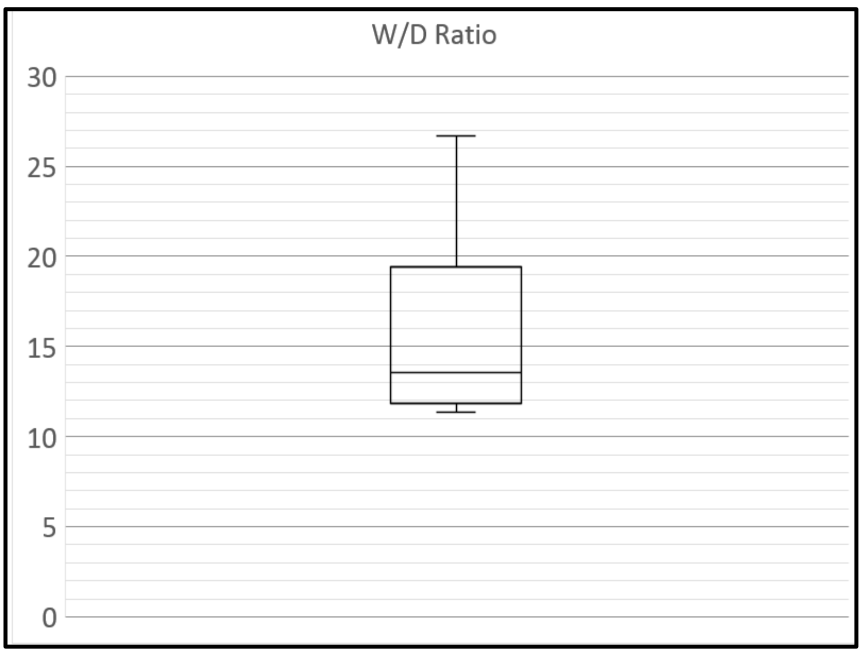


Figure 19. Bankfull W/D ratios from B reference reach streams in Interior Alaska.

Step 3: Calculate the Bankfull Riffle Width (W_{bkf})

Use the following equation from NRCS (2007) to calculate the bankfull riffle width.

(5) Bankfull Riffle Width (ft) = $\sqrt{\frac{W}{D} * A}$ Where,

W/D = Bankfull Riffle Width/Depth Ratio selected in Step 2, and

A_{bkf} = Bankfull Riffle Area (ft^2) calculated in Step 1.

Step 4: Calculate the Bankfull Riffle Mean Depth (d_{bkf})

Calculate the bankfull riffle mean depth as follows

(*6*) Bankfull Riffle Mean Depth (ft) = A_{bkf} /W_{bkf} , where

A_{bkf} = Bankfull Riffle Area (ft^2) calculated in Step 1.

W_{bkf} = Bankfull Riffle Width (ft) calculated from Step 3.

Step 5: Calculate the Bankfull Riffle Max Depth Range (d_{max})

Calculate the bankfull riffle max depth range as follows:

(*7*) Bankfull Riffle Max Depth (ft) = d_{bkf} * 1.3 (low end of range)

(*8*) Bankfull Riffle Max Depth (ft) = d_{bkf} * 1.8 (high end of range)

The range selected for the riffle max depth ratio came from a box plot of the reference reach data (Figure 20). The plot shows the riffle max depth divided by the riffle mean depth. The 25th percentile is just under 1.4 and the 75th percentile is just over 1.8. This ratio is used in the design process to design the riffle thalweg, which is the deepest part of the channel. A 1.3 multiplier was selected to create the low end of the max depth range to provide flexibility for designers concerned about creating a channel that might be too deep. This can happen with small channels, especially those with channel bottom widths less than 10 feet. The upper end of the range (the 1.8) should be reserved for projects with cobble/boulder beds and bottom widths greater than 10 feet.

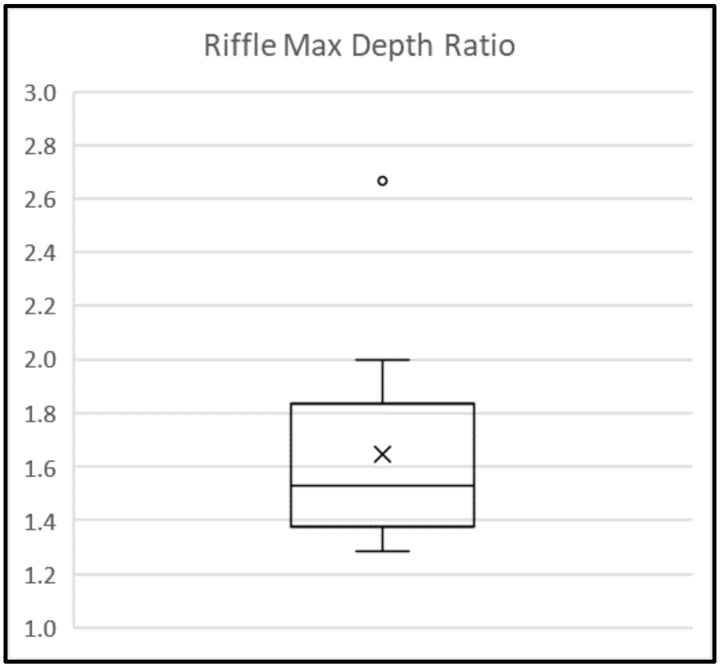


Figure 20. Bankfull Riffle Max Depth ratios from B reference reach streams in Interior Alaska.

Step 6: Calculate the Bankfull Pool Width (W_{bkfp})

Design of the pool dimension follows the riffle. Pool widths should be between 10 to 30% larger than the riffle. The final pool width will be selected when the typical pool cross sections are drawn. The design range for the pool width is as follows.

(*9*) Minimum Bankfull Pool Width (ft) = W_{bkf} * 1.1

(*10*) Max Bankfull Pool Width (ft) = W_{bkf} * 1.3, where

W_{bkf} = Bankfull Riffle Width (ft) calculated from Step 3.

Step 7: Calculate Bankfull Maximum Pool Depth (d_{mbkfp})

Figure 21 shows pool depth ratios from reference reach streams in the Interior Alaska. The ratio is calculated as the bankfull max pool depth divided by the riffle mean depth. The range is just under 1.0 to a max of 3.7 with a median value of 2.1. Values less than 1.0 occurred in small streams where the pool depth was limited by bedrock or large bed material. Figure 21 shows that the typical pool depth ratio range, as defined by the 25th and 75th percentile, is 1.8 to 2.7 times deeper than the average depth of the riffle. The max ratio observed was 3.7. From a design perspective, it is better to use ratios near the higher end of the range to provide more energy dissipation and habitat quality. It is okay to build overly deep pools and allow them to fill slightly during storm events as long as the pools remain at least 1.8 times deeper than the riffles, and preferably greater than 2 times the riffle.

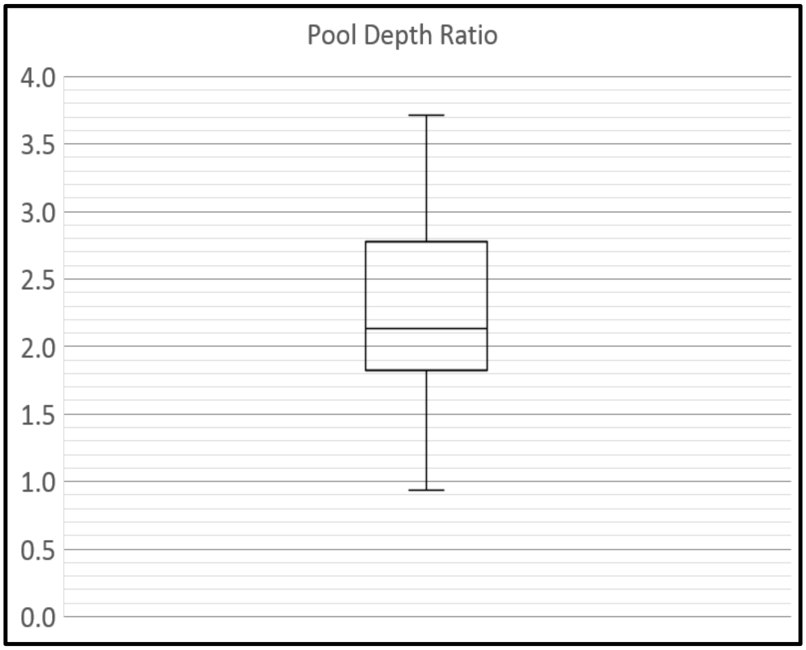


Figure 21. Pool Max Depth divided by Riffle Mean Depth ratios from B reference reach streams in Interior Alaska.

Using the range above, calculate the maximum pool depth range as follows:

(*11*) Minimum Bankfull Pool Max Depth (ft) = d_{bkf} * 2.2

(*12*) Maximum Bankfull Pool Max Depth (ft) = d_{bkf} * 2.8, where

d_{bkf} = Bankfull Riffle Mean Depth calculated from Step 4.

10.2 Channel Pattern/Alignment Design

Step 8: Create an alignment for the reclaimed channel

Channel pattern design is the planform geometry of the channel. In single-thread, meandering channels, pattern measurements include sinuosity, meander wavelength, radius of curvature, belt width, and meander arc length. In Rosgen B stream types, the planform geometry design primarily ensures that the stream path follows the lowest part of the valley. If the valley meanders slightly, the stream will too. However, sinuosity will remain low, typically less than 1.2. The other planform measurements are generally not included in the design process for Rosgen B stream types.

The location of the reclaimed channel may also be dictated by the mining plan. Whenever possible, the reclaimed channel alignment should avoid areas used for settling ponds. In some cases, settling ponds could remain to provide emergent wetlands or fish habitat, e.g., a slough/side channel. However, the new channel alignment should avoid settling ponds because the small sediment sizes increase the risk of bed degradation. In addition, bypass channels located at elevations higher than the valley bottom should not be used as the reclaimed channel. If the bypass channel alignment is in the valley bottom (lowest elevation of the valley) it could potentially be used for the reclaimed channel alignment. The designer is encouraged to coordinate with the BLM or the appropriate agency to determine the final channel alignment. This alignment should be drawn onto the base map. A centerline should be drawn and stationed from the upstream to the downstream end of the reach. An example is provided in Figure 22.

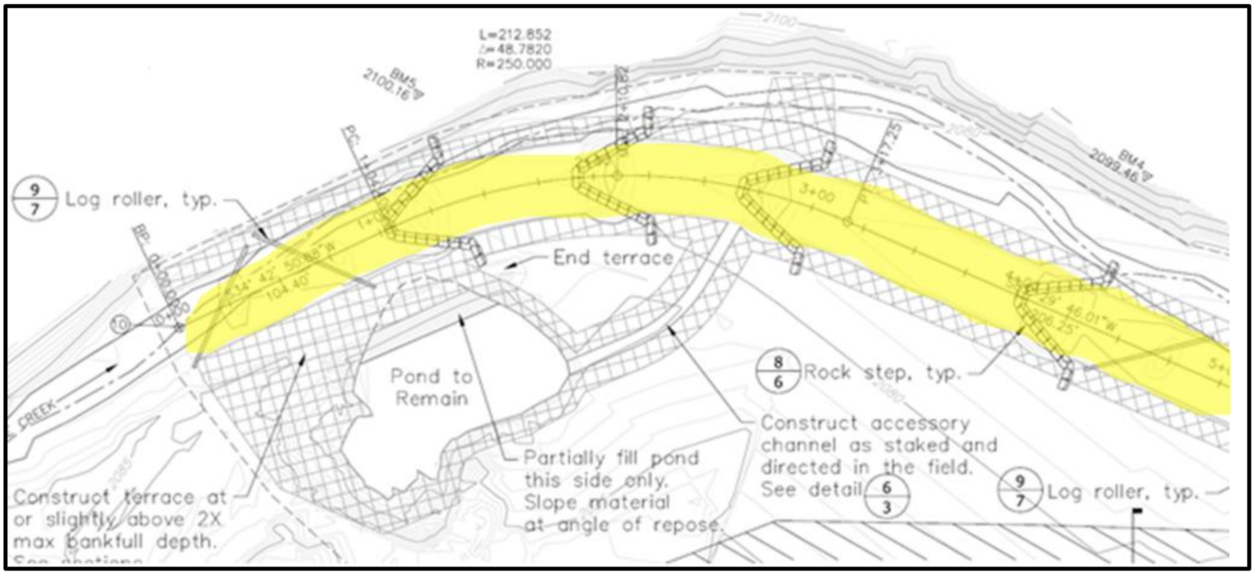


Figure 22. Example channel alignment with centerline stationing. Station starts at upstream beginning of reach (left) at 0+00. Tick marks are provided every 25 feet and labels every 100 feet. This example is a Rosgen Bc stream type. The alignment follows the lowest elevation portion of the valley. Cross vanes were used to create a step-pool profile.

Step 9: Calculate Sinuosity

Using the base map from Step 8, calculate sinuosity (k) as follows.

(*13*) Sinuosity (ft/ft) = Channel Length / Valley Length (CL/VL), where

Channel Length equals the total stationing length from Step 8.

Valley Length = A straight-line that follows the fall-line of the valley. If the valley is straight, measure from station 0 to the end station.

10.3 Vertical Stability Assessment of the Design Dimension and Slope

A vertical stability assessment should be completed before proceeding to the profile design.

Before designing the channel profile, a vertical stability assessment of the proposed dimension and channel slope should be completed. This assessment uses the valley and design channel slopes as inputs, and therefore must be calculated first. Calculations for each are shown in steps 10 and 11.

Step 10: Calculate Valley slope (VS) as:

(*14*) Valley Slope (ft/ft) = Elevation change over the reach length / Valley Length (VL), where,

The elevation change over the reach length is the difference in the elevation at station 0 and the elevation at the downstream most station. This measurement assumes that the beginning and end feature is a riffle, so that these elevations are taken from the beginning or head of the riffle.

Valley Length = Same length calculated in Step 8.

This will likely be the same value as the valley slope calculated in Section 8.1, equation 1. Slight differences can be caused during valley re-grading / reclamation.

Step 11: Calculate the Average Channel Slope (S) as:

(*15*) Design Channel Slope (ft/ft) = Valley Slope / Sinuosity (VS/k), where

Valley Slope (VS) is the result of Step 10.

Sinuosity (k) is the result of Step 9.

Step 12: Calculate the boundary shear stress (τ) for the proposed design

Shear stress is a force exerted on the streambed by flowing water that can initiate movement of bed sediments. Shear stress can be estimated as the product of the specific weight of water (γ), the riffle mean depth from the bankfull flow, and the average channel slope (Wohl et al., 2010). This shear stress value can then be used to predict the sediment size that is likely to be transported during a bankfull discharge. Shear stress (and other parameters) can also be used to evaluate floodplain stability during flows that are larger than bankfull. Floodplain shear stress and floodplain stability is discussed in Section 10.4.

Shear stress ($\tau = \gamma d_{bkf} S$) is calculated as follows.

(*16*) Shear Stress (τ) in $lbs/ft^2 = 62.4 * d_{bkf} * S$, where:

62.4 is the unit weight of water (lbs/ft^3)

d_{bkf} = Bankfull riffle mean depth (ft)

S = Average channel slope (ft/ft) from step 11.

Note, shear stress is provided as an output in the Reference Reach Spreadsheet (Mecklenburg, 2006), on the cross section sheet. The spreadsheet calculates shear stress using the hydraulic radius instead of mean depth. This is generally considered a more accurate way to calculate shear stress and therefore can be used rather than the manual calculation above. Either option is acceptable.

Step 13: Predict the particle size that will move during a bankfull discharge

Using the shear stress value calculated in Step 12 and Figure 23, determine the particle size that can be mobilized during a bankfull flow. For shear stress values between 0.05 and 1.5 lbs/ft^2, use the dashed red line to predict the grain size in millimeters (mm). For shear stress values less than and greater than this range, use the solid black line to predict the grain size (Rosgen, 2006).

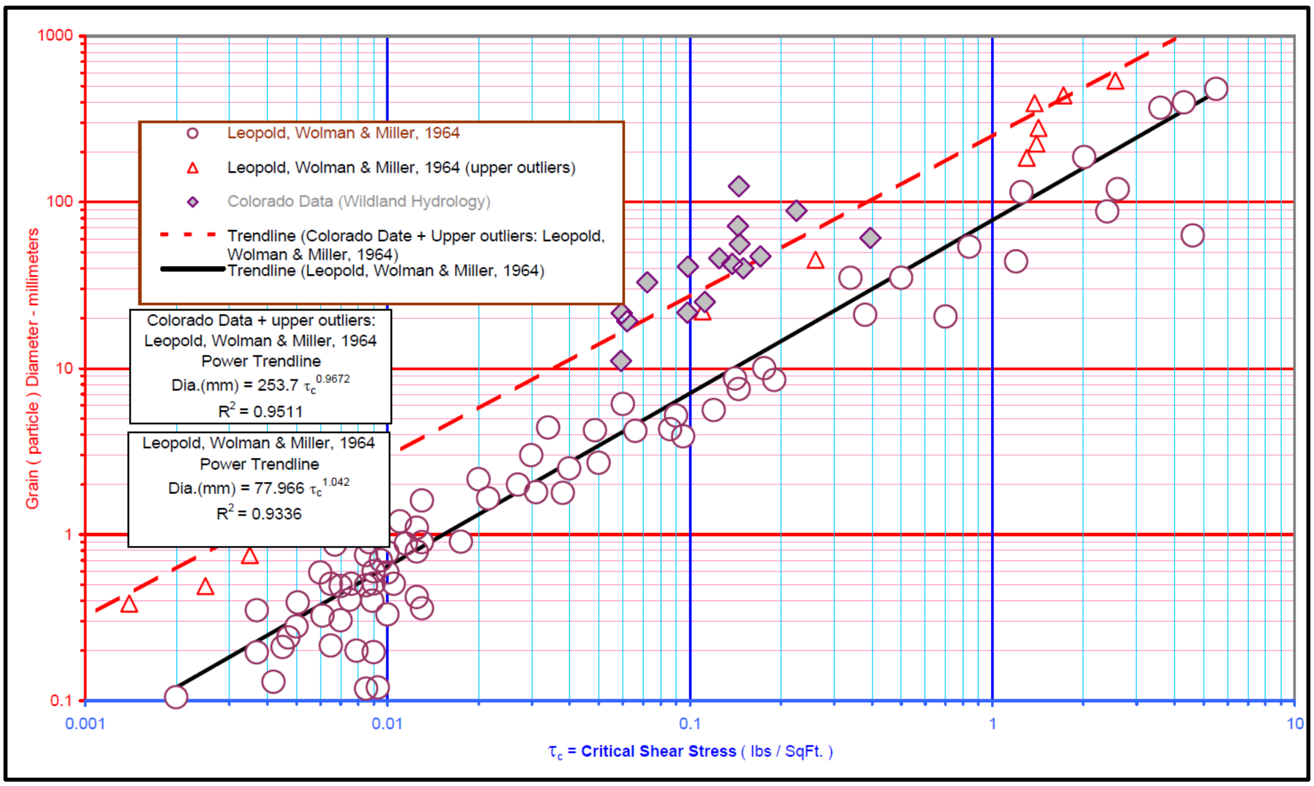


Figure 23. Shear Stress Curve (From, USEPA Watershed Assessment of River Stability and Sediment and Dave Rosgen (WARSSS) v. 1.0).

Step 14: Determine risk of degradation and aggradation

The purpose of step 14 is to determine the overall risk of stream bed degradation (incision) or aggradation (filling). The analysis is applied to riffles/cascades and not to steps. The step structures are constructed from boulders that are much larger than the riffle/cascade material.

Furthermore, if the overall risk of degradation is high, the designer may choose to use constructed riffles/cascade material sized to be larger than what this analysis will show. Sizing cascade and step rock in settings where degradation is a concern is discussed in Section 12.1.

A grain size distribution of bed sediments was completed per Section 8.3. Compare the D_{84} (grain diameter representing the 84th percentile and shown on the y-axis of the grain size distribution) to the grain size predicted in Step 13. If the predicted grain size is larger than the D_{84} it means that the design has more shear stress than is needed and there is a risk of degradation. The next step is to compare the predicted grain size to the D_{100} from the grain size distribution. If the predicted grain size is larger than the D_{100} there is a high likelihood that the bed will degrade (incise or lower in elevation) during bankfull or higher flows. In other words, the bigger the difference between the predicted grain size and the actual size, the bigger the risk of degradation.

To reduce shear stress, the riffle dimension can be re-designed by repeating steps 1-4 and selecting a smaller bankfull cross-sectional area, a higher W/D ratio, or both. However, the newly selected area should not be below the range of scatter used to create the bankfull regression line, and the W/D ratio should not be higher than the values shown in Figure 19. Another way to decrease shear stress is to decrease the slope. However, the only way to reduce slope is to increase the sinuosity, which is not advisable in colluvial or confined alluvial valleys, and physically impossible in V-shaped valleys. A very slight increase in sinuosity may be appropriate in confined alluvial valleys, but the value should stay below 1.2 and in no scenario should the designer incorporate meandering processes into the design.

If the predicted shear stress value from Figure 23 is smaller than the measured D_{84} it means that the design does not create enough force to move the D_{84} and there is risk of aggradation (the bed elevation increases after a bankfull or higher flow). The shear stress can be increased by repeating design steps 1-4 and decreasing the W/D and/or increasing the bankfull area. However, the bankfull area should not exceed the range of scatter used to develop the regional curve and the W/D ratio should not be less than what is shown in Figure 19.

If these iterations do not yield an acceptable shear stress value that maintains bankfull area and W/D ratios that are representative of reference reach data, more sophisticated methods of sediment transport analysis may be needed. It is beyond the scope of this technical report to provide guidance on complex sediment transport competency and capacity analysis. The designer should refer to the National Engineering Handbook, Part 654 (NRCS, 2007), the Manual for Computing Bed Load Transport Using BAGS Software (Pitlick et al., 2009), and/or the Hydrologic Engineering Center – River Analysis System (HECR-RAS, https://www.hec.usace.army.mil/software/hec-ras/) for guidance and methods to perform sediment transport analysis. This is only a partial list of sediment transport resources. The designer may user other methods if they are more suitable to the project reach conditions.

The designer should recall from Section 1.0 that past reclamation projects have failed in part due to changes in bed material size. Densmore and Karle (2009) estimated that the average size of the bed material decreased by 50% after placer mining. This skewed the relationship between shear stress and particle size; design calculations assumed larger bed material sizes than what were actually present after mining. The more recent BLM demonstration projects included constructed riffles/cascades with steps on the downstream end to provide grade control and reduce the risk of degradation. The constructed riffles/cascades also provide risk management against the uncertainty associated with these particle size versus shear stress relationships in mined environments. In other words, after the channel dimension and slope have been adjusted to optimize the shear stress needed, constructed riffles/cascades will still be needed for all projects to provide grade control. Design guidance for constructed riffles/cascades is provided in Section 12.1.1.

10.4 Floodprone Area Design and Stability Assessment

Step 15: Calculate floodprone area hydraulics.

The width of the floodprone area is similar to the width of the valley bottom. Mathematically, it is the width of the floodprone area measured at a depth that is twice the max bankfull riffle depth (Rosgen, 1996). The width of the floodprone area is then divided by the bankfull width to calculate the entrenchment ratio. A schematic cross section drawing of the floodprone width used in the entrenchment ratio calculation is provided in Figure 24.

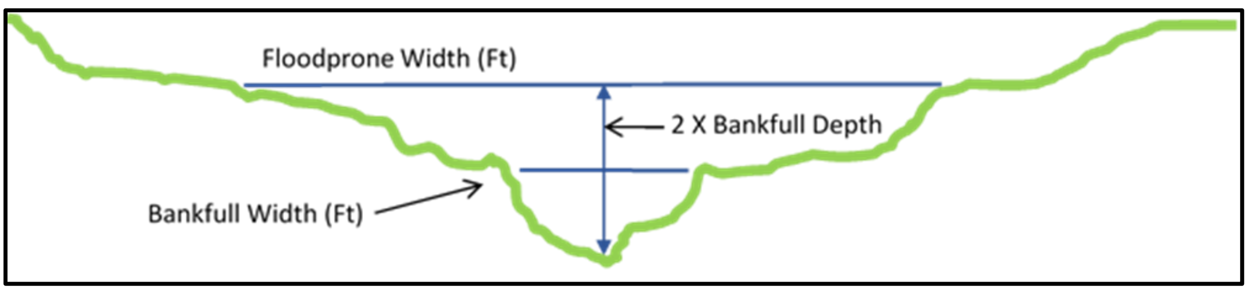


Figure 24. Floodprone width in cross section view. The entrenchment ratio is the floodprone width divided by the bankfull width. The floodprone width is measured at an elevation that is twice the bankfull riffle max depth. Floodprone width is measured perpendicular to the valley axis.

Entrenchment ratio is a delineative criterion used in the Rosgen Stream Classification system. The range for B stream types is 1.4 to 2.2 with a +/- 0.2 variance (Rosgen, 1996). The range of entrenchment ratios measured in Alaska reference reach data is 1.4 to 2.3 with a median value of 2.0. However, the design should select an entrenchment ratio that is as large as the valley width and mining constraints will allow. In general, large widths are preferred over low widths because it generates a wider bankfull bench that can dissipate energy during flood flows. An exception to this is valley settings that have minimal transplants, rock, and wood. These materials are needed to provide floodplain bench vegetation and roughness. See Section 12.2 for design guidance on stabilizing the bankfull bench.

Once the floodprone width has been determined, the floodprone area is calculated for several riffle cross sections along the project reach. Enough cross sections should be selected to represent the range in floodprone widths. If the valley contracts and expands, more cross sections are needed. If the valley has a uniform width, fewer cross sections are needed. A spreadsheet or CADD program will make these calculations easier. The reference reach spreadsheet could be used; however, the elevation of the floodprone width would have to be identified as “bankfull” for the spreadsheet to make the calculation. If this program is used, note that the spreadsheet marked bankfull line is not really bankfull, it is the floodprone width and area. An example of this is shown in Figure 25 and Figure 26. Figure 25 shows the original cross section with bankfull identified correctly. The blue line is bankfull and the red line is the floodprone width. The bankfull area is 28 ft^2, the discharge is 147 cfs, and the velocity is 5.3 ft/s.

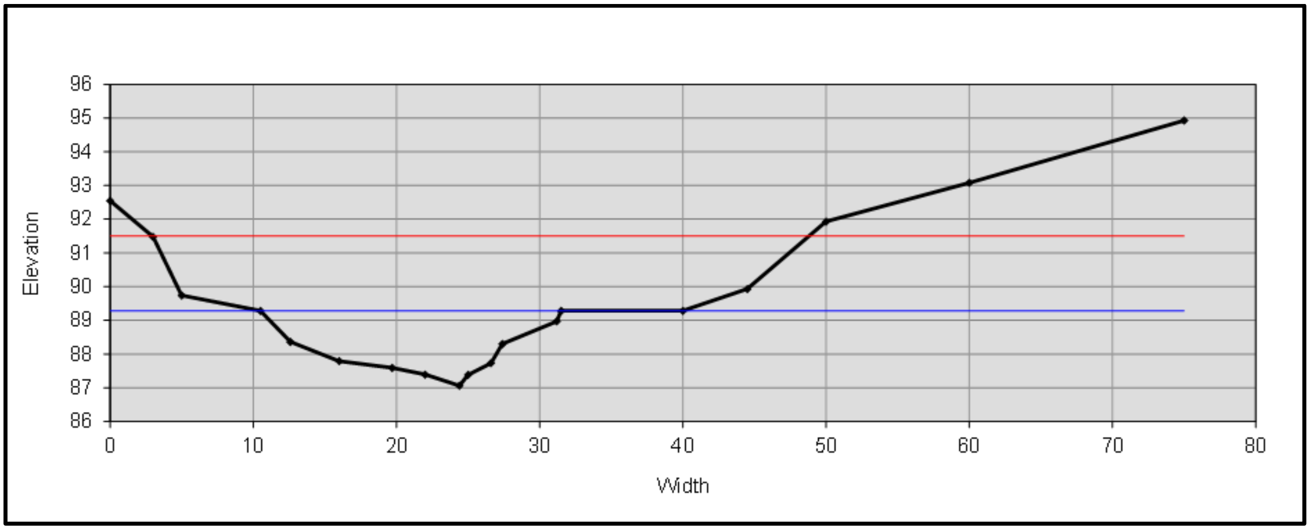


Figure 25. Cross section with bankfull line in blue and floodprone width in red.

In Figure 26, this same cross section is used to calculate the floodprone area by identifying the floodprone elevation as “bankfull.” In other words, the bankfull line is moved up to represent the floodprone width for **calculation purposes** in the spreadsheet. So, the floodprone area is provided in the spreadsheet as the bankfull area and in this example equals 118 ft^2. The shear stress is 7.09 lbs/ft^2, discharge is 763 cfs, and velocity is 6.5 ft/s. Note, this stream has a channel slope of 4.6%, so the hydraulic force values are high.

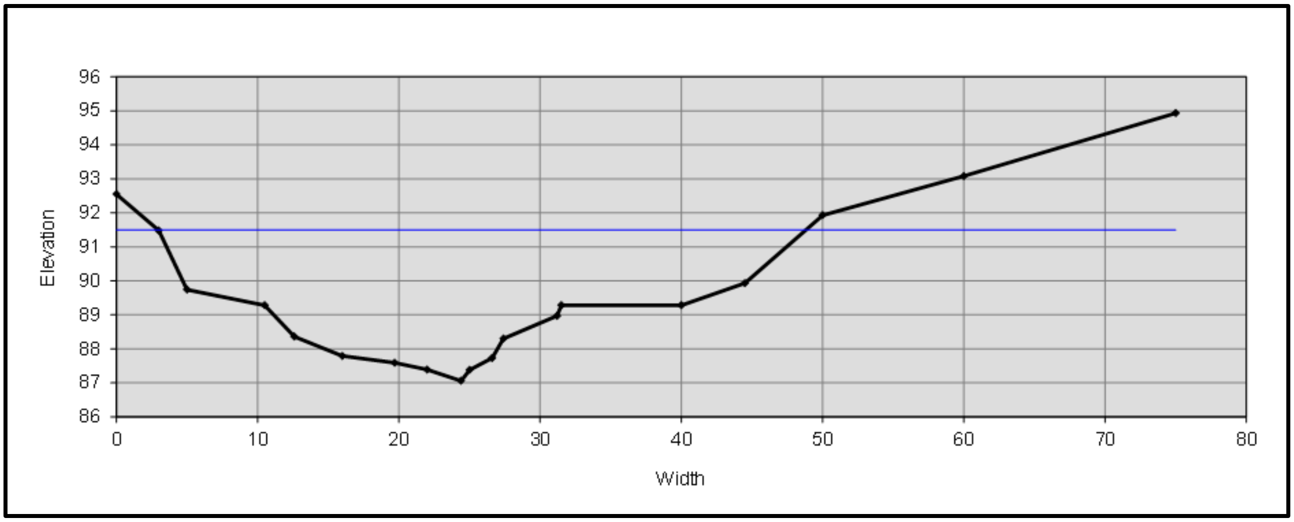


Figure 26. The same cross section as Figure 25 but using the floodprone width elevation as bankfull in order to calculate the floodprone area. The blue line now equals the floodprone width.

10.5 More Sophisticated Ways to Assess Floodprone Area Hydraulics

The method described in Step 14 is a simple and somewhat crude way to calculate shear stress and velocity for flows that access the floodplain bench. The calculated shear stress and velocity are average values for the entire cross section. More sophisticated models are available that can separate shear stress and velocity values between the channel and the floodplain bench. Examples include HEC-RAS and River 2D. However, these models require more data and expertise than what may be available for most mine reclamation projects.

Step 16: Evaluate the shear stress associated with a 50 year and 100-year flow event

The shear stress values calculated in step 14 are used to evaluate channel and bankfull bench stability, and more specifically, the risk of instability. The shear stress values calculated in step 15 can be used as a surrogate for the 50-year discharge event. HEC-RAS or other models will be needed if the shear stress for the 100-year event is assessed. For the following guidelines, the shear stress and velocity results from step 15 can be used.

Fischenich (2001) provides design guidance on developing stability thresholds for a variety of stream restoration materials. The report notes that vegetated soils can generally withstand shear stress values between 0.5 and 4 lbs/ft^2; erosion control materials and bioengineering techniques between 0.5 and 8 lbs/ft^2, and hard armoring up to 13 lbs/ft^2. The report also notes that gravel/cobble beds can withstand shear stress values between 0.33 and 4.0 lbs/ft^2 before instability occurs; however, there are many other factors that can affect these results. Table 10 below provides more detailed guidance for gravel/cobble beds, a range of vegetation, bioengineering, and hard armoring techniques. Shear stress and velocity thresholds are provided. The table is a modified version from Fischenich (2001). Modifications were made to better reflect Alaska conditions and stabilization techniques that will likely be used. Specific stabilization techniques will be discussed in Phase 7 (Section 12). Designers should refer to Fischenich (2001) for additional guidance on how to evaluate shear stress and permissible values when considering stability methods.

Table 10. Permissible shear and velocity values for select materials and stabilization techniques. Modified from Fischenich (2001).

Select Material	Description	Permissible Shear Stress (lbs/ft^2)	Permissible Velocity (ft/sec)
Gravel/Cobble	1-in	0.33	2.5 to 5.0
	2-in	0.67	3 to 6
	6-in	2.0	4 to 7.5
	12-in	4.0	5.5 to 12.0
Vegetation	Long native grasses	1.2 to 1.7	4 to 6
	Hardwood tree plantings	0.41 to 2.5	N/A
Erosion Control Matting. Example is RG Geocoir 700. Values vary by product	Coconut fiber without plastic	3.0	9.2
Bioengineering	Brush mattress	0.4 to 4.1	4
	Brush layer	0.4 to 6.25	12
Riprap	6 in	2.5	5 to 10
	9 in	3.8	7 to 11
	12 in	5.1	10 to 13
	18 in	7.6	12 to 16
	24 in	10.1	14 to 18

Given the high slopes and therefore high shear stress values, along with the unconsolidated sediments and high sand content associated with placer mining, rock and robust vegetation will be needed to maintain channel stability. It is rare that a placer mine reclamation site can use gravel/cobble for the beds and no transplants or large rock on the bankfull bench.

It is rare that a placer mine reclamation site can use gravel/cobble for the beds without transplants or large rock on the bankfull bench.

11.0 Phase 6: Channel Profile and Cross Section Design

Once the vertical stability analysis has been completed and the designer is confident that the design dimension and average channel slope will meet the desired stability goals, a detailed profile can be designed. This is the crux of the design process for B stream types. The detailed profile includes the design of riffles/cascades, steps, and pools. The designer should vary the profile to include some sections of step-pool profile and other sections of cascade-step-pool, especially in smaller drainage areas (e.g., less than 5 mi^2). In larger watersheds, it is acceptable to only design cascades/riffles between pools. Steps can be placed at the downstream end of the cascade/riffle. Figure 27 shows a section of step-pool profile including step spacing, step height, pool length, and pool depth. All these features must be included in the design. Figure 28 shows the profile with cascades or riffles between the pools. This configuration is more common than only steps between pools, and again, is the preferred approach in larger watersheds. If step-pools are used (Figure 29) it should be for a short length of channel, e.g. one or two series of step-pools, and then back to cascade/riffle-pools. The variability of profile design between step-pools and cascade-pools is most applicable in the smaller watersheds.

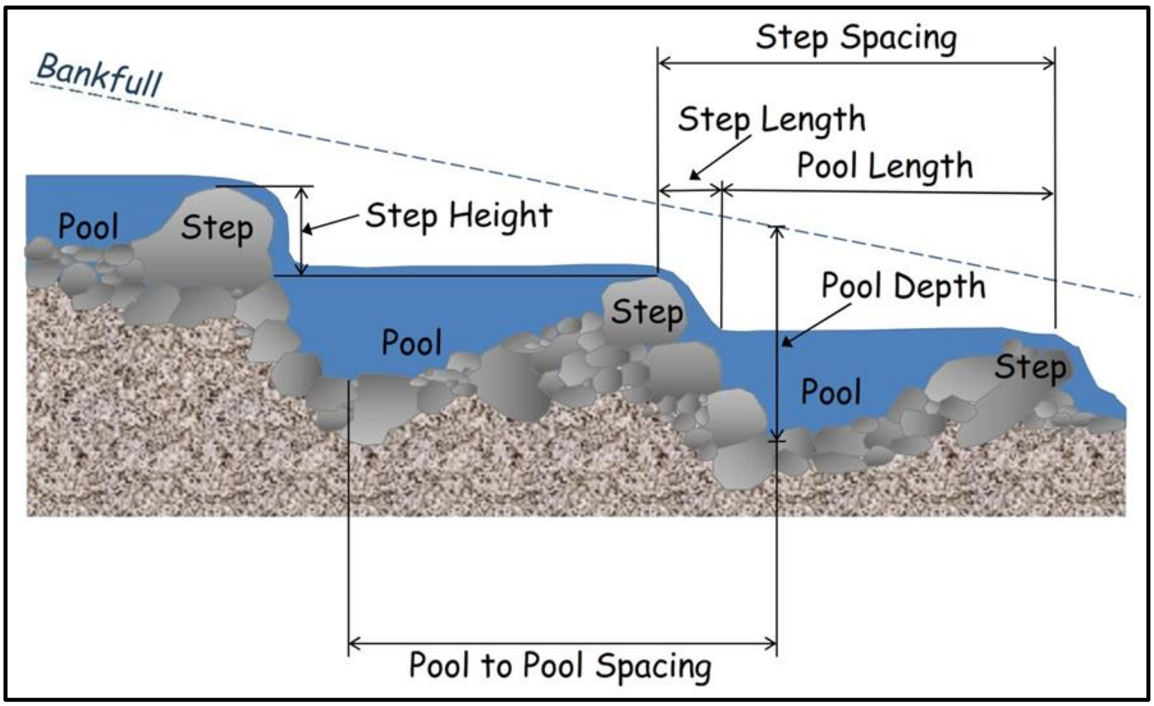


Figure 27. A typical profile of a B stream type with a step-pool profile.

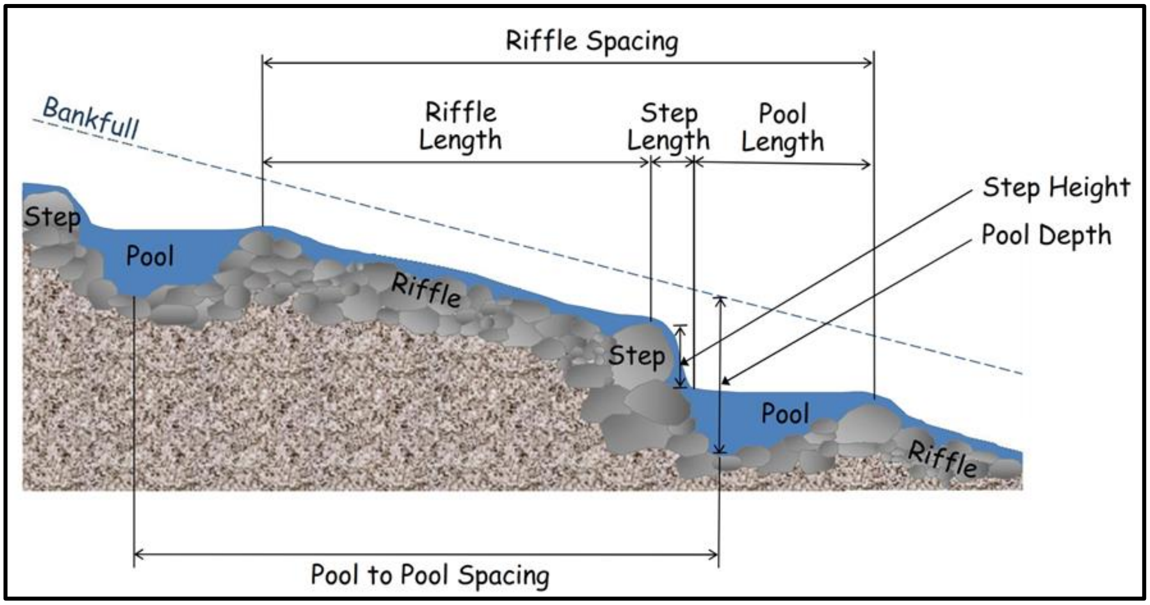


Figure 28. A cascade or riffle-step-pool sequence. This sequence will be used more regularly in a design than the step-pool sequence.

The design criteria used to develop these features include pool spacing, pool depth, step height, and percent feature length. Design criteria for each are provided in the following steps.

11.1 Pool Spacing

Pool spacing (P_s) is stratified by step-pool and riffle/cascade-pool features. Therefore, separate design criteria are needed for both. The pool spacing is the distance between the max depth of sequential pools. The range for riffle/cascade pool and step pool is calculated using the following equations and ratios from the box plot in Figure 29. The ratios shown in Figure 29 are the pool spacing divided by the bankfull riffle width (Wbkf).

Step 17. Calculate pool spacing (P_s) for profile sections that have a riffle or cascade between pools as follows:

(*17*) Pool Spacing Min = Bankfull Riffle Width * 1.0

(*18*) Pool Spacing Max = Bankfull Riffle Width * 4.0

Step 18. Calculate step-pool spacing as follows:

(*19*) Pool Spacing Min = Bankfull Riffle Width * 0.4

(*20*) Pool Spacing Max = Bankfull Riffle Width * 1.0

Figure 29 shows that the range of riffle/cascade-pool spacing is 0.4 to 6.0 times the bankfull width. The range is normally distributed with the 25th and 75th percentiles equaling almost 2.0 and 3.7, respectively. The median value is 2.7. The values for step-pool spacing are obviously much lower and the range is much tighter. The design values used in steps 17 and 18 came from

Figure 29 and were then adjusted to simplify the design process and prevent overlap between the design. In other words, for design purposes, a feature that is longer than 1 times the bankfull width is called a cascade/riffle and a feature shorter than 1 times the bankfull width is a step.

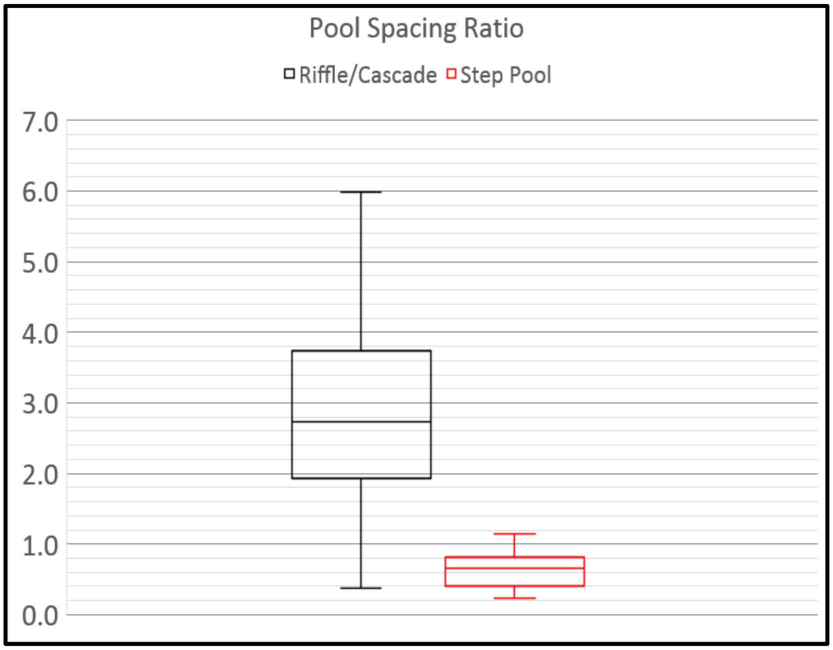


Figure 29. Pool Spacing Ratios from reference reaches in the Alaskan Interior.

Step-pool structures should be used sparingly within a design reach; meaning, most pools should be separated by a cascade/riffle. As a general rule, a reach should not have more than two or three steps unless the reach is long, e.g., greater than 20 times the bankfull width. And, it is okay for the reach to not have any steps, other than steps associated with the downstream end of a cascade. One caveat to this is steep channels, e.g., those greater than 3 or 4% slope and with new channel alignments. New channel alignments refer to a relocated stream or a channel adjacent to an existing channel. In these systems, steps should be used more frequently to ensure vertical stability.

11.2 Pool Depth

The pool depth range was calculated in Step 7 during the typical pool dimension design. Use the pool depth range calculated from that step in the profile design. Remember that this is the maximum pool depth from the thalweg to bankfull.

11.3 Step Height

Step 19. Calculate the max step height.

Figure 30 shows the distribution of step heights and step height ratios measured from the reference reach data set. To keep things simple and to focus on constructability only the actual step height range is used. A minimum step height calculation is not required; however, a minimum height of 0.3 feet is suggested. Otherwise, it would not be considered a step. The maximum step height should not exceed 1.0 feet from a design-stability perspective. Figure 30 shows step heights in reference streams exceeding this value (max step heights were about 1.8 feet). However, as step height increases the risk of instability also increases, especially when working in unconsolidated sediments like those found on placer mine sites. In addition, high step heights may seasonally limit fish passage. Designers should consult with the Alaska Fish and Game Department for permitting and design requirements related to step heights and fish passage.

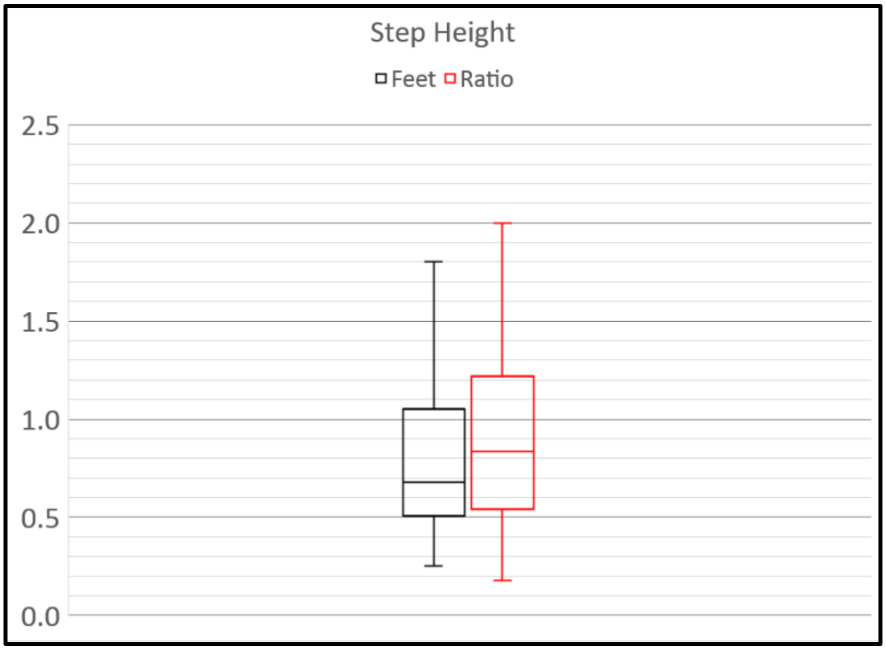


Figure 30. Step heights and step height ratios from reference streams.

11.4 Riffle/Cascade, Step, and Pool Lengths

Figure 31 shows the length ratios for each bed feature. The ratio is the feature length divided by the bankfull width (W_{bkf}). Cascades/riffles are the longest feature. Pools and steps are much shorter and the range is less.

Step 21. Calculate feature lengths as follows:

(*21*) Minimum riffle/cascade length (ft) = 1.0 * W_{bkf}

(*22*) Maximum riffle/cascade length (ft) = 5.0 * W_{bkf}

(*23*) Minimum step length (ft) = 0.1 * W_{bkf}

(*24*) Maximum step length (ft) = 1.0 * W_{bkf}

(*25*) Minimum pool length (ft) = 0.5 * W_{bkf}

(*26*) Maximum pool length (ft) = 1.3 * W_{bkf}

The maximum pool length ratio shown in Figure 31 is about 1.1. However, lessons learned from building demonstration projects indicate that a slightly higher ratio may allow for better energy dissipation in the pool and less stress on the downstream head of riffle. This higher value also allows for the natural formation of a glide bed feature between the pool and riffle. Therefore, a 1.3 ratio is recommended for most projects. A value closer to 1.1 should be used in small, steep watersheds (e.g., drainage areas less than 5 mi^2 and slopes greater than 3%).

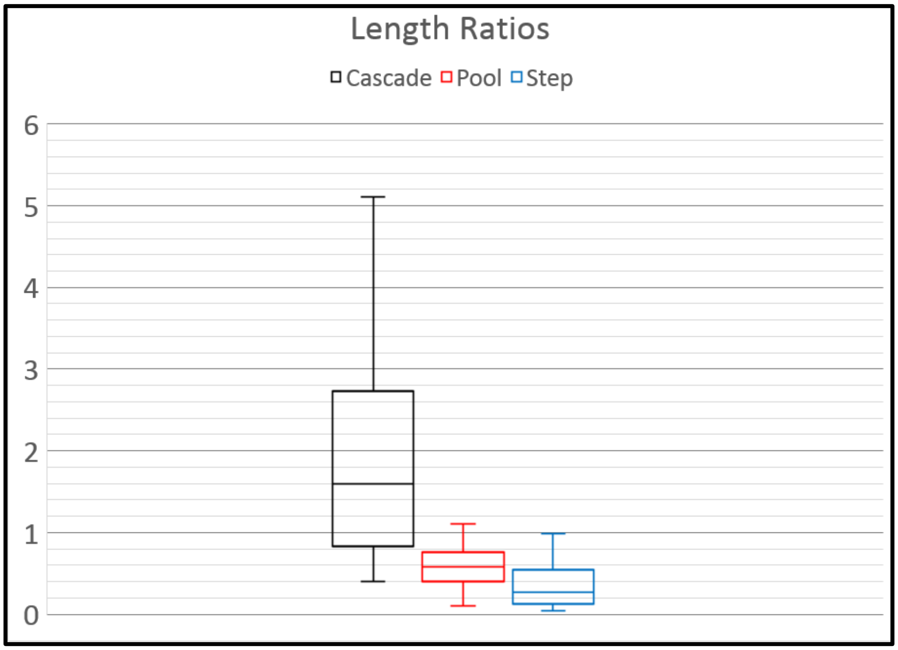


Figure 31. Feature length ratios from reference streams.

<u>Rationale and Design Guidance for Feature Lengths</u>

The following rationale and guidance for designing feature lengths is provided to help the designer think through design options.

- A ratio of 1.0 has arbitrarily been used to separate a cascade/riffle length from a step length. So, lengths that are greater than 1.0 X riffle width are cascades/riffles and lower ratios are steps. This criterion is used to simplify communication and decision making about whether a feature is a riffle or a step.
- For reaches that have unconsolidated sediments or new channel alignments, lower ratios should be used more frequently than higher ratios. New channel alignments refer to channels that are being constructed outside the boundary of an existing channel.

11.5 Drawing the Profile

Step 22. Create the design profile

Once the design criteria have been calculated using steps 16 through 21, the final profile can be created in an Excel Spreadsheet or CADD. The x-axis of the profile represents the stationing or stream length created in step 8. The profile should show the design thalweg, existing ground, and bankfull elevation/profile (BKF). An example of an Excel generated profile is provided in Figure 32. The final profile design will be completed as part of the plan set.

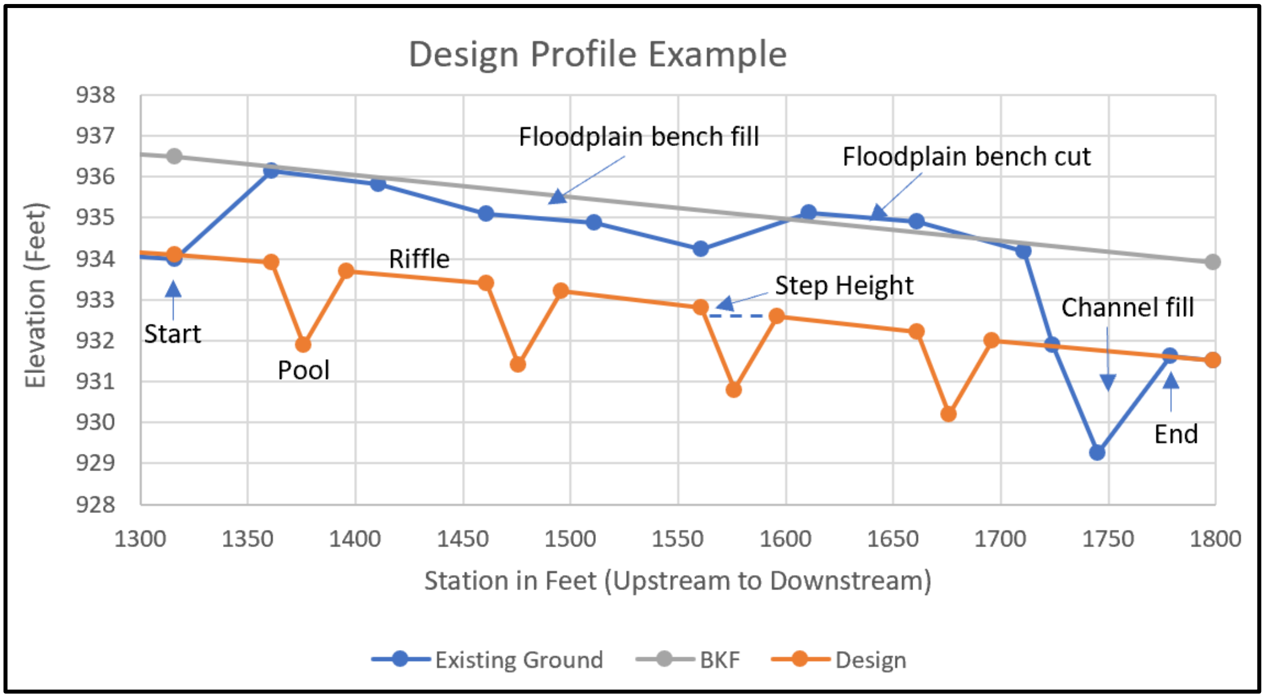


Figure 32. Example profile design using Microsoft Excel. Note, that the bed feature sequence is a riffle (or cascade) followed by a step and then a pool. Riffle/cascade features should be included between pools. Also note that the riffles are not flat, they have a slope that is designed from the reference reach data.

There are several important observations to note from Figure 32, including:

1. The design elevation and existing ground elevation are equal to each other at the start and end points. These points are where the design channel ties into the existing channel, so those elevations should be the same.
2. The first riffle point downstream of a pool is a slightly lower elevation than the last riffle point upstream of the pool. The difference in elevation between these two points is the step height.
3. The existing ground line is higher than the design line in areas where a new channel is being excavated.
4. Places where the existing ground is below the design line, the channel bed will be filled. It is best to fill the bed material with onsite gravel and cobble.
5. The bankfull (BKF) line is established by using the bankfull riffle max depth from the design. This line is used to determine if the floodplain or floodplain bench will need to be cut or filled in order to ensure that the bankfull depth is equal to the top of bank depth.

6. Places where the bankfull line is above the existing ground line will be filled to meet the bankfull riffle depth design.

Step 23. Calculate the feature percent as follows:

(*27*) Percent Cascade/Riffle (%) = Total cascade/riffle length divided by total reach length

(*28*) Percent Step (%) = Total step length divided by total reach length

(*29*) Percent Pool (%) = Total pool length divided by total reach length

To make these calculations the total length of each feature is used. For example, if there are five riffle/cascade features, the sum of those five lengths is divided by the total reach length. The result of each feature percentage is then compared to Figure 33 to ensure that the results fit within the range shown. For example, a 65% cascade/riffle percentage is within the range shown but 90% is not. If the design value is outside of the range, the number or length of cascade/riffles should be redesigned until the percentage is within the range. This rule applies to all three features: riffle/cascades, steps, and pools.

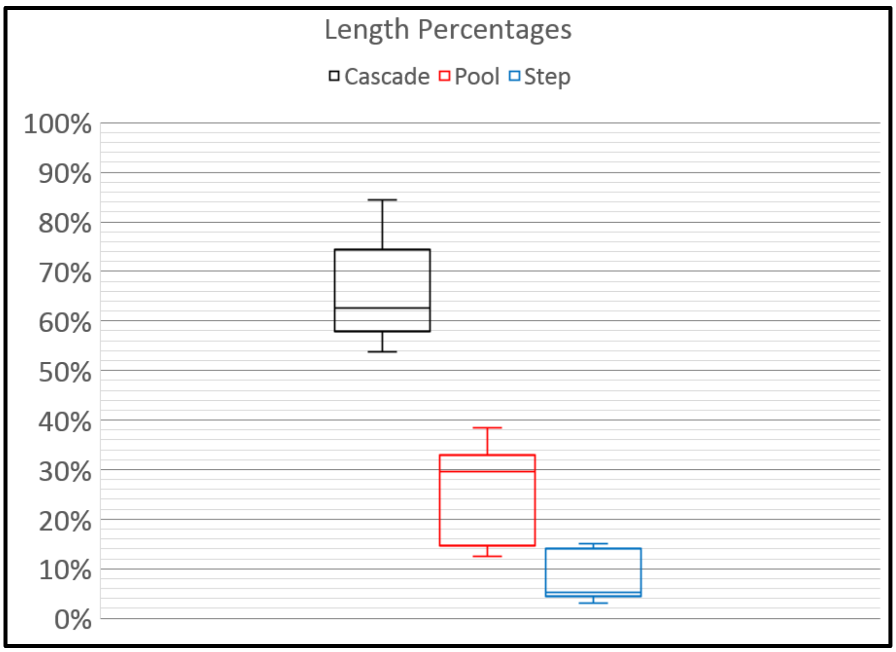


Figure 33. Cascade, pool, and step lengths as a percent of total reach length.

11.6 Plan View Drawing

The channel pattern/alignment design was completed in Step 8 under Section 10.2. This step laid out the channel plan view and included stationing along its centerline. Use this plan view to complete step 24.

Step 24. Show riffle/cascade and pool locations and channel widths on the plan view.

Using the profile stationing as a guide, show the pool locations on the plan view. Use the pool length from the profile to draw the pool length on the plan view. Note, the stations for a given pool on the plan view and profile should be the same. Also show the riffle locations. Use the bankfull riffle width from step 3 to show the width on the plan view. Do the same for the pools using the pool width calculations from step 6.

11.7 Cross Sections

Step 25. Create cross sections and determine earthwork quantities

Once the typical sections, horizontal alignment, and profile have been developed, the cross sections can then be created. Earthwork quantities are generated from the cut or fill associated with each cross section and the channel length between the cross sections in a method called Average End-Area Method. The general concept of the Average End-Area Method is that the earthwork volume (V) can be approximated with the following equation:

(*30*) $V = \sum L \frac{A1+A2}{2}$; where,

V = Volume of cut or fill (ft^3),

A = The area (ft^2) of cut or fill associated with a cross section,

L = the channel length (ft) between the two cross sections,

The volume of cut or fill for each pair of cross section is summed to get the total volume of cut or fill.

Computer software, such as Civil3D, is a powerful design tool that allows the designer to make changes on the fly and update the entire design accordingly. The designer studies the alignment, profile, and cross sections together and iteratively develops the final design. Earthwork quantities can be generated for each design iteration to help balance cut and fill requirements. This software is expensive and requires considerable expertise; it is typically used by engineers.

12.0 Phase 7: In-Stream and Bankfull Bench Structure Design

In-stream structure design comes after the channel geometry has been designed. Structures alone cannot fix instability problems.

In-stream structures are used to provide vertical and lateral stability to a newly constructed channel. Their design comes after the channel dimension, pattern, and profile have been designed because structures alone cannot fix channel geometry problems. This section provides design guidance for vertical and lateral stability structures. The rock, vegetation, and wood located during the existing condition survey (refer to Section 8.6) are used to design and construct the in-stream and bankfull bench structures. Detail drawings and specifications for many of the structures described below can be found in Appendix F. Once the structures have been selected, show their location on the plan view drawing.

12.1 Vertical Stability Structures

Designing a proper channel and floodplain bench dimension along with a cascade-step-pool and step-pool profile are key elements in providing vertical stability; however, it may not be enough in highly modified placer-mined valleys. The grain-size distribution has been altered and riparian vegetation has been removed to such a degree that sediment supply and bed mobility is high to extreme (very low erosion resistance). As watersheds become more extensively mined, the risk increases. As a result, some type of constructed grade control will be a routine part of the design process. Recommended structures include constructed cascades/riffles and steps. Cross vanes and grade-control J-hook vanes are common grade control structures in Natural Channel Design (NCD) and have been used in Alaska successfully since the early 2000s; however, these structures are not commonly recommended in placer mine reclamation due to their design and construction complexity.

12.1.1 Constructed Cascades/riffles

Constructed cascades and riffles should be the primary method for providing grade control on placer mine reclamation sites. These structures should include bed material sizes that are a mix of gravel, cobble, and boulders; however, the majority of the structure should be cobble- and boulder-sized particles. Care should be taken in sizing the cascade/riffle material and the design should consult appropriate design manuals for sizing rock. Refer to step 15 and Table 10 for a list of shear stress and velocity values for given rock sizes. If possible, more robust forms of design should be used. One design guide is the USDA-NRCS National Engineering Handbook, Part 654, Technical Supplement 14G: Grade Stabilization Techniques. The section titled “Rock Sizing for Loose Rock Structures,” starting on page TS14G-7 may be beneficial.

Monitoring from past BLM demonstration projects show that constructed cascades can be an effective method of providing grade control if they are constructed properly. These lessons learned have led to the following design criteria, which should be used in conjunction with rock sizing procedures.

1. The structure should extend well below the bed elevation and extend beyond the channel width. Generally, the structure depth should be 18 to 24 inches below the bed elevation and extend beyond the bankfull width, with more width being preferred.
2. Boulder sills should be used near the top and downstream end of the cascade, and these rocks should be placed first. The downstream sill can serve as a step. Sills should be installed flush with the thalweg design elevation and should slightly concentrate flows towards the center of the channel.
3. Filter fabric should be placed immediately upstream of the boulder sills. For the upstream-end sill, backfill should be placed against the filter fabric to secure the fabric to the boulders. Additional material should be placed upstream of the fabric for a distance of 5 to 10 feet to further protect the fabric. For the downstream sill, the fabric should be placed before the cascade is filled. The cascade rock should be placed against the filter fabric to hold in place (See step 4).
4. Cobble should be placed after boulders with gravel supplied last. The material should be “washed in” by pouring water over the structure using a track hoe bucket and water from a nearby source, so that voids within the boulders and cobble are filled with progressively smaller stone to effectively plug the structure.

Figure 34 shows a constructed cascade using quarried boulders and onsite cobble. Miners can often use onsite boulders salvaged during the mining process.

Figure 34. Constructed riffle/cascade with a step on the downstream end.

Figure 36 shows the installation of a boulder sill at the upstream end of the constructed riffle. Filter fabric has been placed along the upstream edge. Figure 37 shows the riffle after construction has been completed.

Figure 35. Boulder sill with filter fabric being constructed at the head of a constructed riffle.

Figure 36. Riffle (from previous figure) after construction has been completed.

12.1.2 Steps

Boulder steps should be placed on the downstream end of most cascades to reduce cascade slope and to create a small drop into the pool. The step also provides grade control for the cascade. In addition, steps can sometimes be used to create a step-pool sequence, which is two pools separated by one step. Figure 37 shows a step-pool sequence. Each step should include a row of footer rocks below the top row of header rocks and "splash" rocks downstream of the step. Filter fabric should be installed on the upstream side of the steps. The steps should be lower in the center of the channel and slightly higher near the bank. The structure should arc slightly so the invert is farther upstream than tie-ins to the bank. Ideally, no more than one-half the depth of the top boulder (header) should be exposed during baseflow.

Figure 37. Constructed step-pool structure.

12.2 Lateral Stability Structures

Lateral stability is necessary in reclaimed placer-mining sites to maintain channel dimension, reduce sediment supply from bank erosion, and prevent the channel from migrating into un-vegetated areas. For valley settings that have bankfull shear stress values below 2 lbs/ft^2, vegetation techniques like transplants can be used along the streambanks and bankfull benches. For settings with higher shear stress values, a mixture of boulders and cobble will be needed to build the entire channel, as well as the foundation for the bankfull benches. Transplants, wood, and vegetation can be placed over the rock. In addition to this, boulder and log toes may be needed to provide additional stability, especially where the channel turns and bank stress is increased. More details are provided below for each method.

12.2.1 Toe Protection

For bioengineering practices to be effective at stabilizing the streambank, the streambed and bank toe must first be stabilized. The streambed refers to the bottom of the channel, spanning from one edge to the other and including the deepest part of the channel (called the thalweg). The streambed elevation must be relatively stable and show no signs of degradation (bed lowering). The streambed elevation can be stabilized using grade control methods described in Section 12.1. Once the bed is stable, the toe of the bank must be stabilized before using bioengineering methods. The toe of the bank is the area where the streambank meets the streambed. It is the bottom portion of the streambank.

The bioengineering methods listed in this section and described by NRCS (2007) and Alaska Fish and Game (2005) provide a variety of options for stabilizing the bank toe prior to installing bank stabilization measures. This section provides an alternative to those methods based on lessons learned from BLM demonstration projects. This method uses a combination of wood and/or boulders that can often be found on the mine site to create a stable bank toe prior to installing bioengineering methods or transplants. A trench is dug along the bank toe to a depth that is 2 feet below the streambed. The trench is then filled with alternating boulders and/or wood, and brush. The boulders and large wood should be placed first. The trench is then backfilled with smaller rock and soil. The top of the boulders, wood, and fill should be one-third to one-half of the bank height. A brush layer and/or transplants should then be placed on top of the structure. Figure 38 through Figure 40 show examples of the boulder/wood toe protection structure.

Figure 38. A bankfull bench being constructed. Toe wood is used to stabilize the bottom (toe) of the bank, Transplants are used to stabilize the remainder of the bank and the bench.

Figure 39. Boulder and log toe protection with transplants placed on top. Live cuttings are included with brush. The large wood and brush cuttings were placed between the boulders.

Figure 40. Same bank as Figure 39 showing the boulder/log toe protection and a bankfull bench with transplants three years after construction.

Sometimes sites do not have access to wood. In these cases, large boulders can be used to provide toe protection. Figure 41 shows an example of toe protection using boulders.

Figure 41. Toe protection using boulders and no wood. This is less desirable than a mixture of wood and boulders.

12.2.2 Transplants

Transplanted vegetation includes the root mass of woody vegetation along with associated herbaceous vegetation. Transplants can be used to stabilize streambanks and the bankfull bench. If shear stress values from step 16 are below 2 lbs/ft^2 then transplants can be placed directly on the existing sediments/soil. If possible, transplants should cover the entire streambank and bankfull bench area. If shear stress values are greater than 2 lbs/ft^2 or the transplant quality is poor, rock or other bank stabilization techniques will be needed to prevent bank and bench erosion.

Lessons learned from demonstration projects show that young willows growing within herbaceous ground cover work best. However, larger willows, alders, and even trees such as birch mixed with black spruce have been successfully transplanted. Based on the monitoring and lessons learned from the demonstration projects, the following design criteria are suggested. An example of the transplanting operation is shown in Figure 42 through Figure 45.

1. Transplants should be harvested near the project site. If possible, transplants should be moved once with a wheel-loader rather than harvested, stockpiled, and then moved again for installation. The largest wheel-loader available should be utilized. Mining operations are encouraged to move transplants directly from new mining areas to the reclamation area.
2. Do not cut too far below the root zone, but make sure all of the root zone is acquired. Willow roots only grow to a depth of approximately one foot in Interior Alaska. So, a cut depth of 1 to 1.3 feet is recommended. If the cut depth is too deep, then sand, gravel, and “soil” is transferred to the bank site and may result in the transplant being placed too

high. Additionally, the excess material below the rooting depth of the vegetation is highly susceptible to erosion from the stream channel and could result in undermining and loss of the transplant.

3. For banks that are more than 1-foot tall, transplants should be stacked in a shingle-like format to achieve the final bank elevation. The first row of transplants is placed in a shallow trench that parallels the channel. The second (and third or more if needed) row is placed so that ¼ of the transplant sits on the back edge of the first row. This is what is meant by the shingle-like format. Care should be taken to ensure that the design depth is not exceeded, which would result in an incised channel. Once all rows have been installed, gaps around the transplants should be filled with soil, along with the seams along the top and toe.

Monitoring of demonstration projects has shown that transplants are often installed at elevations greater than intended by the design. The result is that channels are deeper than the bankfull design elevation. This is an installation error that increases risk because it increases shear stress in the channel. Under no circumstance should transplants be installed that create an incised channel. The design depths should be used as strict guidance, but if error is accepted, it is better for the channel to be slightly shallower than the design rather than deeper.

Under no circumstance should transplants be installed that create an incised channel.

Figure 42. Preparing the site for transplants by excavating a shallow trench beside the stream channel. Transplants are placed in the trench.

Figure 43. Transplanting with a wheel-loader. After the transplants are placed, a track hoe is used to finalize their placement, cover the seams, and to meet grade requirements.

Figure 44. Transplants placed into the trench shown in Figure 42.

Figure 45 shows a transplanted bank with a floodplain bench after a bankfull event. The transplants and bench reduce floodplain velocities, thereby creating deposition. This deposition further fills in the seams between transplants making them stronger for the next event.

Figure 45. Transplanted vegetation and deposition after a bankfull event. The sediment deposition further improves transplant stability which translates into better bank stability. The stream is located on the far side of the transplanted vegetation at the base of the hillslope.

12.2.3 Bioengineering

Bioengineering methods are useful additions to transplants. Methods used in demonstration projects included brush mattresses, brush layering, live staking, and erosion control matting. Each technique works well when used appropriately. General guidance for each technique is provided below. Detailed design guidance is provided in the USDA-NRCS National Engineering Handbook, Part 654, Technical Supplement 14I, and the Streambank Revegetation and Protection: A Guide for Alaska (Revised 2005) by the Alaska Department of Fish and Game.

Brush mattresses, brush layering, live staking, and other bioengineering techniques require the use of live cuttings. Certain plants native to Alaska can be used for cuttings but not all plants can handle the process. Table 11 provides a list of plants that can be cut and used in these techniques. Several species of willow are provided below, but any willow species found is suitable for dormant cuttings. It is recommended that the types of species on the list be compared to what is present at or near the project site. Using local plants offers the best chance for successful re-growth. The timing of installation is also important. Ideally, bioengineering practices and plantings will occur in the spring to maximize the amount of root growth prior to winter.

Table 11. Plant species suitable for dormant cuttings that can be used in bioengineering methods. This list is adapted from Streambank Revegetation and Protection: A Guide for Alaska by the Alaska Department of Fish and Game.

Species suitable for dormant cuttings	Description
feltleaf willow *Salix alaxensis*	Tree-like shrub on gravel bars, floodplain terraces of rivers, lakes, and streams. Has dense, white felt-like appearance to underside of leaves.
Pacific willow *S. lasiandra*	Tree-like shrub found on sand, silt bars and alluvial deposits in forested areas. Has lance shaped leaves with glassy upper surface.
undergreen willow *S. commutata*	Low to medium shrub forming thickets along streams and rocky slopes. Densely hairy when young.
little tree willow *S. arbusculoides*	Tall shrub to small tree found in openings of mixed forest and along streams. Has slender glossy leaves. Best mixed with other willows for revegetation.
diamond leaf willow *S. planifolia ssp. pulchra*	Medium shrub, forms thickets along streams, lakes, and in alpine tundra. Slender twigs root readily. Best mixed with other species for bulk
balsam poplar- cottonwood *Populus balsamnifera* *P. trichocarpa*	These trees occur on floodplains and openings in forests. Balsam Poplar is a medium sized tree and Cottonwood is the largest broadleaf tree in Alaska. Appearance and habitat of two species overlap. Should be used sparingly and mixed with Willow species.
red osier dogwood *Cornus sericea ssp. sericea*	Red-barked medium tall shrub with opposite leaves, white flowers and berries. Moist soils on floodplains and forest openings. Best mixed with other species for revegetation.

12.2.4 Brush Mattress

A brush mattress is defined in National Engineering Handbook (NEH), Part 654, Technical Supplement 14I as a layer of live cuttings placed flat against the sloped face of a bank (Figure 46 and Figure 47) (NRCS, 2007). Dead stakes and biodegradable string (plastic should not be used) are used to anchor the cutting material to the bank. The brush mattress is installed in a location where the bank toe is stable or has been stabilized using another method (see Toe Protection). The most common applications for placer mine reclamation will be streambanks and the toe of the hillslope where the bankfull bench ends and the slope begins.

Figure 46. Brush mattress placed at the transition from the bankfull bench and the hillslope. Cuttings extend into the ground to a depth that is equal to the water table.

Figure 47. Another brush mattress on the same project site as previous figure. Note the willow growth from the base of the structure. This growth is supported by the contact of the mattress with the water table.

Material and installation guidance from NEH Part 654, Technical Supplement 14I has been adapted for use in Alaska and provided in Appendix F.

12.2.5 Brush Layering

Brush layering is defined in NEH Part 654, Technical Supplement 14I as alternating layers of live cuttings and soil that are placed on a flat, horizontal bench. Brush layering is similar to a brush mattress except a brush mattress is installed on a slope and a brush layer is installed on a flat surface. The most common application for placer mines will be to use brush layering as a way to re-vegetate a bankfull bench when transplants are not available or there are not enough transplants to vegetate the entire bench.

Material and installation guidance from NEH Part 654, Technical Supplement 14I have been adapted for use in Alaska and provided in Appendix F.

12.2.6 Live Stakes

Live staking is the final bioengineering method and should only be used as a way to increase the re-generation of woody vegetation. Live staking alone is not a sufficient way to provide streambank stability. Common applications will include live staking along stable banks and benches that need woody vegetation or augmenting transplanted vegetation mats. In addition, live staking can be used in conjunction with brush mattresses and layers. Willow species should be used for live staking. Examples are shown in Figure 48 and Figure 49.

Material and installation guidance from NEH Part 654, Technical Supplement 14I have been adapted for use in Alaska and provided in Appendix F.

Figure 48. Live stake sprouting shortly after installation.

Figure 49. Several live stakes starting to grow along a streambank.

12.2.7 Erosion Control Matting

Erosion control matting is not typically used on placer mine reclamation sites due to site conditions and transportation costs. However, this technique may be applicable to sites with sandy/silty banks, low gradient valleys, and where transportation costs permit its use. If matting is used, the U.S. Fish and Wildlife Service recommends avoiding the use of materials that contain plastic. Prior to degradation, plastic materials, especially mesh netting found in erosion control mats, can entangle wildlife, including amphibians, birds, small mammals, and fish. These materials also contribute to plastic debris pollution ranging from large sections of dislodged netting to small bits of plastic fragments entering the environment and posing secondary hazards to fish and wildlife. Therefore, the FWS recommends using temporary erosion and sediment control products that either do not contain plastic netting, or that contain netting manufactured from 100% biodegradable non-plastic materials such as jute, sisal, or coir fiber. Due to the shear stress and velocity typical of most reclamation projects, jute or coir fiber netting is often used. Degradable, photodegradable, UV-degradable, oxo-degradable, or oxo-biodegradable plastic netting (including polypropylene, nylon, polyethylene, polyester, poly-jute, etc.) are not acceptable alternatives as all these materials contain plastics. If netting is used, it should have a loose-weave, wildlife-safe design with movable joints between the horizontal and vertical twines, allowing the twines to move independently and thus reducing the potential for wildlife entanglement.

12.3 Bankfull Bench Stabilization and Revegetation Techniques

Once the vertical and lateral stability structures have been installed and the bankfull bench has been graded, stabilization and revegetation measures are needed to prevent or at least minimize bankfull bench erosion. This is particularly important in Alaska because it takes so long for vegetation to grow from a seed to a mature level that can withstand flood flows. Two techniques are provided here based on lessons learned from the demonstration projects. The first is called transplant wings and the second is called brush bars.

12.3.1 Transplant Wings

Transplant wings are a row of transplants on the bankfull bench that are oriented perpendicular to the flow. The purpose of these transplants is to reduce flow velocities on the floodplain and encourage deposition. They are particularly important in the early years following reclamation when the bankfull bench does not have a well-established ground cover of herbaceous and woody vegetation. Transplant wings extend from the toe of the streambank across the bankfull bench and tie into the adjacent hillslope. To be effective, wings should extend up the slope to an elevation that approximates that height of streamflow at two times bankfull. The width of the wings are typically around 10-20 feet. The spacing of the wings should be no greater than two times the bankfull width. Detail drawings and specifications are provided in Appendix G. Figure 51 and Figure 51 below shows examples of transplant wings.

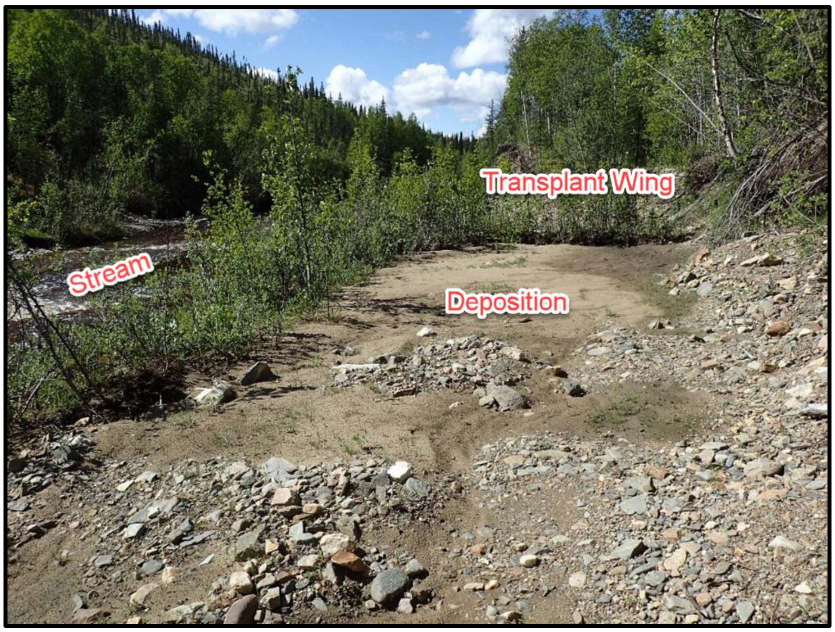


Figure 50. Transplant wings with sediment deposition upstream.

Figure 51. Transplant wing with bank transplants and deposition on bench from a recent flood.

12.3.2 Brush Bars

Brush bars are a mix of live and dead cuttings placed on the bankfull bench perpendicular to the flood flow. Their purpose is the same as transplant wings, to slow flood velocities and encourage deposition. Brush bars are not as robust as transplant wings but are a good substitute on sites where transplants are not plentiful or as a way to augment transplant wings. Another benefit is that brush bars can be installed by hand and do not require the use of heavy equipment. Over time, the brush bars will grow and expand, providing a method for revegetating the bankfull bench. Brush bars should be placed using the same spacing as transplant wings, about two times the bankfull width. An example is provided below in Figure 52.

Figure 52. Brush bar installed by hand on a section of bankfull bench devoid of vegetation. This technique was used due to the low supply of transplants.

12.3.3 Ground Cover

Areas on the bankfull bench not covered with transplants or brush bars and upland areas that do not receive transplants should be planted with native vegetation. The Interior Alaska Revegetation and Erosion Control Guide (Czapla and Wright, 2012) provides design, plant lists, and installation guidance. A planting plan should be developed using this guide and then approved by the BLM or other appropriate agency.

13.0 Phase 8: Final Design Plan Set and Specifications

The above sections provide design steps that can be completed with spreadsheets or even manual methods (for example, paper and calculator). However, it is preferrable and sometimes essential that designs be completed using CADD software. Small mines in steep gradient, V-shaped valleys may not need this level of sophistication. Larger mines, mines with more topographic complexity, and mines in lower gradient and wider valleys will need to complete their designs using CADD.

At a minimum, the final design plan set includes design drawings and specifications. The design drawings typically include: a title sheet; plan view of the reclaimed channel alignment with stationing; profile along the channel alignment showing the design bed; bankfull and existing ground; typical and detailed cross sections; details of the in-stream structures, bank stabilization structures, and floodplain structures; and a planting plan. Specifications are also included to provide written instructions, tolerances, quantities, and construction sequencing. If a bid process is used to hire a construction contractor, a contract will also be needed.

There are many benefits to developing a plan set with specifications. These benefits include:

- The plan set is the critical communication mechanism between the designer(s) construction contractor(s), and the mine operator(s).
- The plan set and specifications provide greater detail to the BLM and other agencies for reclamation review. This can potentially make plan approval and reclamation sign-off faster.
- For operations that hire a contractor, the plan set and specifications are part of the contract.
- Provides the needed information to lay out the channel alignment and determine cut/fill amounts.

An example plan set with specifications is provided in Appendix G for the demonstration project on Wade Creek at Milepost 87 on the Taylor Highway, Northeast of Chicken.

14.0 Phase 9: Permitting

Permitting requirements will vary based on the type of project being implemented. Placer mining projects associated with BLM managed lands must include a detailed description of reclamation activities. Mining on BLM managed lands is authorized under provisions outlined in 43 CFR 3809 and may require additional approvals from the State of Alaska and other federal permitting agencies. However, most placer miners in Alaska choose to use the State of Alaska's "Application for Permits to Mine in Alaska" (APMA), formally called the "Annual Placer Mining Application," to apply for permits. Through an agreement with the Alaska Department of Natural Resources (ADNR), the BLM also allows federal claim operators to use the APMA on BLM managed lands. The completed APMA is automatically distributed to other permitting agencies that have jurisdiction over proposed activities in Alaska.

Stream mitigation projects will follow a different permitting process depending on the type of mitigation approach used, e.g., permittee responsible or third party through an in-lieu fee program or private mitigation bank. Designers and permit applications should consult with the appropriate regulatory agency to determine permitting requirements. These agencies include the U.S. Army Corps of Engineers (404 permits), the Alaska Department of Environmental Conservation (401 permits), Alaska Department of Fish and Game (fish habitat permits), and potentially more.

15.0 Phase 10: Construction

The construction phase is where the design is implemented. It is a critical phase. Projects often succeed or fail based on the quality of the construction. The designer and contractor have important roles to play in implementing the project. Often, the designer is needed to interpret the design intent, answer questions, or even making design adjustments based on unforeseen circumstances that occur during construction. The contractor or miner constructing the design is responsible for the means and methods used to build the project.

The following sections include details about some of the most important parts of the construction process. These include staking out the channel and structures, acquiring construction materials, securing construction equipment, and construction inspection.

Projects often succeed or fail based on quality of the construction.

15.1 Channel and Structure Layout

If CADD was used to create the plan view, profile, and cross sections, the information can be transferred to survey equipment like a total station or a survey grade GPS. The surveyor can then stakeout the channel showing the cut and fill requirements by channel station. Sometimes this work is included with the construction contract with the surveyor working as a subcontractor to the general contractor. This process makes construction much easier because cut/fill calculations in the field are not needed, they have already been done.

Structure layout is typically done after the channel has been graded. Ideally, someone with experience designing and observing the installation of structures will do the layout. The layout includes locating and staking out the footprint of the structure.

If CADD was not used as part of the design process, the designer or construction contractor will need to use the design output from the above phases along with the existing topography to layout the channel and establish grades before construction begins. This process requires a thorough understanding of surveying principles and procedures. However, the general process for doing this is provided below.

Step 1: Before starting this process, make sure the valley has been rough-graded to approximate elevations. This will make layout and construction easier.

Step 2: Create a control network (if one doesn't already exist) using an arbitrary datum or tied into an established coordinate system, e.g., state plane. Place benchmarks throughout the project but outside the limits of disturbance.

Step 3: Pull a tape measure down the center and low point of the valley. Pull the tape from upstream to downstream. This will be the channel centerline. The beginning of the reach will be station 0+00. Install a wooden grade stake and label it with this station.

Step 4: Refer to the profile that was designed in a spreadsheet or by hand. Note that the station 0 (x-axis) on the spreadsheet equals 0+00 on the grade stake. This is the beginning of the reach. Using the profile as a guide, install a grade stake in the channel at the head (beginning) of each riffle, step, and pool. Also install a grade stake at the max depth of each pool. Record the station from the profile onto each grade stake.

Step 5: Install offset grade stakes that correspond to each channel stake installed in Step 4. These grade stakes should be located on both sides of the channel (i.e., two offsets per station) and outside the limits of channel and bank transplant construction. Label each stake as offset with the channel station number and the distance between the offset stake and the channel stake.

Step 6: If the elevations shown in the design profile (e.g., spreadsheet) use the same datum as the control network in Step 2 and station 0+00 on the ground equals station 0+00 on the profile, follow this step. Record the existing ground elevation at each grade stake using surveying equipment like a laser level. Subtract this value from the design elevation shown on the profile for that station. If the result is a negative number write "Cut" and the value on the grade stake. An example is shown in Table 12. The "2" result would be recorded on the grade stake as Cut 2'. If the difference is a positive number, write "fill" on the grade stake. For the example below, write Fill 2'. Note, these elevations represent the thalweg (deepest part of the channel).

Table 12. Example of cut and fill calculations for grade stake installation

Existing Ground Elevation	Design Elevation	Difference (Cut/Fill)
1,010	1,008	1,008 – 1,010 = -2 (Cut)
1,010	1,012	1,012 – 1,010 = 2 (Fill)

Follow this process for every grade stake installed in step 3. Once complete, move to the offset stakes. Survey the elevation difference between the channel grade stake and the offset grade stake. Typically, the offset grade stake will be at a higher elevation than the channel grade stake. For example, the offset grade stake might be 1.00 feet higher than the channel grade stake. Using the Cut 2 feet from the above example, if the offset stake is another 1 foot higher than the channel, the cut or elevation difference between the offset stake and the final channel elevation is 3 feet. This is the 2 feet of actual cut plus the extra foot to reach the offset stake. If it is a fill scenario with the same offset stake that is one foot higher than the existing ground elevation, the difference in the design elevation and offset elevation is one foot.

Step 7: If the elevations shown in the design profile (e.g., spreadsheet) use a different datum than the control network in Step 2, follow this step first. Using survey equipment like a laser level, determine the difference in elevation between the datum and the ground at station 0+00. Use this difference to adjust all the design elevations (e.g., in the profile spreadsheet). For example, if the design profile shows an elevation of 1,010 feet but the ground elevation using the new datum is 1,000 feet, all the elevations in the design must be reduced by 10 feet. Once this change has been made, follow step 6.

Step 8: Now refer to the typical cross sections for the riffle and pool. Using marking paint, paint the riffle width along the riffle sections. Note, the grade stakes are the centerline, so go one-half the bankfull width on both sides of the grade stake. Stop where the pool begins. Next, make a mark at the max width of the pool, which is located at the max-depth station. Connect the riffle width to the max pool width mark. This will show the pool gradually getting wider from the beginning of the pool to the max width, and then gradually getting narrower from the max width back to the riffle. These lines will need to be re-marked several times during construction.

15.2 Acquire Construction Materials

Ideally, the majority of the construction materials will come from the mine site. Recall that in Phase 3 (Section 8.6) transplant source areas were located. Throughout mining, rock that meets the size requirements shown in Table 7 should be stockpiled. Depending on the complexity of the reclamation, additional materials may be needed. Examples include filter fabric, trees and root wads, additional rock (if rock supplies from onsite are insufficient), seed for re-vegetation, etc.

15.3 Construction Equipment

Heavy equipment and machinery designed for excavation, hauling, and placing rock (including boulders) are required for reclamation work. Below is a list of common equipment needed for a reclamation project.

Excavators – Ideally two excavators (track hoes) will be available. One excavator can be dedicated to digging/shaping the channel and floodplain. The second track hoe should have a hydraulic thumb that can be used to precisely place rock into the in-stream structures (Figure 53).

Figure 53. Track hoe with hydraulic thumb (right) installing a constructed riffle.

Wheel Loader – A wheel loader is used to excavate transplants from the source area and place them along the streambank and floodplain (Figure 54). Ideally, the transplants are only moved once. Large wheel loaders are preferred because they have larger buckets and can thereby keep large mats of transplants together. Large, intact transplants are more likely to stay in place than small volumes of transplants.

Figure 54. Wheel loader with vegetation transplants.

Dump Trucks – Dump trucks are useful for transporting rock and other materials from the stockpile areas to the construction area.

Bulldozer – A bulldozer is optional but can be helpful in grading floodplain benches and adjacent hillslopes.

15.4 Construction Inspection

Routine inspection of the construction progress is critical to a successful project. Inspection is typically completed by the designer and includes checking grades, in-stream structures, transplants, floodplain structures, plantings, and more. Checking grade involves using surveying equipment, such as a laser level and tape, to verify that the channel depth and width match the design. It is critically important to make sure the channel is not too large. The construction specifications will provide tolerances to show what is too deep or wide. Generally, the constructed channel should be within 0.2 feet of the design depth, and the bankfull width should be within 0.5 feet of the design width. The larger tolerance is provided for the width when transplants are used to build the streambank. Without transplants the tolerance is closer to 0.2 feet.

Routine inspection of the construction progress is critical to a successful project. Inspection is typically completed by the designer and includes checking grades, in-stream structures, transplants, floodplain structures, plantings, and more.

In-stream structure inspection is used to make sure the constructed riffles, steps, and other structures were constructed as shown in the detail drawings. This involves comparing surveyed invert elevations to the design elevations, making sure step heights are not too high, ensuring that the correct mix of rock size and amount were used, and ensuring that the structure has the correct dimensions, e.g., extends into the bed and bank per the plan drawings (details) and specifications. At times, the inspection may need to be performed before the structure has been backfilled. For example, to ensure that the constructed riffle extends into the bank/floodplain bench.

Transplants should be inspected to make sure they were installed per the detail drawings and specifications. Key things to look for include the elevations (make sure the transplants along the streambank do not create an incised channel), seams between transplants (one transplant should touch the next or be within a couple inches of touching), and location (make sure transplants are in high stress areas like streambanks).

Construction inspection should also include taking photographs of the different phases of construction and documenting field changes. It is common for the designer to make minor changes during construction, like shifting in-stream structure locations, adding structures, managing the extent of transplants, and more. These changes should be noted on a plan set, maintained as the record drawing set, and provided to the BLM or other appropriate agency.

16.0 Phase 11: Monitoring, Inspection, Maintenance, and Adaptive Management

16.1 Monitoring & Inspection

Monitoring is a critical aspect of stream reclamation since it not only provides insight into how the project is performing but also if any maintenance might be necessary. The early detection of potential problems can greatly reduce the risks associated with project failure. The BLM's regulations require that all mining plans of operation include a monitoring plan (43 CFR 3809.401(b)(4)), which is designed to:

- Demonstrate compliance with the approved plan and other federal or state laws and regulations.
- Provide early detection of problems that could lead to UUD.
- Supply information to assist in directing corrective actions.

A monitoring plan should include measures specifically tied to the objectives outlined in the approved reclamation plan. Objectives commonly include a target percentage for foliar cover on the streambank and floodplain, and the composition of pools compared to riffle habitats. Other objectives might relate to the connectivity of the stream to the floodplain and acceptable levels of bank erosion. Collectively, the monitoring data help managers (and the miner) identify problem areas that could lead to UUD and/or failure.

The following list identifies the topics that must be included in the Monitoring Plan:

<u>Proposed Monitoring Devices and Sampling Locations</u>

The monitoring plan must describe what, where, and how samples or measurements will be collected. An 'as built' profile and several surveyed cross sections often serve as the basis for assessing habitat rehabilitation, while streambank and floodplain vegetation plots throughout the reclamation reach aid in assessing the rate of revegetation and erosion control.

<u>Sampling Process and Quality Control</u>

Monitoring programs can include sampling by the miner, a consultant, or some combination of the two. Quality control and assurance procedures must be included in the monitoring plan to ensure that samples collected are representative of site conditions and accurate. Data that are accompanied by photos and video of the site are often all that is needed for validating the quality of the collected data.

<u>Analytical Methods</u>

The monitoring plans must describe how data will be analyzed, which should be relatively straightforward based on the stream reclamation plan objectives and measures used to assess the effectiveness of implementation. BLM policy provides guidance on data interpretation for key stream reclamation metrics so that operators can easily determine if reclamation is functioning as intended or if problem areas exist.

Reporting Procedures

The monitoring plan must describe how the results will be documented and reported to the BLM and other agencies, if appropriate.

16.2 Maintenance

It is rare for a stream reclamation or restoration project to not need some form of maintenance or corrective action. These projects are most vulnerable to channel adjustment and floodplain, bankfull bench, and hillslope erosion within the first five to ten years after the project has been constructed and before permanent vegetation has become well established. An abundant use of transplants on the streambanks and floodplain/bankfull bench can minimize the amount of maintenance needed but it will not eliminate the need. In addition, designing Rosgen B, Bc (step-pool) rather than C (meandering) streams can further reduce the potential for maintenance. Nevertheless, a maintenance plan that includes funding to complete the work should be developed for all projects. Concurrent reclamation activities are essential to ensuring that key equipment is available if maintenance needs arrive.

It is rare for a stream reclamation or restoration project to not need some form of maintenance or corrective action. These projects are most vulnerable to channel adjustment and floodplain, bankfull bench, and hillslope erosion within the first five to ten years after the project has been constructed and before permanent vegetation has become well established.

The primary purpose of the maintenance plan is to ensure that performance standards are met by the end of the monitoring period. Therefore, the maintenance plan should pull from knowledge gained from the project goals and objectives, performance standards (section 4.0), risk assessment (section 9.3), and monitoring (section 16.0). Ultimately, monitoring and inspection will identify the maintenance needs. It is important to note that not all disturbance to the channel, streambank, and bankfull bench will necessitate maintenance. Therefore, it is important to know when maintenance is needed and when an area of concern can simply be further monitored. The additional monitoring will determine if the area heals on its own or gets worse and therefore needs maintenance. Table 13 provides guidance on when an area of concern needs maintenance versus continued monitoring. The key consideration is whether the area of concern will continue to get worse (more unstable) rather than recover and become stable again without intervention.

16.2.1 Examples of Activities Needing Maintenance

All the observations and maintenance requirements noted in Table 13 have been experienced in the demonstration projects. This section provides photographic examples of each observation that needs maintenance along with a description of what was done to fix the problem. Section 16.2.2 below provides examples of issues that do not need immediate maintenance but do require additional monitoring to ensure that the area of concern does not worsen.

Table 13. Common observations during monitoring or inspection that will require maintenance or further monitoring.

Observation	Action Required
Headcut – Abrupt elevation drop in the streambed. Sign of bed degradation.	Maintenance
Channel Avulsion – A new channel is formed across the floodplain during a large storm event. These problems are more common in meandering streams (channel forms across a point bar; also called a chute cutoff) but avulsions can occur in step-pool channels.	Maintenance
Bank Erosion of Concern – Bank erosion that will not correct itself quickly and will likely lead to worsening bank conditions and perhaps channel avulsions. Will typically score a High or greater Bank Erosion Hazard Index (BEHI) score (Rosgen, 2014).	Maintenance
Upland gully erosion – Erosion on the bankfull bench or hillslope that has formed gullies (channels) that transport water and sediment directly to the channel. May also cause bank erosion.	Maintenance
Structure Failure – A vertical or lateral stability structure that is displaced to such a degree that it is no longer providing the intended function and is leading to channel degradation or widening.	Maintenance
Upland rill erosion – Erosion on the bankfull bench or hillslope that is slightly worse than surface erosion but not as deep as gully erosion. Channels have not formed that carry water and sediment to the channel. Does not create bank erosion.	Monitoring
Minor Bank Erosion – Erosion that will likely not get worse and will stabilize on its own over time. Will typically score a Moderate Bank Erosion Hazard Index (BEHI) score (Rosgen, 2014).	Monitoring
Structure Movement – A vertical or lateral stability structure that is partially displaced but still providing the intended function.	Monitoring
Vegetation re-establishment on bankfull bench and uplands – Slow growth of ground cover vegetation from seeding activities, and establishment of woody vegetation.	Monitoring

Figure 55 shows a headcut that has formed on a reclamation site. The headcut will require immediate maintenance to prevent the headcut from migrating upstream and the channel from lowering, creating an incised channel that disconnects the stream from the adjacent floodplain bench. The maintenance will require installing a grade control feature such as a constructed riffle/cascade (see section 12.1.1).

Figure 55. Headcut.

Figure 56 shows an example of a channel avulsion. Flood waters cut a new channel across a point bar. The meander bend is being "cut off" by the new channel. This is a sign that the wrong channel pattern was designed. In this case, a straighter channel type (Bc) should have been designed rather than a meandering channel type C. If an avulsion is observed after a flood event, a thorough assessment should be completed to determine if a new design approach is needed. In other words, simply filling in the avulsion and returning to the original channel pattern will likely not work.

Figure 56. Floodplain erosion and channel avulsion.

Figure 57 shows “bank erosion of concern.” The bank toe has started to fail through the erosion and displacement of the toe wood. This is causing the transplants that were placed on top of the toe wood to collapse. The erosion is located downstream of the bend’s apex, which is an area of high stress. These problems result in a high risk of overall bank failure and down-valley migration of the meander bend. The toe wood should be replaced immediately with the boulder and wood toe and additional transplants should be added.

Figure 57. Bank erosion of concern. Loss of toe wood and streambank transplants in a meander bend.

Figure 58 shows an example of upland gully erosion. This is a common problem along newly graded terrace and hill slopes. These gullies should be stabilized immediately. Stabilization techniques can vary depending on the severity of the gully. Gullies that do not have a consistent source of concentrated flow can be stabilized with erosion control fabric (without plastic), transplants, or bioengineering. If concentrated flow is present, rock may be required.

Figure 58. Gully erosion on a freshly graded hillslope.

Figure 59 shows an example of a constructed riffle that has failed. The rock material used to create the riffle has been transported downstream. The elevation of the riffle has lowered (degradation) and a headcut has migrated upstream, stopping at the next structure. This increases the step height of that structure. The constructed riffle should be re-built using larger rock that will not be transported during bankfull and flood flows.

Figure 59. Degradation failure of a constructed riffle (structure failure).

Figure 60 shows an example of a log roller structure that is failing. Bed material is being transported from the upstream side of the log downstream into the pool by moving underneath the filter fabric. This is increasing the bed slope on the upstream side of the log. A proper functioning log roller has a low slope on the upstream side. The filter fabric should be re-installed to a deeper elevation. Larger rock should be placed on the upstream side of the log to ensure that the material stays in place.

Figure 60. Log roller structure failure.

Figure 61 shows an example of a complete loss of transplants along the streambank. This would count as a lateral stability structure failure. The transplants should be replaced.

Figure 61. Erosion and loss of streambank transplants. Red line shows bank length that has eroded.

Figure 62 shows an example of a mid-channel bar that formed after reclamation construction. This is a sign that the riffle does not have enough sediment transport capacity to transport the incoming sediment load. It is generally better to fix this problem rather than monitoring to see if the bar disappears over time. However, monitoring can be an option if the mid-channel bar is small and occurred during a very large flood. Repairing a mid-channel bar may require a design adjustment. The riffle width/depth ratio may need to be decreased to improve sediment transport capacity. Bar samples and sediment transport competency tests should be completed before attempting a repair.

Figure 62. Mid channel bar formation.

Figure 63 shows an example of gully erosion on a floodplain bench. This erosion occurred during the first flood event after reclamation construction. Generally, it is best to repair this erosion by installing floodplain stability measures (see section 12.3).

Figure 63. Gully erosion on the floodplain.

16.2.2 Examples of Activities Needing More Monitoring

As noted above, some areas of concern may not need immediate maintenance. Rather, additional monitoring and inspection can be used to determine if the area worsens or improves. If the area worsens by becoming less stable and/or threatens other project areas then maintenance will be required. Evaluating the area of concern against the performance standards can also be used to gauge the need for maintenance. If the area is not meeting performance standards, maintenance should be performed.

Photograph examples are provided below of situations where an area has experienced a disturbance during a flood but maintenance was not performed. The rationale for not doing maintenance is also provided.

Figure 64 shows minor sheet and rill erosion on the bankfull bench that has exposed the underlying mixture of cobble, gravel, and sand. The transplants along the streambank and transplant wings have remained intact. The area of erosion will likely vegetate over time without the need for maintenance; however, routine monitoring/inspection is needed to make the determination.

Figure 64. Minor rill erosion of the floodprone bench surface.

Figure 65 shows an area of the floodplain/bankfull bench where re-vegetation establishment has been slow. The floodplain is mostly devoid of vegetation. Erosion is minimal to absent; deposition and vegetation should establish over time. Since the area is vulnerable to erosion until permanent vegetation is well established, inspection and monitoring should continue.

Figure 65. Slow revegetation rates in seeded or unseeded areas of the floodprone bench.

Figure 66 shows an example of minor erosion of a constructed riffle. Rock from the downstream portion of the riffle has eroded, which has created a step at the downstream end. As long as the step does not convert to a headcut, no maintenance is needed. However, if the step moves upstream it becomes a headcut that will cause degradation. At that point, maintenance is required.

Figure 66. Riffle incision at the downstream end of a constructed riffle.

Figure 67 shows an example of minor bank erosion along a riffle feature. Since the bank heights are low, vegetation is becoming established and the stream flow is parallel to the bank, it is unlikely that this bank will erode further. Stability should improve over time as the vegetation becomes better established. However, additional monitoring is needed to verify that this process occurs.

Figure 67. Minor bank erosion.

16.2.3 Maintenance Implementation

The implementation of maintenance activities can vary from simple measures completed with hand labor and only taking a day to complete to activities requiring heavy equipment, new materials, and skilled operators. The level of maintenance needed is determined by the issue being addressed and the risk of project failure. Examples of simple maintenance include re-vegetating areas where seeding or other forms of vegetation did not grow or did not grow well enough to meet performance standards. An example of maintenance needing heavy equipment is structure failure that leads to headcutting or channel avulsions. For these types of maintenance activities, the designer should consult with BLM or the appropriate agency before proceeding with the maintenance. Additional permits may also be needed depending on the nature of the maintenance.

16.2.4 Catastrophic failure

A catastrophic failure means that the project has experienced vertical and/or lateral stability changes to such a high degree that maintenance alone will not fix the problem. This is typically a result of designing the incorrect stream type for a given valley type, implementing high risk designs, or where aspects of the project failed to adhere to design specifications during construction, e.g., consistently placing transplants too high and therefore building an incised channel. If catastrophic failure occurs, the designer should contact the BLM or other appropriate agency immediately to determine next steps. These types of failures typically require additional assessments with different designs and construction methods.

References

Alaska Department of Fish and Game. 2005 (rev). Streambank Revegetation and Protection: A Guide for Alaska. Alaska Department of Fish and Game, Division of Sport Fish. Original Technical Report No. 98-3, March 1998.

Alaska Stream Quantification Tool Steering Committee (Steering Committee). 2021. Stream Quantification Tool and Debit Calculator for the Alaskan Interior User Manual and Spreadsheets. Version 1.0. Salcha-Delta Soil and Water Conservation District, Delta Junction, AK.

Arnett, H. 2005. Harrison Creek reclamation, phase I; an overview of issues and approaches for the reclamation of placer-mined lands. Doc. No. WO 769306. Prepared by USKH, Inc. for the Bureau of Land Management, Washington, DC. 81 p.

Bair, T.B.; Olegario, A.; MacFarlane, B.; [and others]. 2008. Daves Creek Watershed Restoration Plan. USDA Forest Service, Chugach National Forest, Seward Ranger District and TEAMS Planning Enterprise.

Brady, C., Varner, M., Post, J., Miller, S., Cappuccio, N. 2018. Developing Quantifiable Management Objectives from Reference Conditions for Wadeable Streams in the Eastern Interior Field Office. BLM Open File Report #169, May 2018. Bureau of Land Management, Anchorage, AK. 35pp.

Bridge, J.S. 2003. *Rivers and Floodplains*, Forms, Processes, and Sedimentary Records. Blackwell Publishing, Malden, MA.

Bureau of Land Management (BLM). 2017. AIM National Aquatic Monitoring Framework: Field Protocol for Wadeable Lotic Systems. Tech Reference 1735-2. Denver (CO): US Department of the Interior, Bureau of Land Management, National Operations Center. https://www.blm.gov/documents/national-office/blm-library/technical-reference/aim-national-aquatic-monitoring-0

Carlson EA. 2009. Fluvial riparian classifications for national forests in the Western United States [thesis]. [Fort Collins (CO)]: Colorado State University.

Carlson, R.F., K. Karle, and B. Schalk. 1998. Channel Stability of Reclaimed Placer Mined Streams in Alaska. Phase I – Assessment of Past Reclamation Activities. Interim Report.

Castro, JM, Thorne, CR. 2019. The stream evolution triangle: Integrating geology, hydrology, and biology. *River Res Applic*. 2019; 35: 315– 326. https://doi.org/10.1002/rra.3421

Curran, J.H., Barth, N.A., Veilleux, A.G., and Ourso, R.T., 2016, Estimating flood magnitude and frequency at gaged and ungaged sites on streams in Alaska and conterminous basins in Canada, based on data through water year 2012: U.S. Geological Survey Scientific Investigations Report 2016–5024, 47 p., http://dx.doi.org/10.3133/sir20165024

Czapla, P.K., and S.J. Wright. 2012. Interior Alaska Revegetation and Erosion Control Guide. Alaska Department of Natural Resources, State of Alaska Plant Materials Center, Palmer, AK

Densmore, R.V. and Karle, K.F. (2009), Flood Effects on an Alaskan Stream Restoration Project: The Value of Long-Term Monitoring1. JAWRA Journal of the American Water Resources Association, 45: 1424-1433. https://doi.org/10.1111/j.1752-1688.2009.00373.x

Fischenich, C. (2001). "Stability Thresholds for Stream Restoration Materials," EMRRP Technical Notes Collection (ERDC TNEMRRP-SR-29), U.S. Army Engineer Research and Development Center, Vicksburg, MS.

Harman, Will. 2018. Application of Natural Channel Design Techniques in Sub-Arctic Alaska. U.S. Department of Interior, Bureau of Land Management, Anchorage, Alaska.

Harman W, Starr R, Carter M, Tweedy K, Clemmons M, Suggs K, Miller C. 2012. A function-based framework for stream assessment and restoration projects. EPA 843-K-12-006. Washington (DC): US Environmental Protection Agency, Office of Wetlands, Oceans and Watersheds. https://www.epa.gov/sites/production/files/2015-08/documents/a_function_based_framework_for_stream_assessment_3.pdf

Harrelson CC, Rawlins CL, Potyondy JP. 1994. Stream channel reference sites: an illustrated guide to field technique. General Technical Report RM-245. Fort Collins (CO): US Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. https://www.fs.fed.us/biology/nsaec/fishxing/fplibrary/Harrelson_1994_Stream_Channel_Reference_Sites_An_Illustrated.pdf

Harris SA, French HM, Heginbottom JA, Johnston GH, Ladanyi B, Sego DC, van Everdingen R0. 1988. Glossary of Permafrost and Related Ground-ice Terms. Ottawa, Canada: National Research Council of Canada Technical Memorandum 142

Hawkins CP, Kershner JL, Bisson PA, Bryant MD, Decker LM, Gregory SV, McCullough DA, Overton CK, Reeves, GH, Steedman RJ, Young MK. 1993. A hierarchical approach to classifying stream habitat features. Fisheries, *18*(6): 3-12.

Knighton, D. 1998. Fluvial forms and processes: a new perspective John Wiley and Sons. New York.

Leopold, L. B., Wolman, M. G. and Miller, J. D. 1964. Fluvial Processes in Geomorphology, Freeman, San Francisco, 522 pp.

Leopold LB. 1994. A View of a River. Cambridge (MA): Harvard University Press, Harvard University.

Mecklenburg D. 2006. The reference reach spreadsheet for channel survey data management, A STREAM Module: spreadsheet tools for river evaluation, assessment and monitoring. Version 4.01L. Ohio Department of Natural Resources.

Milner, A.M. and R.J. Piorkowski. 2004. Macroinvertebrate assemblages in streams of interior Alaska following alluvial gold mining. River Research Applications 20:7 I 9-731.

Montgomery DR, Buffington JM. 1998. Channel processes, classification, and response. River Ecology and Management, 112: 1250-1263.

Muller SW. 1945. Permafrost or Perennially Frozen Ground and Related Engineering Problems, Special Report. Strategic Engineering Study, 62. 2nd ed. Washington: United States Geological Survey.

Natural Resources Conservation Service (NRCS). 2007. National engineering handbook part 654, stream restoration design. Washington (DC): US Department of Agriculture NRCS. https://directives.sc.egov.usda.gov/OpenNonWebContent.aspx?content=17807.wba

Pitlick et al. 2009. Manual for computing bed load transport using BAGS (Bedload Assessment for Gravel-bed Streams) software. USFS, Rocky Mountain Research Station.

Reid, Leslie M., and Thomas Dunne. *Rapid evaluation of sediment budgets*. Vol. 29. Reiskirchen, Germany: Catena, 1996.

Roni, P. and Beechie, T., 2013. Stream and watershed restoration – A guide to restoring riverine processes and habitats. John Wiley & Sons, Ltd.

Rosgen DL. 1996. Applied river morphology. Fort Collins (CO): Wildland Hydrology Books.
Rosgen DL. 2006. A watershed assessment for river stability and sediment supply (WARSSS). Fort Collins (CO): Wildland Hydrology Books.

Rosgen, D.L. 2006. Watershed Assessment of River Stability and Sediment Supply (WARSSS). Fort Collins (CO): Wildland Hydrology Books.

Rosgen DL. 2014. River stability field guide. 2nd ed. Fort Collins (CO): Wildland Hydrology Books.

Schumm SA. 1985. Patterns of alluvial rivers. Annual Review of Earth and Planetary Sciences.13:5-27.

Shulski, M.; Wendler, G. 2007. The climate of Alaska. Fairbanks, AK: University of Alaska Press. 208 p

Tidwell, A. B. Shalk, R.F. Carlson, and K. Karle. 2000. Development of improved techniques to reclaim placer-mined watersheds. University of Alaska Fairbanks, Department of Civil and Environmental Engineering. Fairbanks, AK. 80p.

United States Army Corps of Engineers (USACE). 2008 Compensatory Mitigation for Losses of Aquatic Resources. 73 FR 19670.
https://www.poa.usace.army.mil/Portals/34/docs/regulatory/33cfr332.pdf

U.S. Department of the Interior, Bureau of Land Management (BLM). 1988a. Birch Creek Placer Mining Final Cumulative Environmental Impact Statement. BLM, Alaska State Office, Anchorage, AK.

U.S. Department of the Interior, Bureau of Land Management (BLM). 1988b. Beaver Creek Placer Mining Final Cumulative Environmental Impact Statement. BLM, Alaska State Office, Anchorage, AK.

U.S. Department of the Interior, Bureau of Land Management (BLM). 1988c. Fortymile River Placer Mining Final Cumulative Environmental Impact Statement. BLM, Alaska State Office, Anchorage.

Wilcock, P., J. Pitlick, and Y. Cui. 2009. Sediment Transport Primer, Estimating Bed-Material Transport in Gravel-bed Rivers. U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. General Technical Report, RMRS-GTR-226.

Wolman, MG, Leopold LB. 1957. River floodplains: Some observations on their formation, U.S. Geological Survey Professional Paper 282-C. 87–109.

Wohl EE, Cenderelli DA, Dwire KA, Ryan-Burkett SE, Young MK, Fausch KD. 2010. Large instream wood studies: a call for common metrics. Earth Surface Processes and Landforms. 35:618-625. https://www.fs.fed.us/rm/pubs_other/rmrs_2010_wohl_e001.pdf

Woo, M.K. 2012. *Permafrost Hydrology*. Springer Science, New York.

Appendix A

Summary Description of Demonstration Projects

The following table lists demonstration projects completed through 2022. The definition of a demonstration project is any placer mine reclamation project that received design and construction support services from BLM. Many of these sites also include monitoring and some have been used for workshops and tours.

Number	Demonstration/Technical Assistance Project	Basin	Drainage Area (sq miles)	Design Channel Type	Objectives	Completed Work	Status	Outcomes/Lessons Learned
1	Wade Creek (Demo 1 - Mile Post 85 on the Taylor Highway)	Fortymile	40.4	C4	Geomorphically Stable Channel	Meandering channel constructed in 2015	Requires reconstruction	2018 flood resulted in loss of streambank toe wood, which resulted in alignment shifts that cascaded downstream through the project. Specifications for toe wood lengths must be adhered to and additional measures to dissipate energy and enhance revegetation of the floodplain surfaces should be considered on future projects. Meandering streams should not be attempted in confined alluvial valleys.
2	Wade Creek (Dredge Site - Mile Post 86 on the Taylor Highway)	Fortymile	34.8	B3	Reduce bank erosion and protect highway	Six J-hook vanes constructed in 2016	Continuing to improve with only minor maintenance needed since construction.	Structures and sills should utilize geotextile fabric to reduce the likelihood of maintenance. Vegetation transplants should be used to provide surface protection of structure sills.
3	Wade Creek (Race Site - Mile Post 91 on the Taylor Highway)	Fortymile	12.5	B3	Geomorphically Stable Channel	Step Pool design constructed in 2017	Minor maintenance needed to address	Structures and sills should utilize geotextile fabric to reduce the likelihood of maintenance. Bank heights that exceeded design specifications

							incision in the lower reach.	have contributed to instream structure maintenance needs.
4	Wade Creek (Kuzmin Site - Mile Post 87 on the Taylor Highway)	Fortymile	28.5	B4c	Geomorphically Stable Channel	Step Pool design constructed in 2018	Minor maintenance needed to address streambank erosion.	Areas with increased near bank stress, even in a relatively straight step pool channel, should consider streambank toe protection.
5	Franklin Creek (Upper - Claim AKFF062062)	Fortymile	5.5	B3	Geomorphically Stable Channel	Step Pool design constructed in 2018	No maintenance required.	
6	White Creek (Valdez Creek Mine)	Susitna	9.5	B3	Geomorphically Stable Channel	Step Pool design constructed in 2021	No maintenance required in year 1.	
7	Wade Creek (Race Site - Mile Post 90 on the Taylor Highway)	Fortymile	13.2	B3	Habitat Enhancement	Planning	NA	
8	Davis Creek (SF Koyukuk River)	Koyukuk	2.6	B3a	Geomorphically Stable Channel	Step Pool design constructed in 2021	Minor maintenance needed to address streambank erosion.	Bank heights and structures that exceeded design specifications have contributed to maintenance needs on the lower section of the project.
9	Ironside Creek (SF Koykuk River)	Koyukuk	1.2	B3c	Geomorphically Stable Channel	Design Completed	NA	
10	Kokomo Creek	Chatanika	7.8	B4c	Geomorphically Stable Channel	Planning	NA	

Appendix B
Design Summary Form

This appendix is intended to assist designers during the design process outlined in Technical Report #65 and to aid the BLM or other agency during review. Record information following the step-by-step process in the Technical Report (TR). Additionally, data collection steps are labeled as desktop, field, or both.

Phase 1: Project Reach Delineation, Watershed Assessment, Watershed Hydrology, and Bankfull Identification and Verification

Follow these procedures to identify the project reach, characterize watershed condition, and identify site conditions that pose risks to successful reclamation.

Project Reach Delineation (Section 6.1)

1. Desktop & Field: Delineate reaches following the TR process and assign unique Reach IDs. Provide aerial photos or other maps showing the location and identification of each reach. Enter the reach IDs below followed by a short description, e.g., upstream of confluence, tributary, etc.

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Reach ID: ________ Description: ____

Watershed Assessment (Section 6.2)

1. Desktop: Calculate the drainage area (square miles). The watershed should be delineated at the downstream end of the project reach.

Drainage Area (Section 6.2.1): ________ square miles

2. Desktop & Field: Complete the catchment/watershed assessment form and rate watershed condition as Good, Fair, or Poor. Note, if multiple reaches are being assessed within the same watershed, the watershed condition may be the same. Condition may change based on reach location within the watershed, in which case the watershed condition should be assessed separately for each differing reach. Attach a copy of the completed catchment assessment form to this form.

Catchment Condition (circle one and list applicable reach IDs):

Good: ____

Fair: ____

Poor:____

3. Desktop & Field: Assessing Watershed-Scale Risk Factors (Section 6.2.3). Write a narrative that qualitatively describes the watershed-scale alterations that could impact the runoff and sediment supply (erosion) processes and increase the risk of reclamation failure. Use results from the catchment assessment and from Table 1 in the TR to examine risks.

____
____
____
____
____
____
____
____
____

Watershed Hydrology (Section 6.3)

1. Desktop: Estimate the magnitude and frequency of flood events, if applicable, using the USGS regression equations (Section 6.3.1). Enter the discharge associated with each return interval in the table below.
    a. USGS Regional Regression Equations: use to estimate 2- through 100-year events.

Annual Exceedance Probability (%)	Return Interval (years)	Discharge (Q) (cfs)
50	2	
20	5	
10	10	
4	25	
2	50	
1	100	

2. Provide bankfull discharge estimates using the selected option (Section 6.3.2)

   a. Option 1: Regional Curves (Desktop). Bankfull discharge = __________ cfs
   b. Option 2: Watershed-Specific Regional Curves (Field and Desktop). Bankfull discharge = __________ cfs
   c. Option 3: Extrapolating USGS Regional Regression Equations (Desktop). Bankfull discharge = __________ cfs

Bankfull Identification and Verification (Section 6.4)

1. Bankfull Identification. Describe the bankfull feature, e.g. back of point bar, top of bank, etc. ____
   ____
   ____
   ____

   a. Were other features present? If so, describe the features, e.g. inner berm or terrace. ______
      ____
      ____
      ____

2. Bankfull Verification: Determine whether measured bankfull cross-sectional area data falls between the prediction intervals used to create the regional curve. Check Yes or No as it applies:
   i. Data falls between prediction intervals; bankfull determination is verified.
      ☐ Yes ☐ No
   ii. Data falls above prediction interval; regional curve may not represent the project watershed or the bankfull was not identified correctly. Bankfull determination is not verified.
      ☐ Yes ☐ No
   iii. Data falls below prediction interval; regional curve may not represent the project watershed or the bankfull was not identified correctly. Bankfull determination is not verified.
      ☐ Yes ☐ No

      If bankfull is not verified, contact the BLM or sponsoring agency for assistance.

Phase 2: Goals and Objectives (Section 7.0)

Every project must have clearly developed goals and objectives. Goals can be divided into two categories: programmatic and design. Programmatic goals state why the project is being completed from a funding or regulatory driver perspective. Design goals and objectives should be function-based. Refer to Section 7.0 – Phase 2: Design Goals and Objectives in TR for examples more information and example programmatic and design goals.

Describe the programmatic and design goals for the project.

Programmatic Goals: ____

____

____

Design Goals: ____

____

____

____

Design Objectives. Each project must also include design objectives that describe which function-based parameters will be manipulated in order to meet the goals. Every project must include objectives for the following four parameters, but may include other parameters as well.

Floodplain Connectivity Objective (Write in a way that shows functional lift, Refer to TR): __________

____

____

Bedform Diversity: ____

____

Riparian Vegetation: ____

____

Lateral Migration: ____

____

Other:____

____

Other: ____

____

Other: ____

____

Other: ____

____

Other: ____

____

Phase 3: Existing Condition Assessment Procedures (Section 8.0)

Follow these procedures to assess the existing condition of the project reach.

Determine Valley Type (Sections 8.1 and 8.2)

1. Desktop & Field: Determine Valley Slope and Channel Slope. Refer to TR for more information.
   ______ Valley Slope (ft/ft)
   ______ Channel Slope (ft/ft)

2. Desktop & Field: Collect valley and channel cross-section data. Refer to TR for more information.
   a. Enter cross-section survey data into the Reference Reach Spreadsheet for analysis of bankfull dimensions, valley width, and floodprone width.
   b. Determine valley width ratio. If the valley width ratio is greater than 7.0 the valley likely is an unconfined alluvial valley. If the valley width ratio is less than 7.0 the valley is likely a confined alluvial valley or colluvial valley.
   ______ Valley Width Ratio (ft/ft)

3. Determine Valley Type for the project reach (check one). Refer to Table 5 in the TR for descriptions.

   ☐ V-shaped ☐ Colluvial ☐ Confined-Alluvial ☐ Unconfined Alluvial

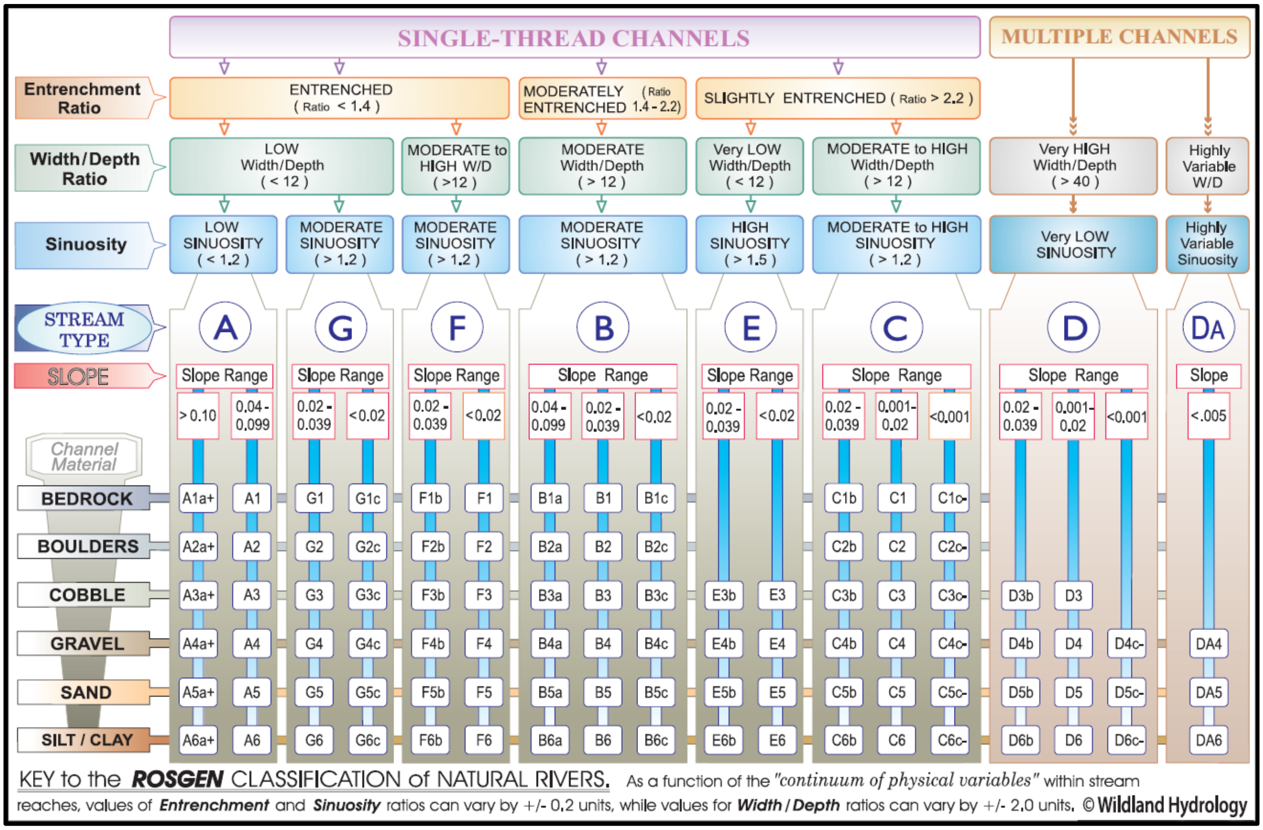
4. Provide the Reference Reach Spreadsheet showing the existing condition cross sections.

Bed Material Characterization (Section 8.3)

1. Field: Perform a zig-zag pebble count across the riffle surface. Enter data into the Reference Reach Spreadsheet.
   a. Note: The median particle size (D_{50}) is used for stream classification.
      ______ D_{50} (mm)
   b. D_{84} and D_{95} particle sizes are used for aggradation & degradation risk assessments (Phase 4).
      ______ D_{84} (mm)
      ______ D_{95} (mm)

Stream Classification

1. Determine Stream Type.
   a. Determine Sinuosity ______ (ft/ft)
   b. Use entrenchment ratio and bankfull width/depth ratio, sinuosity, channel slope, and the median particle size (D_{50}) to determine stream type following the Rosgen Stream Classification (see below figure). Note, that valley type also informs stream type (see below table).
      ______ Existing Stream Type



KEY to the ***ROSGEN*** CLASSIFICATION of NATURAL RIVERS. As a function of the *"continuum of physical variables"* within stream reaches, values of ***Entrenchment*** and ***Sinuosity*** ratios can vary by +/- 0.2 units, while values for ***Width / Depth*** ratios can vary by +/- 2.0 units. © Wildland Hydrology

Valley Types	Typical Stream Type(s)
V-shaped	Aa+, A
Colluvial	B, Bc, Cb
Confined Alluvial	B, Bc, Cb, C
Alluvial	C, E, DA

2. Desktop: Determine Design Stream Type.
   ______ Preliminary Design Stream Type

Base Map (Section 8.5)

1. Desktop: Develop a topographic map of the existing reach and project area.
2. Submit base map as part of the design package.

Transplants, Large Wood, and Rock Source Areas (Section 8.6)

1. Desktop & Field: Identify and spatially record areas (GPS, map) within the project boundary where vegetation transplants, large wood, and rock may be sourced on-site.
   a. Transplant source areas are often found on low terraces, roadside ditches, and future mine areas. The best transplants are young trees and/or shrubs with ground cover.
      i. Transplant Source Area = ___________ acres
   b. In Interior Alaska, large wood typically comes from on-site live trees. The best source areas are whole birch, spruce, cottonwood, or other tree species in future mining areas,

upstream or downstream from the reclamation reach. Nearby terraces are also a good source area. Hillslopes that will not be mined should be avoided.

   i. Approximate number of trees available = __________

c. Large, medium, and small boulders found during the mining process should be stockpiled by rock size for use during reclamation. Refer to Table 7 in TR for large, medium, and small dimensions.

   i. Volume of large boulders available = ___________ ft^3
   ii. Volume of medium boulders available = ___________ ft^3
   iii. Volume of small boulders available = ___________ ft^3
   iv. Volume of cobble available = ___________ ft^3

Areas of Cut and Fill (Section 8.7)

1. Locate areas of cut and fill o the base map and describe here: _______________________________
   ____
   ____
   ____

Phase 4: Developing Design Alternatives (Section 9)

Follow these procedures to select the design approach that provides the highest probability of reclamation success and/or determines whether the risk is too high to successfully mine and reclaim a site.

Stream Evolution Triangle (Section 9.1)

Use the Stream Evolution Triangle (SET) to verify that the process drivers of hydrology, geology, and biology match the plan form geometry and reference/proposed stream type chosen for design. The relationships between plan form geometry, classification, and process drivers are summarized below. Compare the design stream type (selected during the existing condition assessment) with the stream type associated with process drivers described in the SET.

Schumm (1985) Plan Forms	**Rosgen (1996) Classification**	**Process Drivers**
Anastomosed	DA	Low stream power, High biologic control, Moderate erosion resistance.
Braided	D	High stream power, low biologic control, low erosion resistance.
Straight	A	High stream power, low biologic control, high erosion resistance
Straight	B	Moderate stream power, moderate erosion resistance, and low to moderate biotic control.
Meandering	C	Moderate stream power, moderate biologic control, moderate erosion resistance

Determine Final Design Stream Type (Section 9.2)

Refer to the Summary Criteria in TR to aid in final stream type selection.

_____ Final Design Stream Type

NOTES

1. DA and C Stream Types: TR does not provide a method for designing these stream types. Contact BLM or the appropriate organization before proceeding.

2. D Stream Type: Do not proceed. Stream reclamation/restoration is not appropriate.

Risk Assessment (Section 9.3)

Use Table 9 in TR#65 to determine the risk of failure (check one):

☐ High ☐ Medium ☐ Low

Phase 5: Natural Channel Design Steps for B Stream Types (Section 10)

The steps below are for designing a **Rosgen B stream type**.

Riffle and Pool Dimension Design Criteria (Steps 1 through 7) (Section 10.1)

Record information in the below summary table. Each row corresponds to a step in TR#65.

TR Reference	Riffle Dimension	Value(s)
Step 1: Regional Curve Values	Bankfull Width, W_{bkf} (ft)	
	Bankfull Mean Depth, d_{bkf} (ft)	
	Bankfull Cross-sectional Area, A_{bkf} (sq. ft)	
Step 2: See Figure 19 in TR	Initial Bankfull Width/Depth Ratio, W/D (ft/ft)	
Step 3: Equation 5	Bankfull Riffle Width, W_{bkf} (ft)	
Step 4: Equation 6	Bankfull Riffle Mean Depth, d_{bkf} (ft)	
Step 5: Equations 7-8 & Figure 20	Bankfull Riffle Max Depth Range, D_{max} (ft)	

TR Reference	Pool Dimension	Value(s)
Step 6: Equations 9-10	Bankfull Pool Width (W_{bkfp})	
Step 7: Equations 11-12 & Figure 21	Bankfull Maximum Pool Depth Range	

Channel Pattern/Alignment Design (Steps 8 and 9) (Section 10.2)

1. Step 8: Create (draw) an alignment for the reclaimed channel.
2. Calculate sinuosity for the proposed design's planform geometry.

TR Reference	Channel Pattern	Value(s)
Step 9: Equation 13	Sinuosity (ft/ft)	

Vertical Stability Assessment of the Design Dimension and Slope (Steps 10 – 14) (Section 10.3)

1. Complete the table below (Steps 10 through 13).

TR Reference	Vertical Stability Measure	Value(s)
Step 10: Equation 14 (also Equation 1)	Valley Slope (ft/ft)	
Step 11: Equation 15	Design Channel Slope (ft/ft)	
Step 12: Equation 16	Shear Stress (lbs/ft^2)	
Step 13: Figure 23	Particle Size Diameter (mm)	

2. Determine the risk of degradation and aggradation (Step 14)
   a. Compare the D_{84} and D_{95} particle sizes (see Phase 3 – Bed Material Characterization section) to the particle size diameter determined in Step 13. Check one:

☐ Risk of Severe Aggradation ☐ Risk of Moderate Aggradation

☐ Risk of Severe Degradation ☐ Risk of Moderation Degradation ☐ No Risk

<u>NOTES</u>

1. If a risk of degradation exists, to reduce shear stress re-design the riffle by repeating steps 1-4 and selecting a smaller bankfull cross sectional area, a higher W/D ratio, or both.

2. If a risk of aggradation exists, to increase shear stress re-design the riffle by repeating design steps 1-4 and decrease the W/D and/or increase the bankfull area.

Floodprone Area Design and Stability Assessment (Step 15) (Section 10.4)

1. Desktop & Field: Measure floodprone area and record below (see TR). Note, floodprone area is determined by setting floodprone width elevation as bankfull elevation in the Reference Reach Spreadsheet.

TR Reference	Lateral Stability Measure	Value(s)
Step 15: Use Reference Reach Spreadsheet for Calculations	Floodprone Width (ft)	
	Floodprone Area (ft^2)	
Helpful measures to record:	Discharge (cfs)	
	Shear Stress (lbs/ft^2)	
	Velocity (ft/s)	

More Sophisticated Ways to Assess Floodprone Area Hydraulics (Optional: Step 16) (Section 10.5)

Evaluate the shear stress associated with a 50 year and 100-year flow event using modeling techniques (e.g., HEC-RAS, River2D). Use Table 8 in the TR to assist with assessing risk of degradation and aggradation.

Phase 6: Channel Profile Design (Section 11)

After completing the vertical stability analysis, when the designer is confident that the design dimension and channel slope will meet the desired stability goals, design a detailed profile.

Pool Spacing, Pool Depth, and Step Height (Sections 11.1 through 11.3)

Calculate and record pool measures.

TR Reference	Profile Design Measures	Values
Step 17: Equations 17-8 & Figure 29	Pool Spacing Ratio for riffles/cascades Range (Min – Max)	
Step 18: Equations 19-20 & Figure 29	Pool Spacing Ratio for steps Range (Min – Max)	
Step 19: Figure 30 (Range equals 0.3 feet to 1.0 feet)	Step Height (Min – Max)	

Riffle/cascade, Step, and Pool Lengths (Section 11.4)

1. Calculate and record feature lengths. See step 21, equations 23 through 28, and figure 31.

Profile Design Measures	Values
Minimum riffle/cascade length (ft)	
Maximum rifle/cascade length (ft)	
Minimum step length (ft)	
Maximum step length (ft)	
Minimum pool length (ft)	
Maximum pool length (ft)	

Drawing the Plan View and Profile (Step 22-24) (Section 11.5-11.6)

1. Draw the final plan view and profile using the design criteria determined in Steps 17 through 21. See Figure 32 for an example profile. Show the riffle and pool widths on the plan view.
2. Calculate and record the percent feature length. Refer to Step 23 and Figure 32.

Percent Feature	Values	Does the Value fall within the range (Figure 33)? yes/no
Percent Cascade/Riffle (%)		
Percent Step (%)		
Percent Pool (%)		

Cross Sections (Step 25) (Section 11.7)

1. Create cross sections once the typical sections, horizontal alignment, and profile have been developed.
2. Generate earthwork and material quantities using manual or CADD methods listed in the TR.

Phase 7: In-Stream and Bankfull Bench Structure Design (Section 12)

Refer to the Design TR for design criteria, photo examples, and design recommendations for various vertical stability and lateral stability structures, and bankfull bench and floodplain revegetation procedures. Show the type and location of structures on plan view.

Phase 8: Final Design Plan Set and Specifications (Section 13)

At minimum, the final design plan set must include design drawings and specifications. Refer to TR for further information.

Phase 9: Permitting (Section 14)

Permitting requirements will vary based on the type of project being implemented. Refer to TR for further information.

Phase 10: Construction (Section 15)

Projects often succeed or fail based on the quality of the construction. Routine inspection of the construction progress is critical to a successful project. Inspection is typically completed by the designer and includes checking grades, in-stream structures, transplants, floodplain structures, plantings, and more. Refer to TR for more information.

Phase 11: Monitoring, Inspection, Maintenance, and Adaptive Management (Section 16)

Develop a monitoring plan. A monitoring plan should include measures specifically tied to the objectives outlined in the approved reclamation plan. Develop a maintenance plan. Refer to the TR for more information on both plans.

Appendix C
Catchment Assessment Form

The following catchment assessment form is from the Alaska Stream Quantification Tool for the Interior Alaska region (AKSQTint). This form is used in Section 6.2 (Watershed Assessment) to assist in determining reclamation risk, as well as restoration potential for stream restoration/mitigation projects.

More information about restoration potential and the SQT can be found on the Regulatory In-Lieu Fee and Bank Information Tracking System (RIBITS) web page. Filter by "Alaska" and look under Stream Assessment Tools.

Purpose: This form is used to determine the project's restoration potential. The catchment assessment is performed on the catchment and contributing area for the project reach. Note the contributing area may be downstream as well, as in the case where a dam exists downstream which restricts movement/recovery of aquatic communities.

Applicable Reach IDs:____

Watershed Name (HUC 8) and Number:____

Overall Watershed Condition: ____

Restoration Potential: ____

			Description of Catchment Condition			
	Category	**Data Source**	**Poor (P)**	**Fair (F)**	**Good (G)**	**Rating (P/F/G)**
1	Riparian Buffer Vegetation	Imagery	Natural plant community occupies less than 1/3 of the valley bottom or gaps in riparian corridor exceed 30% of the contributing stream length.	Natural plant community occupies at least 1/3 of the valley bottom and gaps in riparian corridor do not exceed 30% of the contributing stream length.	Natural plant community occupies more than 2/3 of the valley bottom and riparian corridor is contiguous for at least 90% of the contributing stream length.	
2	Sediment Supply	Imagery & Site data	Substantially altered sediment supply from upstream bank erosion and surface runoff. Sources of excess sediment (e.g. placer tailings, gravel stockpiles) within 1 mile of the project reach.	Moderately altered sediment supply from upstream bank erosion and surface runoff. Sources of excess sediment (e.g. placer tailings, gravel stockpiles) are present in catchment but not within 1 mile of the project reach.	Low anthropogenic-caused alteration to sediment supply (increase or decrease).	
3	Alaska Impaired Water Body Status (303(d) listed stream)	ADEC database	Category 5 due to nonsupport of aquatic life uses OR Category 4 and aquatic life impairment not actively being mitigated.	Category 4 due to nonsupport of aquatic life uses and aquatic life impairment actively being mitigated.	No streams within the catchment are on the 303(d) list.	
4	Contaminants	In-situ sampling or ADEC database	Water testing from within the project reach has identified contaminant(s) in concentrations that would limit aquatic life uses, or Testing was not conducted but 2 or more sources of contamination within the catchment were identified.	Water testing from within the project reach has identified contaminant(s) in concentrations that may limit aquatic life uses, or Testing was not conducted but 1 source of contamination within the catchment was identified.	No sources of contamination within the catchment were identified and water testing was not conducted, or Water testing from within the project reach identified no contaminant(s) in concentrations that negatively affect aquatic life uses.	
5	Regulated Discharges (APDES permits)	ADEC database	Two or more in catchment and at least 1 within 1 mile of project reach.	Less than two in catchment but none within 1 mile of project reach.	None in catchment or within 1 mile of project reach.	

6	Organism Recruitment	Imagery & Site data	Within 1 mile of project reach, the channel is concrete, piped, or hardened.	Within 1 mile of the project reach, the channel has native bed and bank material that is highly embedded by fine sediment.	Within 1 mile of the project reach, the channel has native bed and bank material.	
7	Barriers/Fish Passage	ADF&G Web Mapper & Imagery	Anthropogenic barriers exist that entirely blocks anadromous fish access to the project reach and/or interferes with the necessary life history movements of resident fish that use the project reach.	Anthropogenic barriers exist but do not block anadromous fish access at all times, and do not interfere with the necessary life history movements of resident fish that use the project reach, e.g., spawning, rearing, and overwintering habitats all occur within the isolated reach.	No anthropogenic barriers upstream or downstream of the reach.	
8	Flow Alteration	ADNR, ADF&G flow regulation & water rights data	Substantial (more than 20%) change in the flow volume from natural flow conditions.	Moderate (10-20%) change in the flow volume from natural flow conditions.	Minimal (less than 10%) change in flow volume from natural flow conditions.	
9	Roads and Trail Networks	Imagery & Spatial data	Roads/trails are located in close proximity to the stream and within the floodplain. As a result, roads/trails directly alter runoff processes; sediment loading, transport, and deposition; channel morphology and stability; water quality; and riparian conditions within the catchment.	Roads/trails exist in the catchment but are largely outside of the floodplain and have minimal effect on natural sediment and hydrologic regimes.	No roads or trails exist in the catchment.	
10	Urbanization	Imagery & NLCD	Urban or rapidly urbanizing with ongoing or imminent large-scale development.	Low density or rural communities or slow urban or suburban growth.	Predominantly natural land cover; or rural.	
11	Resource Development: Oil, Gas, Wind, Pipeline, Mining, Timber Harvest, Roads	USACE and other Permits	High development in contributing catchment or some within 1 mile of project reach, or >1 mile but available information indicates high potential for impacts to project reach.	Moderate development or moderate potential for impacts and none within 1 mile of project reach.	No development or no potential for impacts.	
12	Aufeis	Site data	Aufeis formation caused by land disturbance is extensive within, extends into the reach from downstream, or is found within 1 kilometer (0.62 miles) upstream of the project reach.	Aufeis formation caused by land disturbance is moderate within, extends into the reach from downstream, or is found within 1 kilometer (0.62 miles) upstream of the project reach.	Aufeis formation caused by land disturbance is minor or nonexistent within, extends into the reach from downstream, or is found upstream of the project reach.	
13	Permafrost Degradation	Imagery, Permafrost mapping, & Site data	Areas of permafrost degradation exist within or upstream of the project reach, contributing to hillslope slumping, increased erosion, and/or water quality impacts.	Areas of permafrost degradation exist within or upstream of the project reach contributing to hillslope slumping or increased erosion but are not resulting in impacts to water quality.	No areas of permafrost degradation in the catchment area have been observed.	

14	Other					

Notes: ADEC = Alaska Department of Environmental Conservation ADF&G = Alaska Department of Game and Fish

NLCD = National Land Cover Database APDES = Alaska Pollutant Discharge Elimination ADNR = Alaska Department of Natural Resources

USACE = US Army Corps of Engineers

A Microsoft Excel version of this form can be found at: https://stream-mechanics.com/wp-content/uploads/2021/06/AKSQTint_SQT_v1.xlsx

Appendix D
Bankfull Regional Curves for Interior Alaska

Appendix D is a compilation of regional curves developed by the Bureau of Land Management (BLM) and the National Park Service (NPS) for Interior Alaska. The map on the following page shows the Interior region overall. Two regional curves have been developed to cover this entire region – one is for the northern Interior and the other is for the southern Interior (Figure 1). The solid line for each graph is the regression line (regional curve). The dashed lines are the prediction interval boundaries that can be used to discern geomorphic features such as inner berm, bankfull, and terraces (refer to design manual).

The northern interior curves range in drainage area from about 1 to 500 square miles. The southern curves range from about 0.25 to 400 square miles. These curves may be useful for high-level planning and assessment, and when a project site is not within a watershed-specific curve. In either case (an interior curve or watershed-specific curve), it is recommended to only apply the curves on sites with drainage areas that are within the drainage area range shown on the graphs. Uncertainty increases as curves are extrapolated into drainage areas that are smaller and larger than what is shown on the graphs.

Figure 2 shows all the watershed-specific curves for the Northern Region, and Figure 3 shows the watershed-specific curves for the Southern Region. These curves are preferable for design projects over the two aggregate curves. If a project site is located within a watershed that has its own set of curves, those curves should be used.

These curves may be updated and new curves may be added as more data are collected. Designers should check https://www.blm.gov/alaska/aquatics for updates before using the curves in this appendix.

This appendix is organized as follows. First is the map showing the northern and southern Interior Region. Next is the map showing the watershed-specific curve regions, followed by maps of each watershed-specific curve region with individual watersheds identified. The regional curves are then provided in the following order.

- Northern Interior Alaska Regional Curves
  - Big Salt River
  - Kanuti River
  - Middle Fork Koyukuk
  - South Fork Koyukuk

- Southern Interior Alaska Regional Curves
  - Kantishna
  - Fortymile
  - Valdez Creek

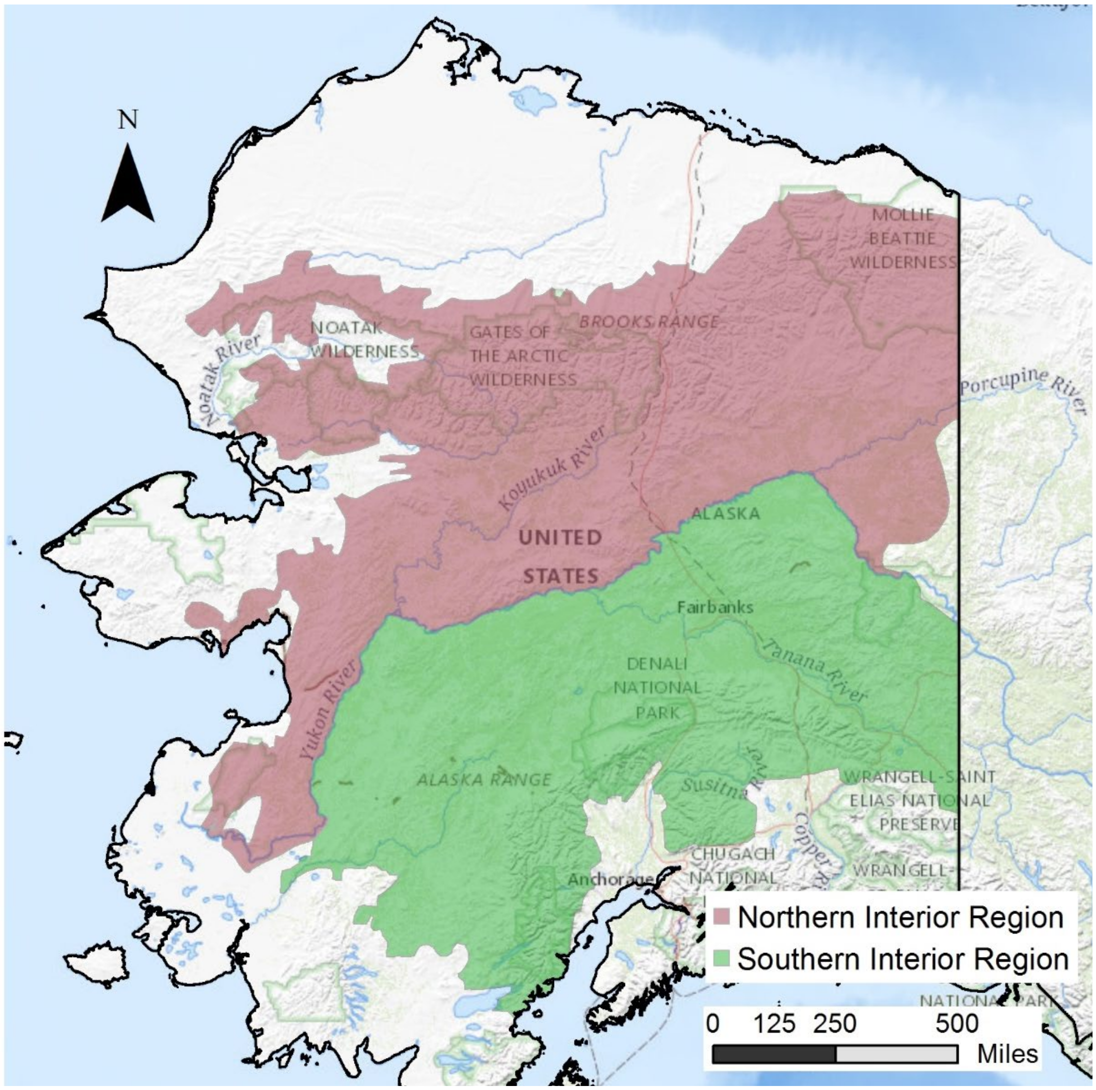


Figure 1. Northern and Southern portions of Interior Alaska for Determining the Application of Regional Curve Data.

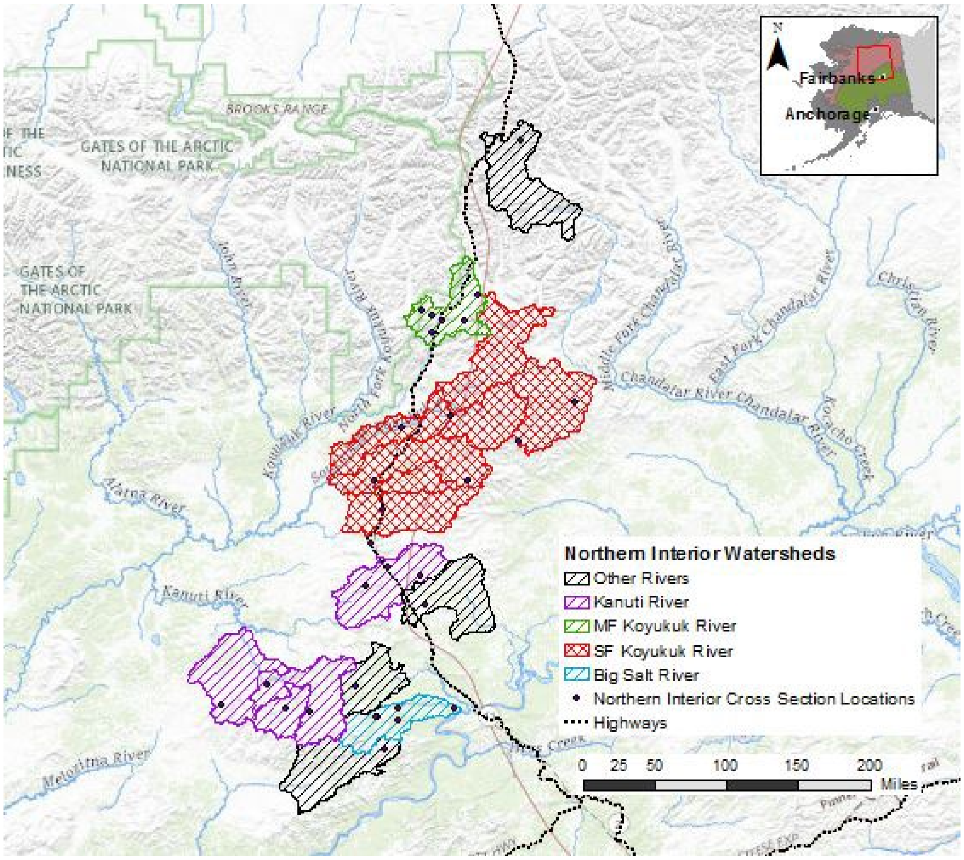


Figure 2. Areas represented by Northern Interior Watershed-Specific Regional Curves

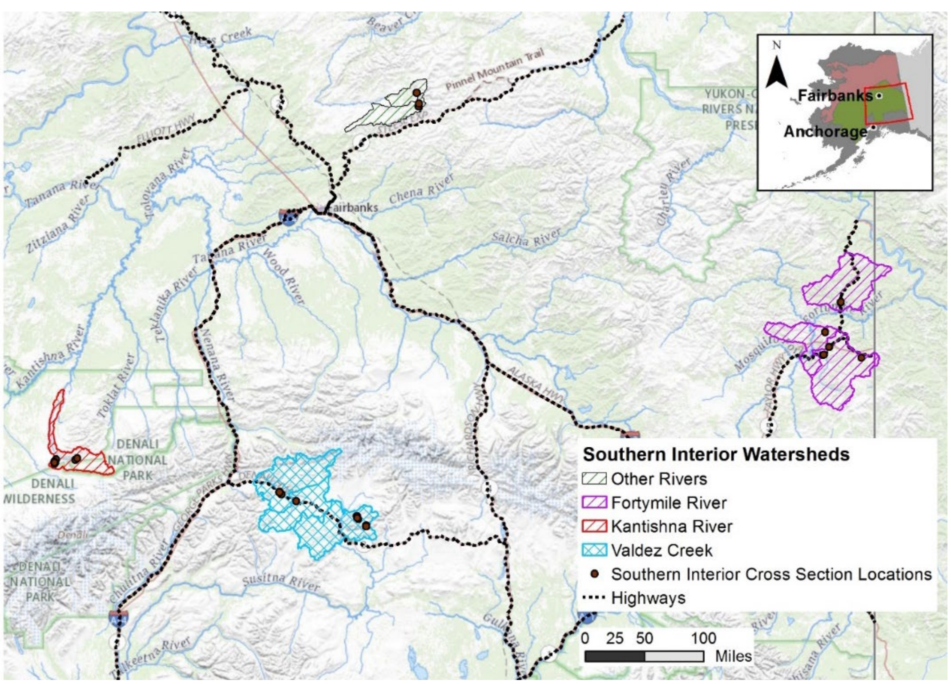


Figure 3. Areas represented by Southern Interior Watershed-Specific Regional Curves

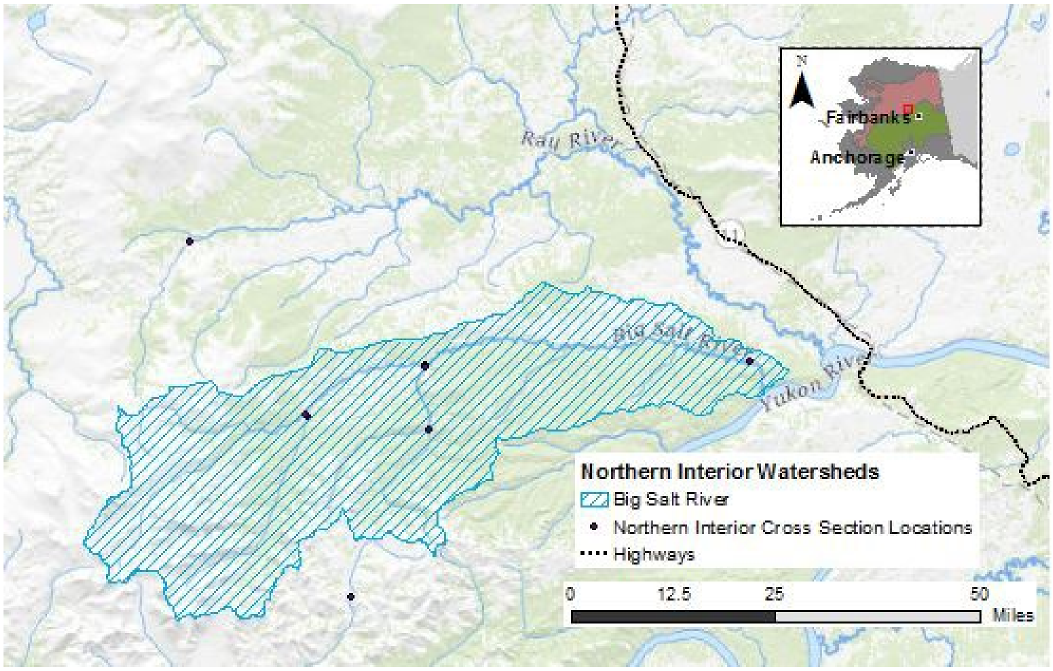


Figure 4. Big Salt River Watersheds

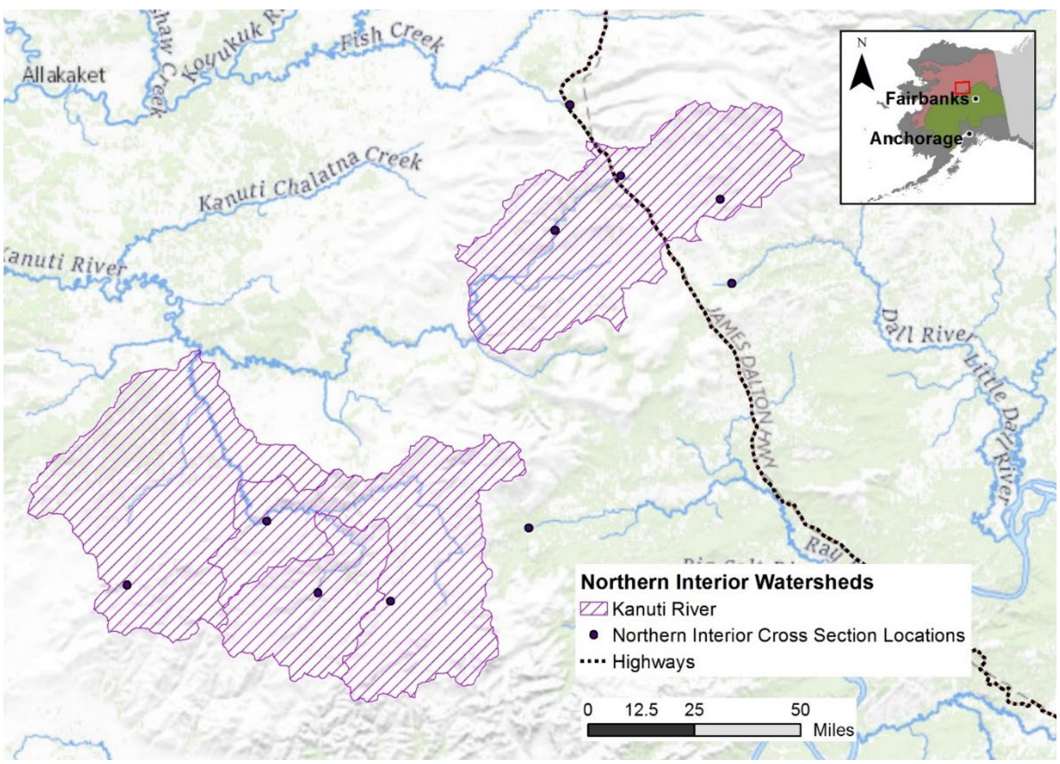


Figure 5. Kanuti River Watersheds

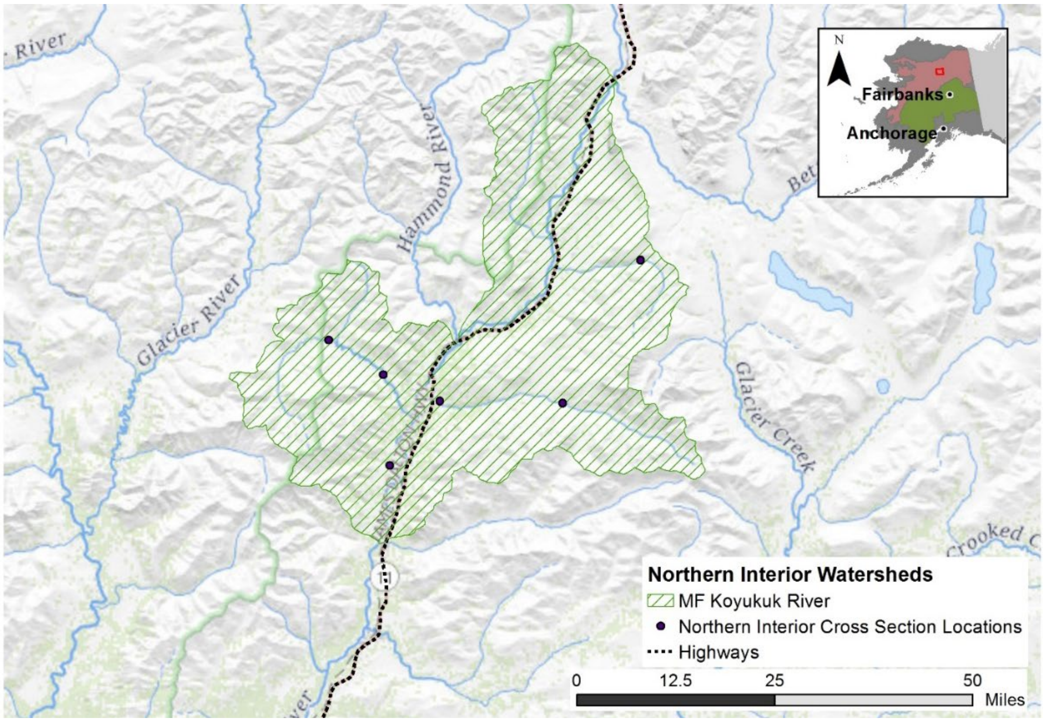


Figure 6. Middle Fork of the Koyukuk River Watersheds

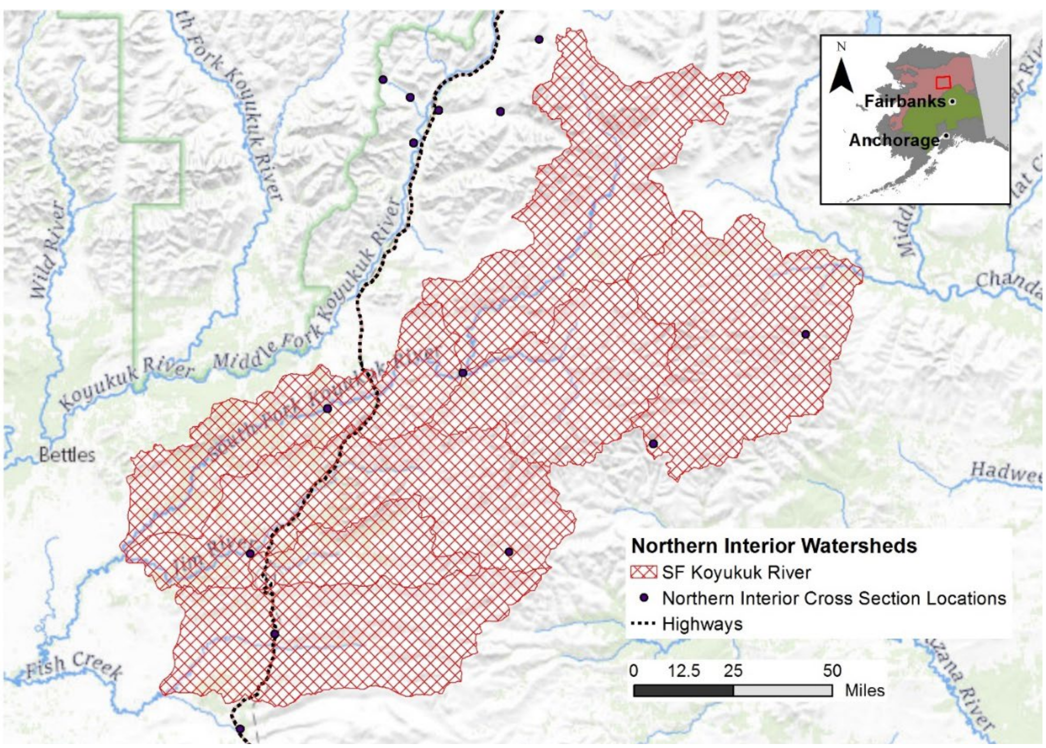


Figure 7. South Fork of the Koyukuk River Watershed

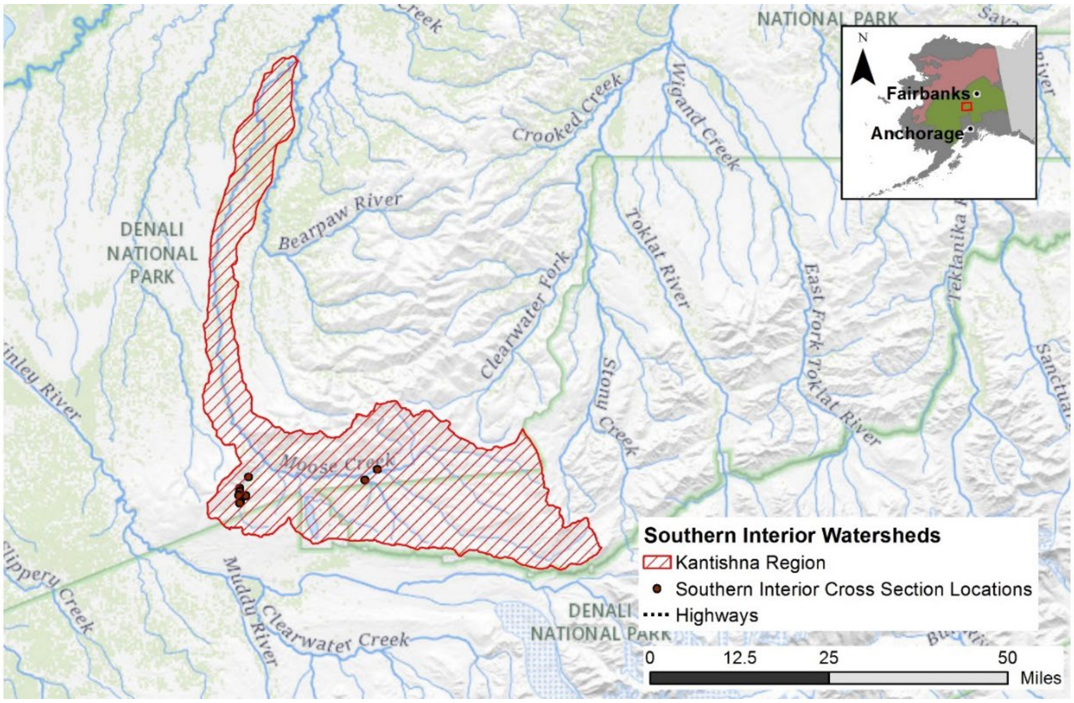


Figure 8. Kantishna Region

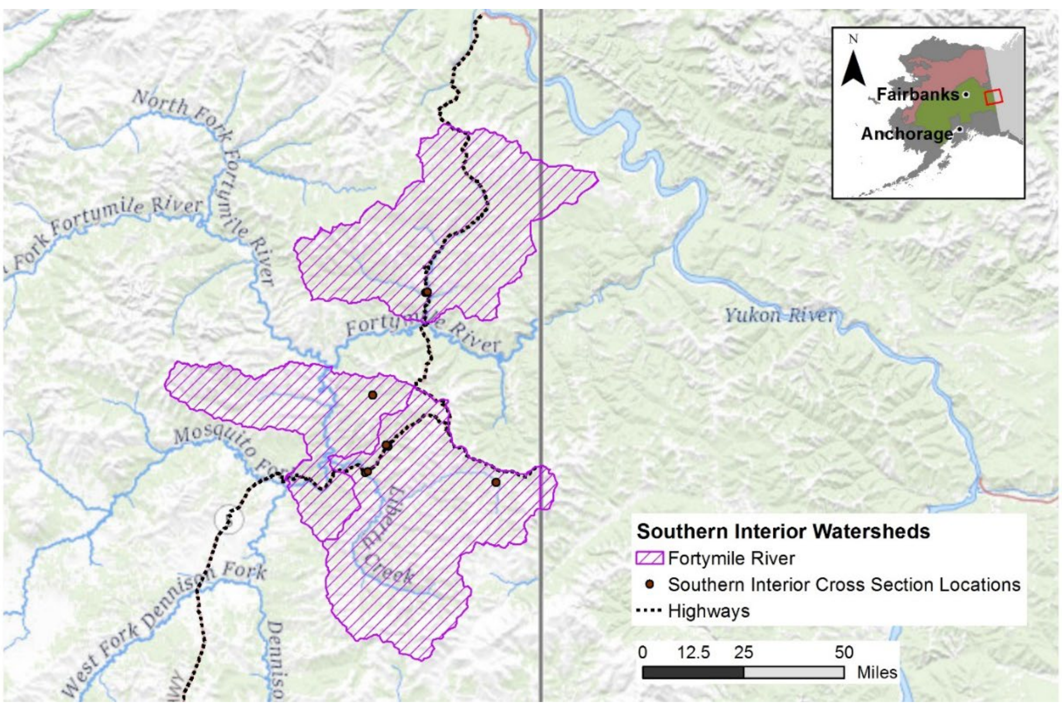


Figure 9. Fortymile River Watersheds

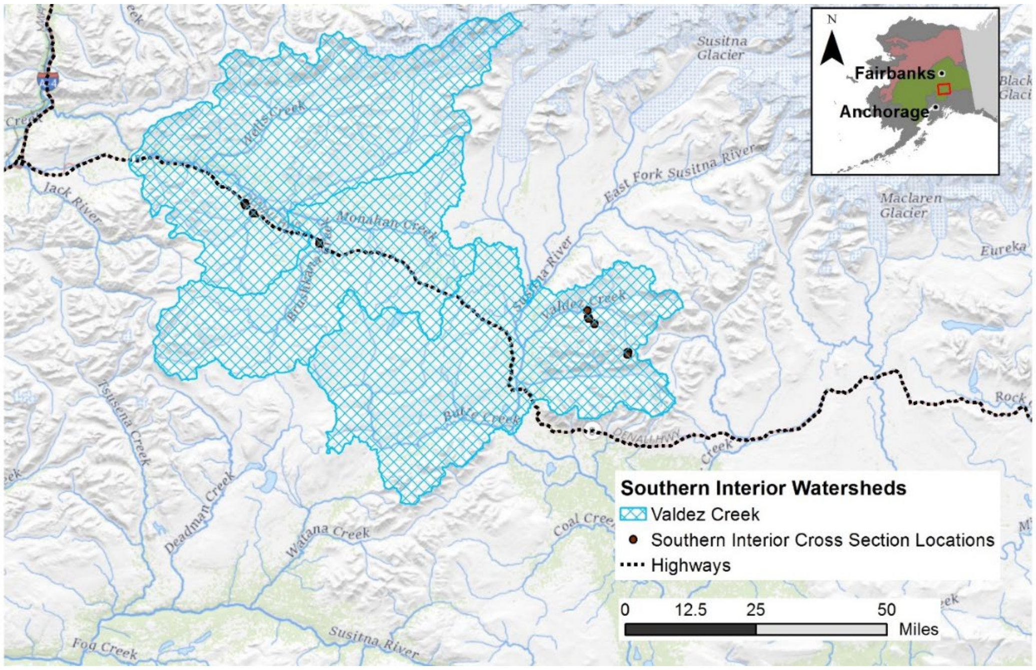
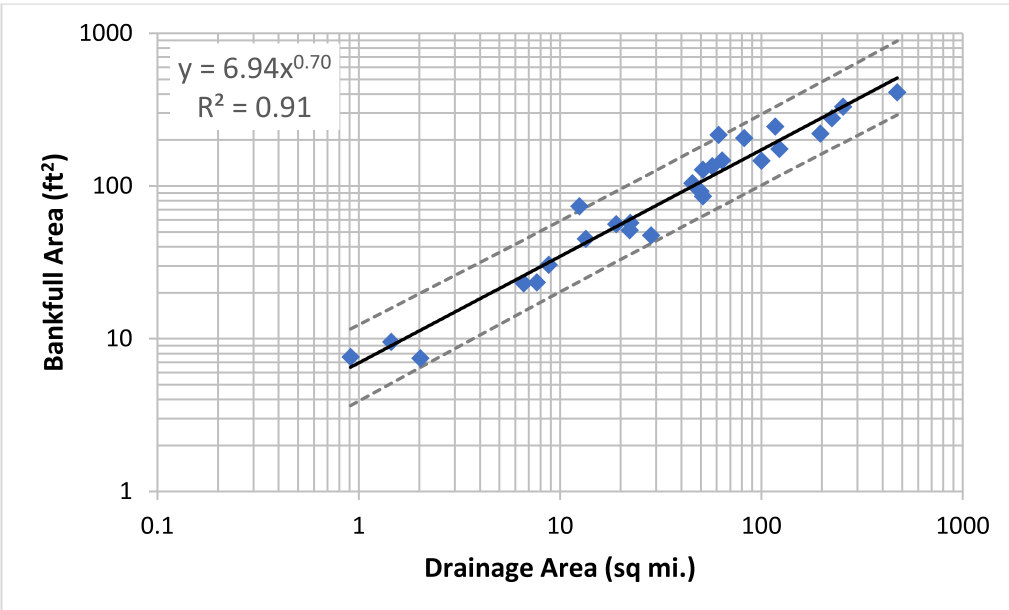
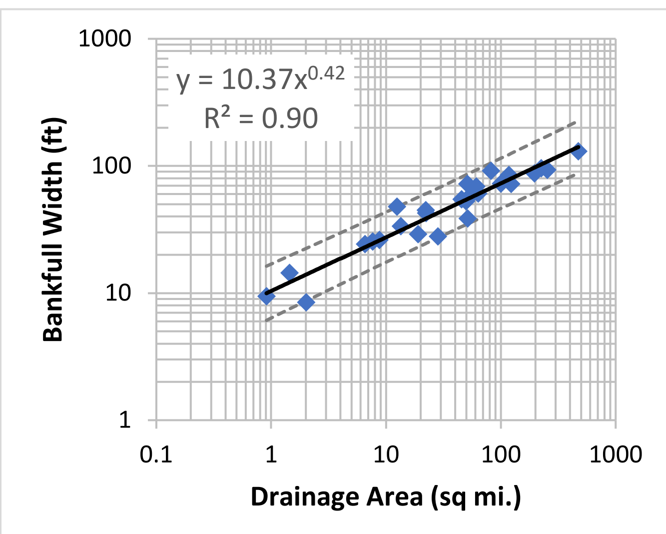


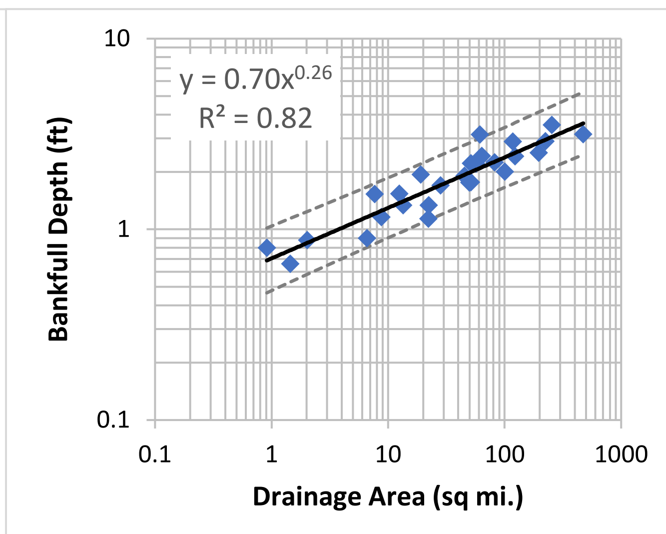
Figure 10. Valdez Creek area watersheds

Northern Interior Alaska Regional Curves (Refer to Figures 1 and 2)
Combined Watershed-Specific Curves

Physiographic Division:	Intermontane Plateau, Rocky Mountain System	**Stream Types:**	B3, B3a, B3c, B4, B4c
Physiographic Province:	Northern Plateau, Arctic Mountains	**Sample size:**	27
Physiographic Section:	Kokrine-Hodanza Highlands, Ambler-Chandalar Ridge and Lowland Section		



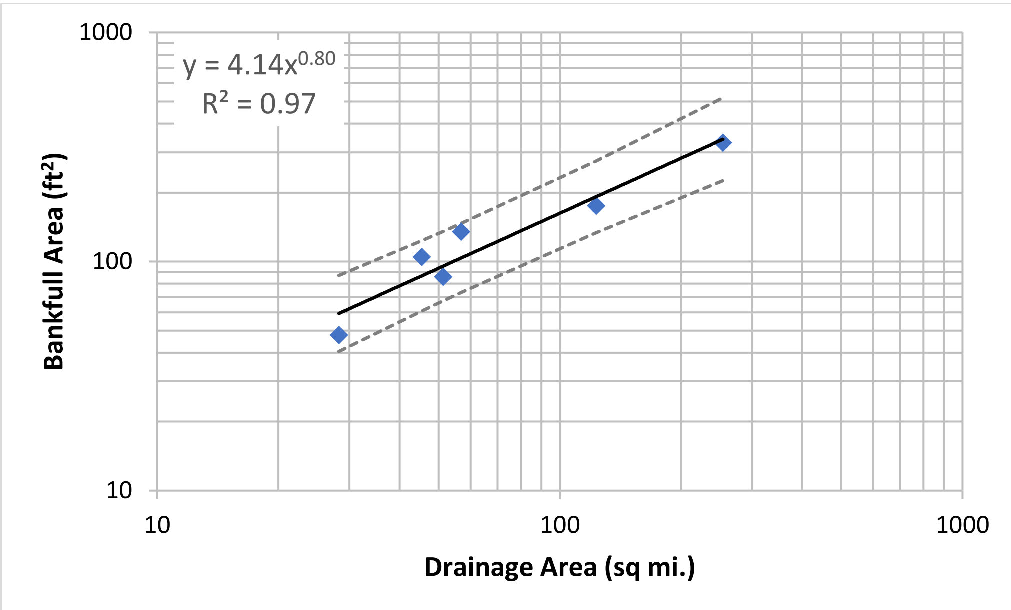


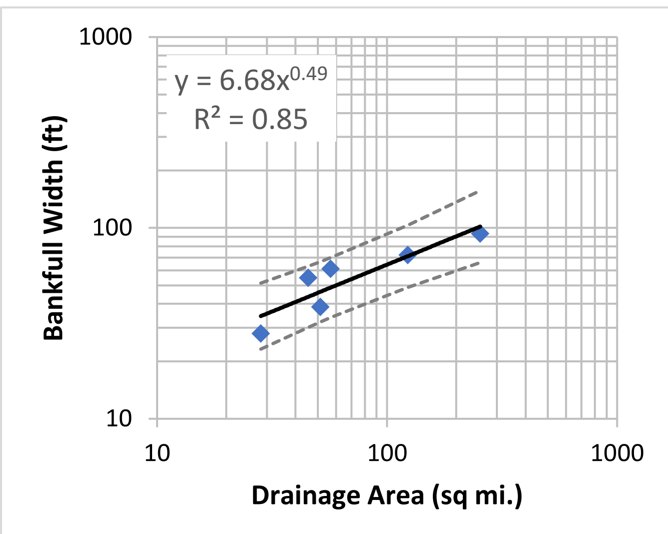


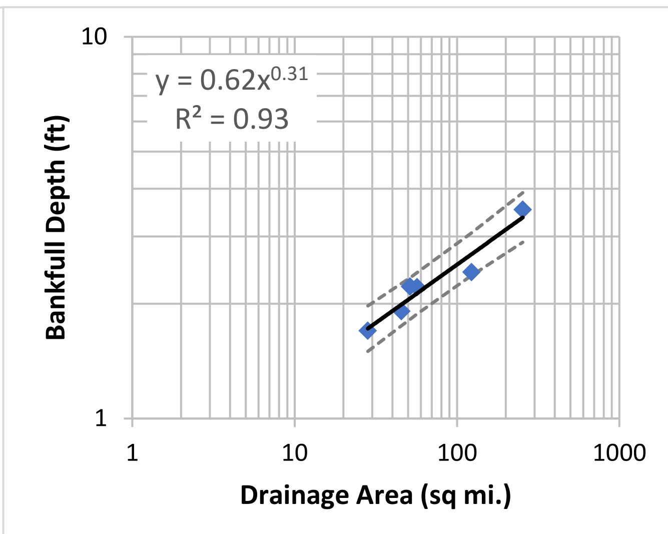
Watershed-Specific Regional Curve, Northern Interior

Watershed Name: Big Salt River (Refer to Figure 4)

Physiographic Division:	Intermontane Plateau	**Stream Types:**	B3c, B4c
Physiographic Province:	Northern Plateau	**Sample size:**	6
Physiographic Section:	Kokrine-Hodanza Highlands		



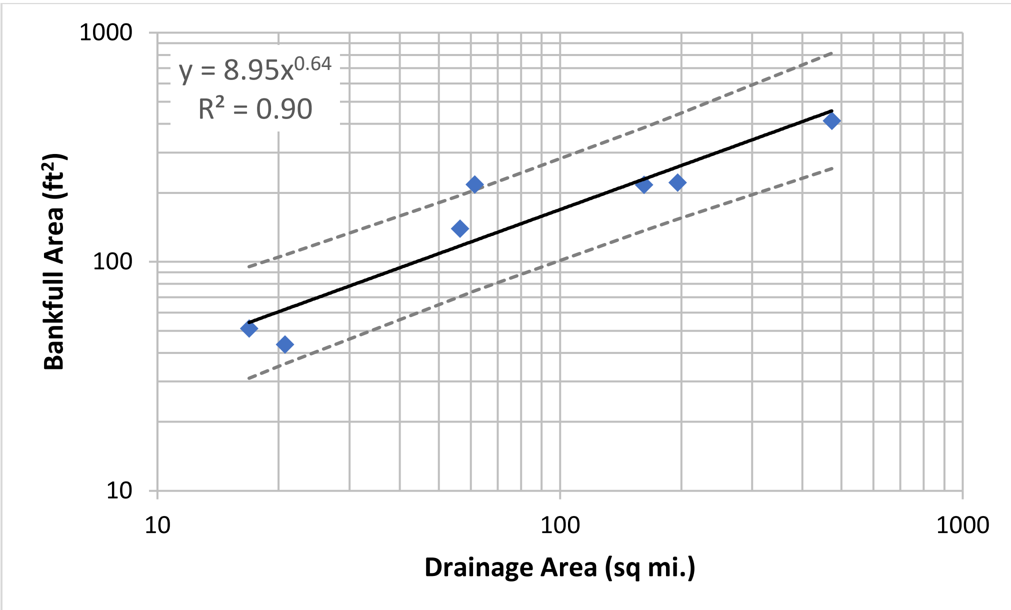


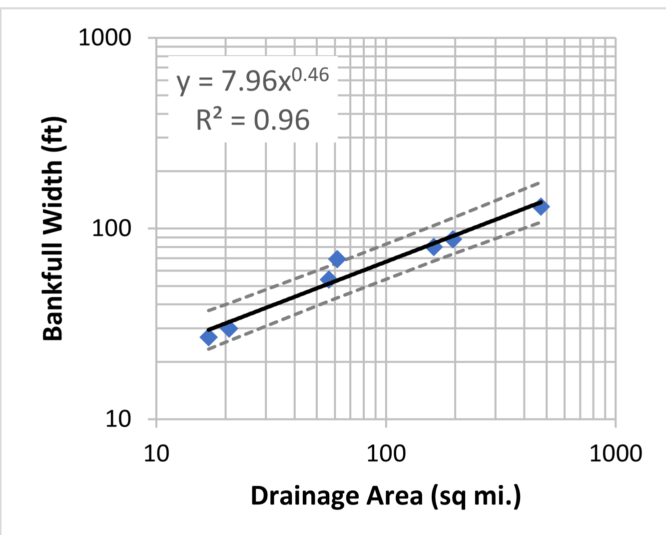


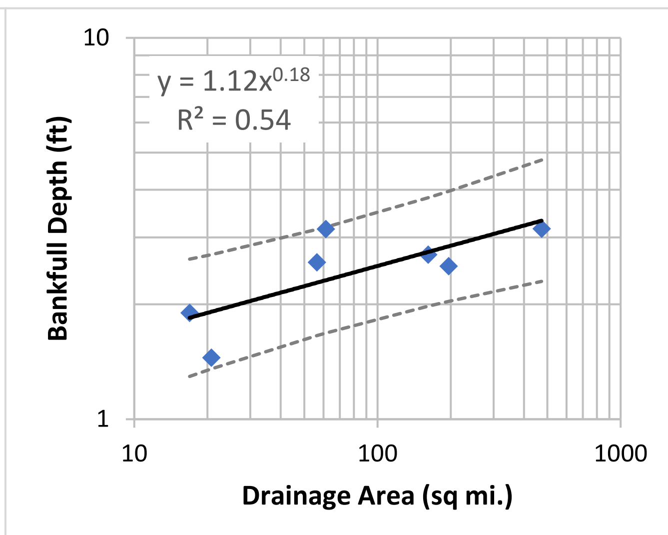
Watershed-Specific Regional Curve, Northern Interior

Watershed Name: Kanuti River (Refer to Figure 5)

Physiographic Division:	Intermontane Plateau	**Stream Types:**	B3c, B4c, C3, C4
Physiographic Province:	Northern Plateau, Western Alaska	**Sample size:**	7
Physiographic Section:	Kokrine-Hodanza Highlands, Kanuti Flats		



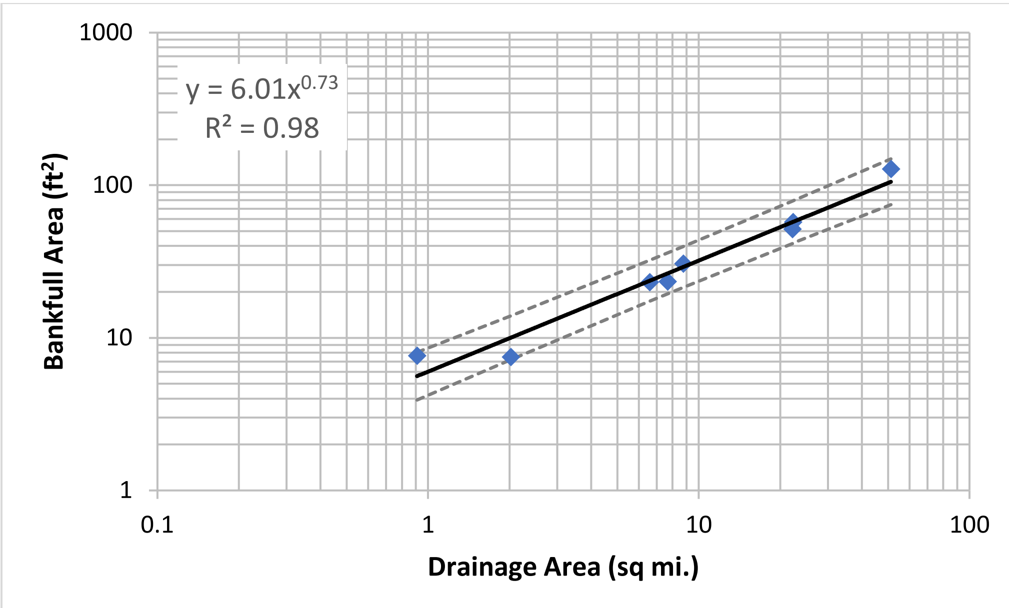


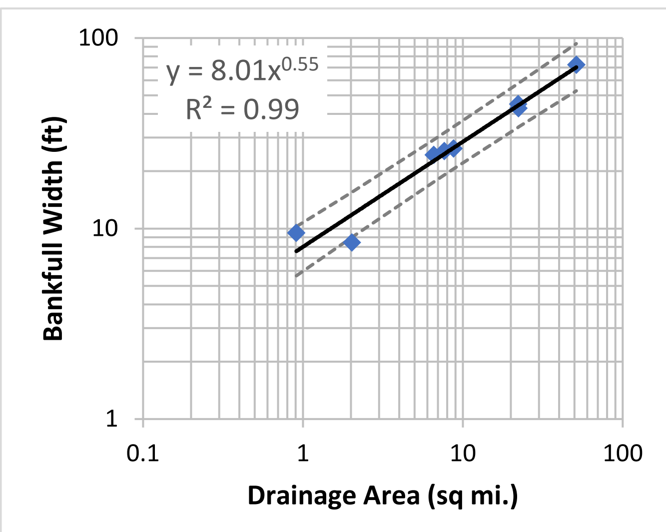


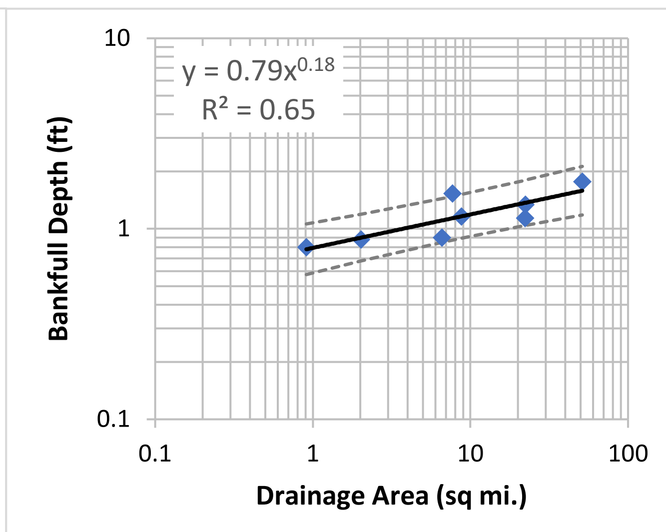
Watershed-Specific Regional Curve, Northern Interior

Watershed Name: Middle Fork Koyukuk River, Rosgen B Stream Types (Refer to Figure 6)

Physiographic Division:	Rocky Mountain System	**Stream Types:**	B3, B3a, B4, B4c
Physiographic Province:	Arctic Mountains	**Sample size:**	8
Physiographic Section:	Ambler-Chandalar Ridge and Lowland Section		





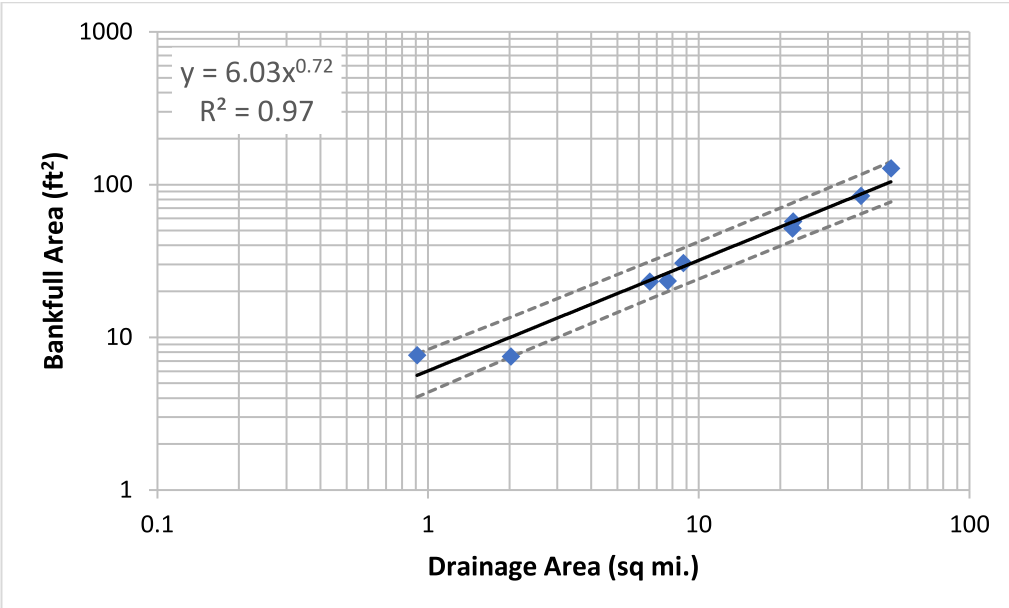


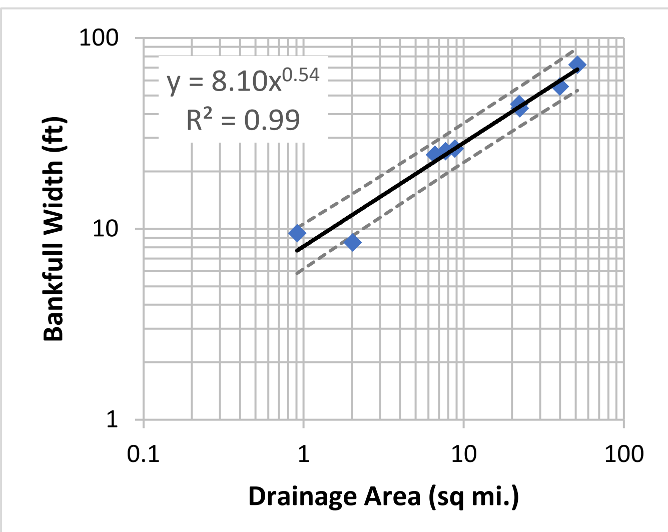
Watershed-Specific Regional Curve, Northern Interior

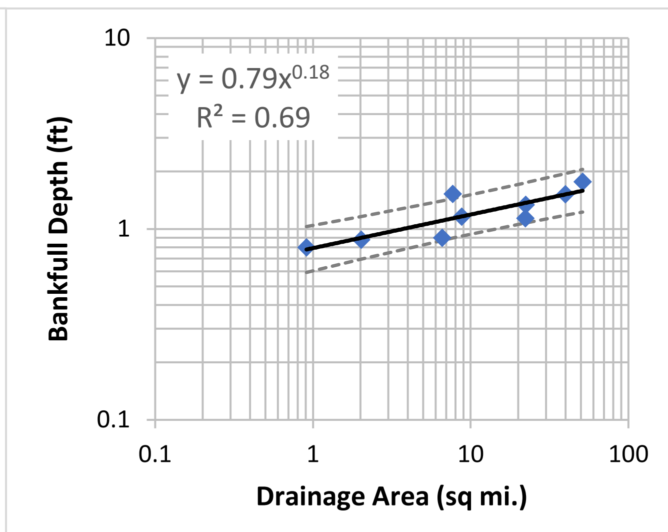
Watershed Name: Middle Fork Koyukuk River, Rosgen B and C stream types

(Refer to Figure 6)

Physiographic Division:	Rocky Mountain System	**Stream Types:**	B3, B3a, B4, B4c, C4
Physiographic Province:	Arctic Mountains	**Sample size:**	9
Physiographic Section:	Ambler-Chandalar Ridge and Lowland Section		



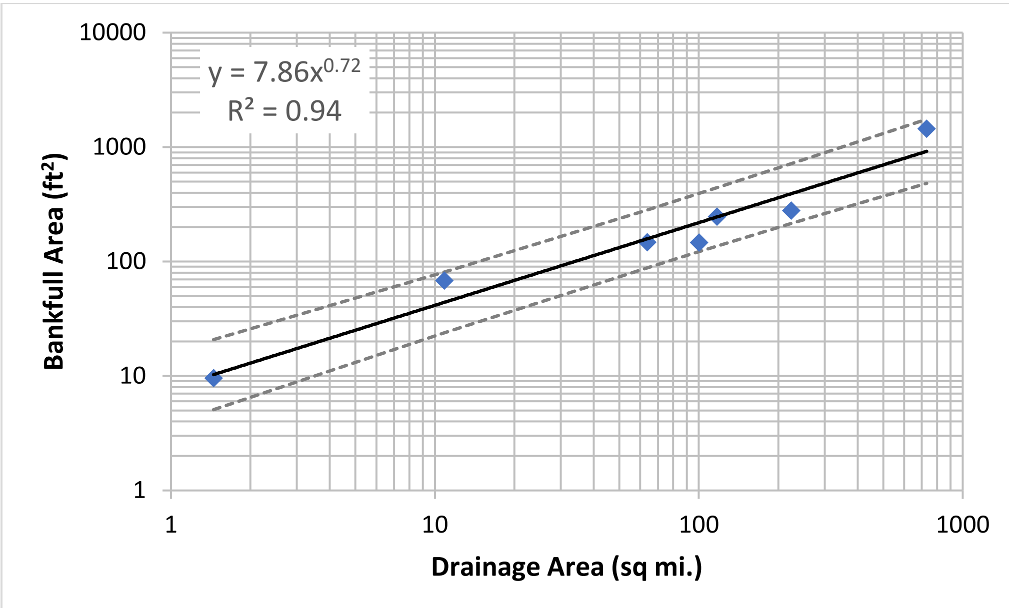


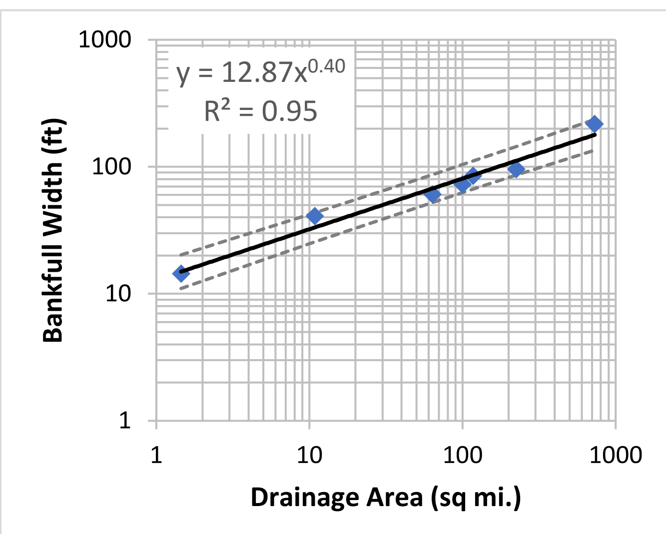


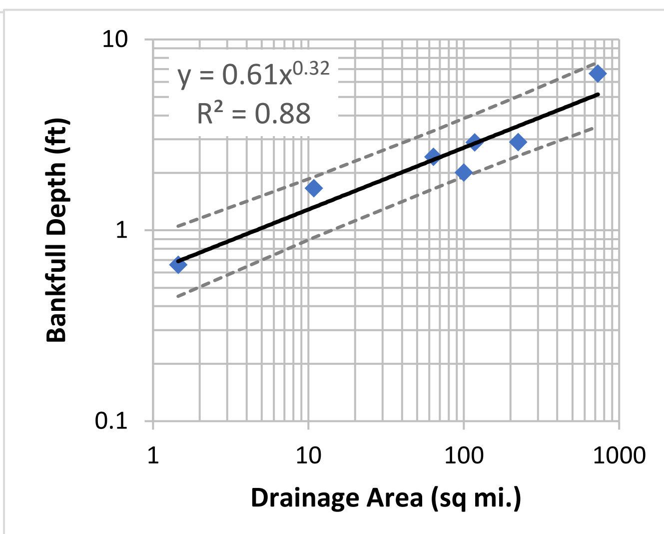
Watershed-Specific Regional Curve, Northern Interior

Watershed Name: South Fork Koyukuk River (Refer to Figure 7)

Physiographic Division:	Intermontane Plateau	**Stream Types:**	B3a, B4, B4c, C3, C3b
Physiographic Province:	Northern Plateau	**Sample size:**	7
Physiographic Section:	Kokrine-Hodanza Highlands		

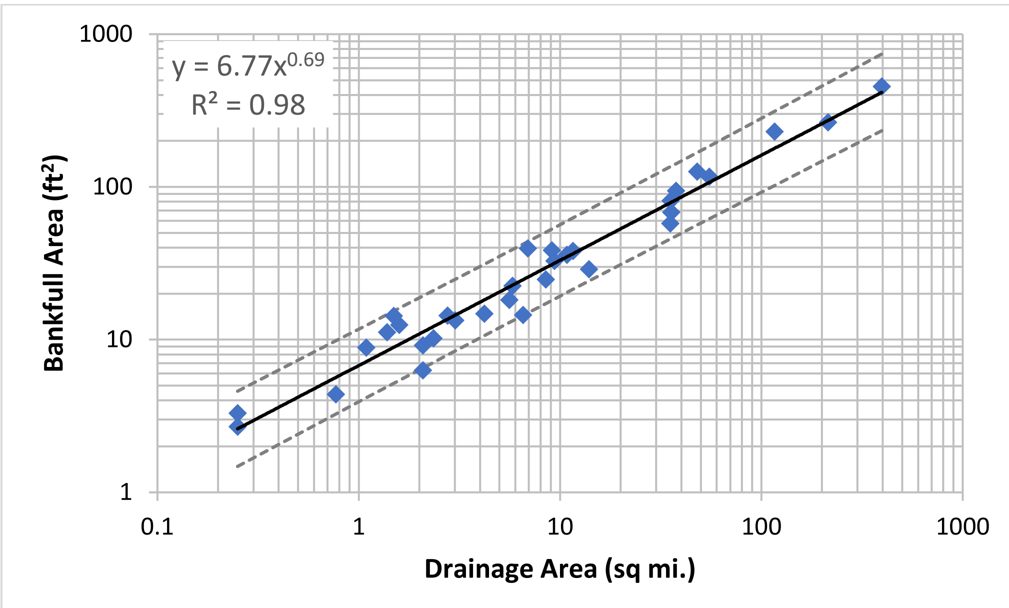


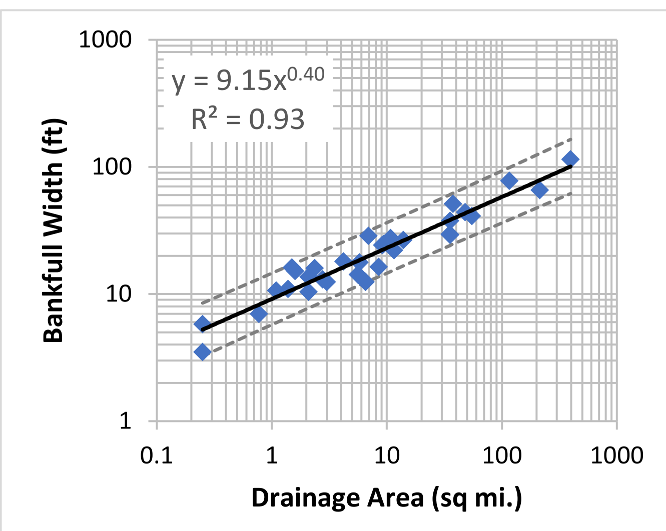


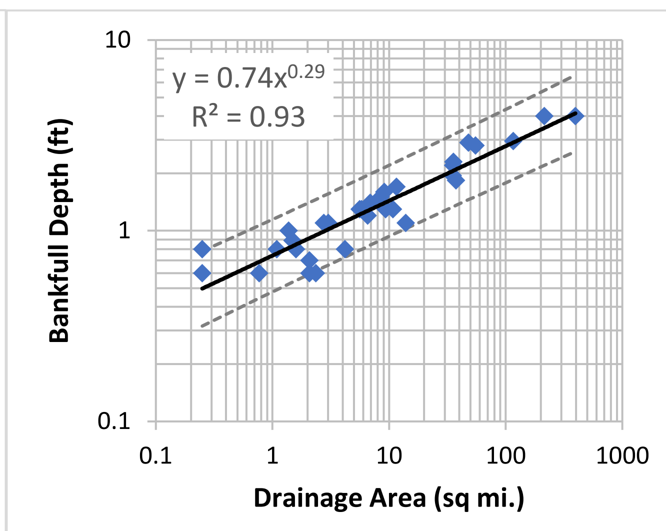


Southern Interior Alaska Regional Curves (Refer to Figures 1 and 3)
Combined Watershed-Specific Curves

Physiographic Division:	Intermontane Plateaus, Pacific Mountain System, Pacific Mountain	**Stream Types:**	Aa+, B3, B3a, B4a, B4c, C3b, C4, C4b
Physiographic Province:	Western Alaska, Alaska-Aleutian, Northern Plateaus, Coastal Trough	**Sample size:**	32
Physiographic Section:	Alaska Range, Northern Foothills, Tanana-Kuskokwim Lowland, Yukon-Tanana Upland, Broad Pass Depression, Clearwater Mountains, Talkeetna Mountains		



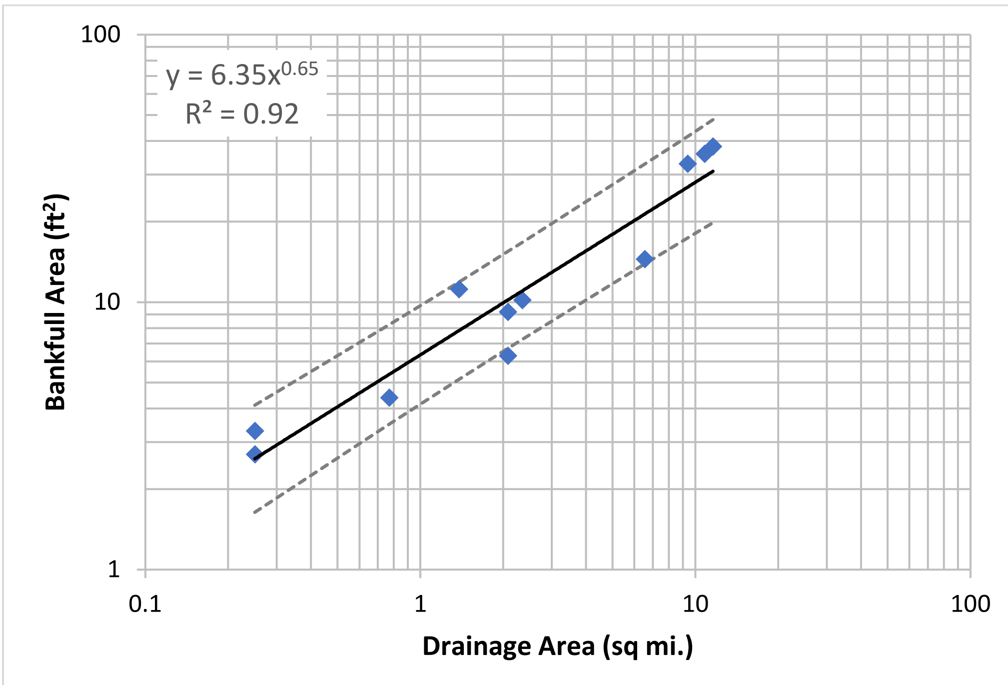


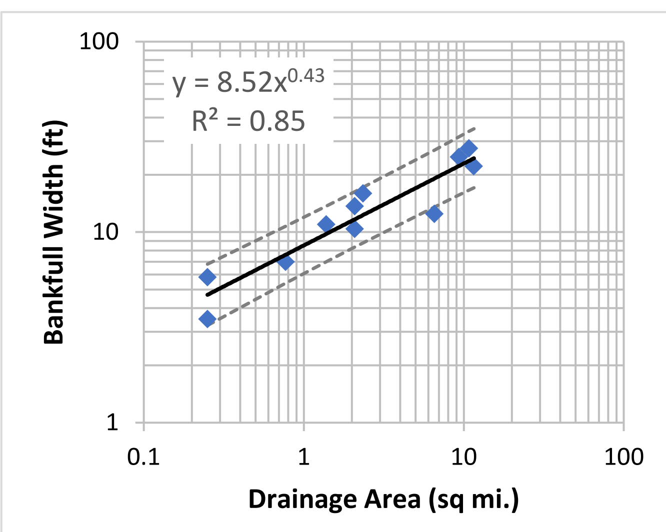


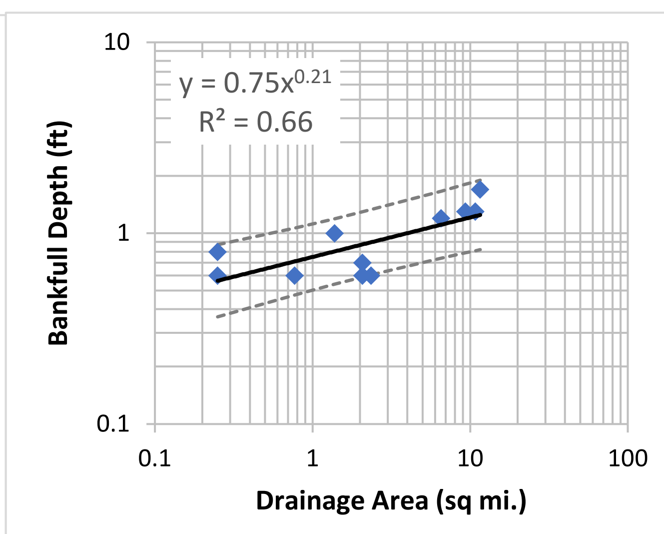
Watershed-Specific Regional Curve, Southern Interior

Watershed Name: Kantishna Region (Refer to Figure 8)

Physiographic Division:	Intermontane Plateaus, Pacific Mountain System	**Stream Types:**	Aa+, B3a, B3, B4a B4, C3b
Physiographic Province:	Western Alaska, Alaska-Aleutian	**Sample size:**	11
Physiographic Section:	Alaska Range, Northern Foothills, Tanana-Kuskokwim Lowland		



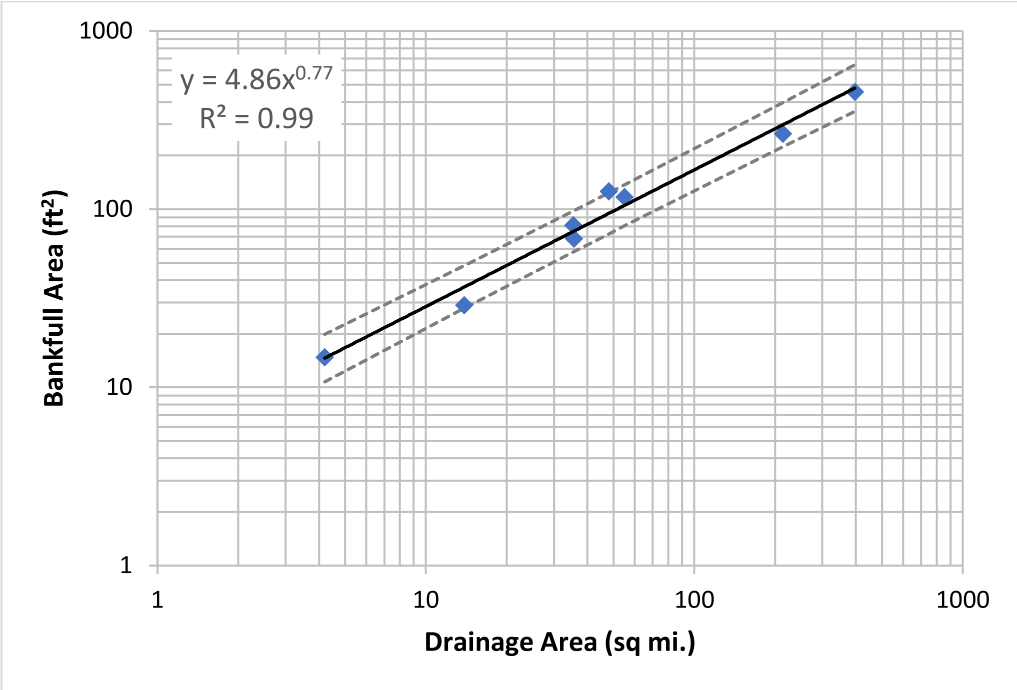


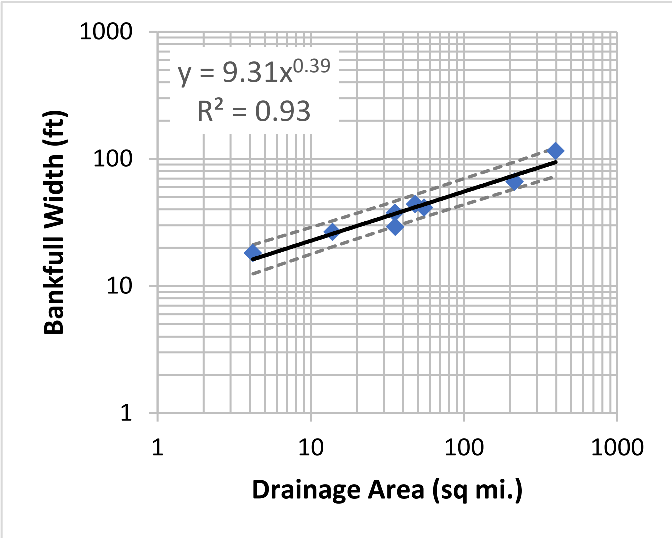


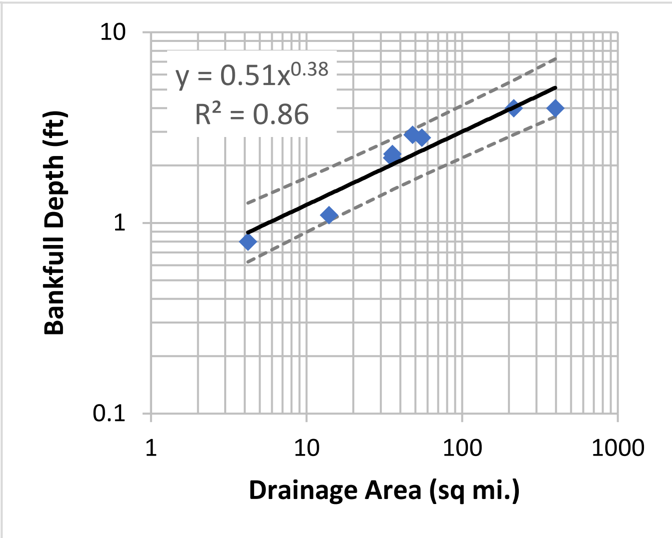
Watershed-Specific Regional Curve, Southern Interior

Watershed Name: Fortymile (Refer to Figure 9)

Physiographic Division:	Intermontane Plateaus	**Stream Types:**	C4, B4c
Physiographic Province:	Northern Plateaus	**Sample size:**	8
Physiographic Section:	Yukon-Tanana Upland		



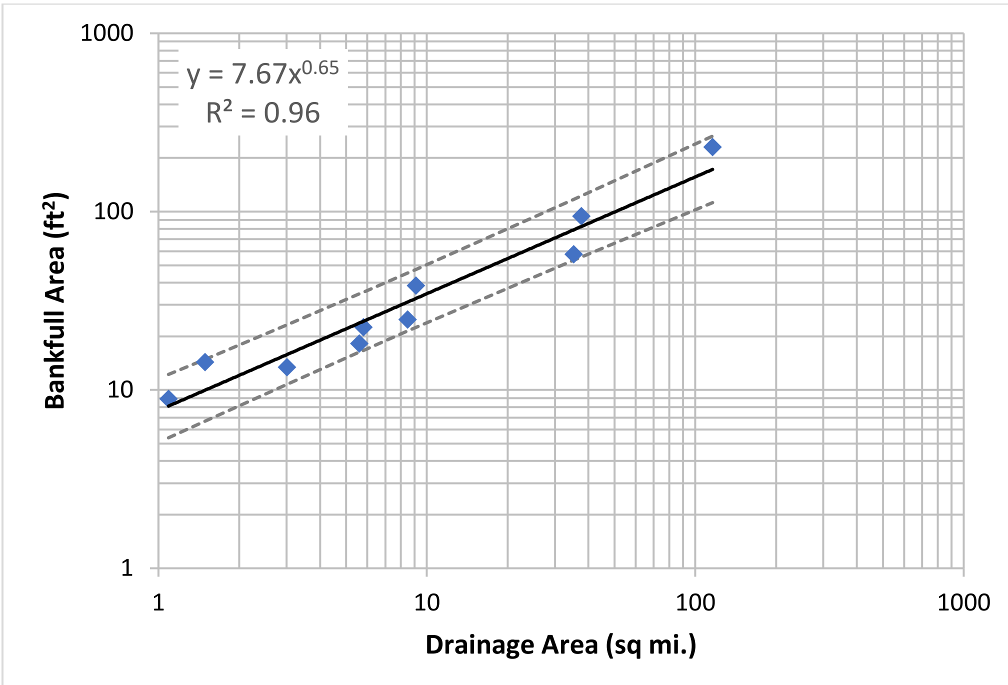


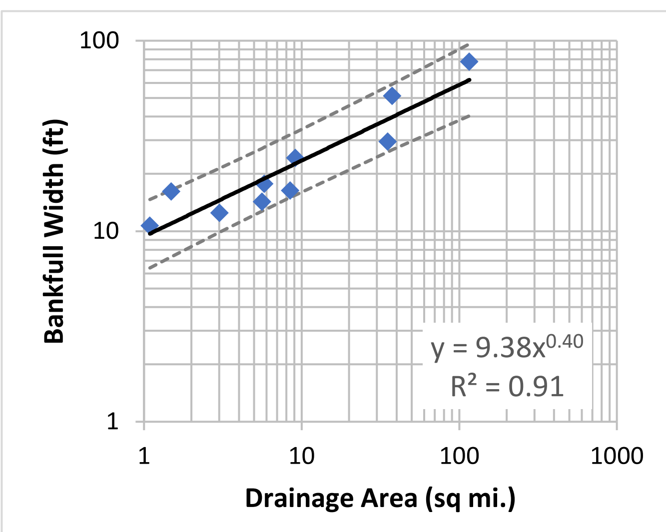


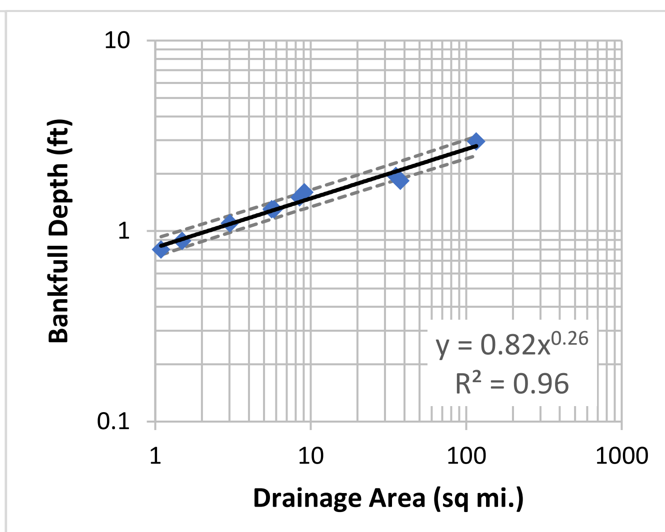
Watershed-Specific Regional Curve, Southern Interior

Watershed: Valdez Creek (Refer to Figure 10)

Physiographic Division:	Pacific Mountain	**Stream Types:**	B3a, B3, B4a, B4, C4b
Physiographic Province:	Alaska-Aleutian, Coastal Trough	**Sample size:**	7
Physiographic Section:	Alaska Range, Broad Pass Depression, Clearwater Mountains, Talkeetna Mountains		







Appendix E
Typical Topographic Surveying and Base Mapping Scope of Work for Stream Reclamation Projects

Control Survey

- When practical and feasible, it is desirable for these surveys to be referenced to an established National Spatial Reference System (NSRS) datum rather than an arbitrary grid system. Provide horizontal data relative to the North American Datum of 1983 (NAD83) State Plane Coordinate System (SPCS). Provide elevation data relative to the North American Vertical Datum of 1988 (NAVD88). Provide relationship to local ground coordinates (i.e. combined scale factor, etc.).
- Projects that are not referenced to NSRS shall use a local reference control system.
- Set permanent control points every 250-350 feet throughout the project site or as directed by the designer for use during design and construction of the project. Establish control points using GPS and total station methodologies to a minimum of 5 cm (0.164 ft) relative vertical accuracy to other connected, adjacent control points at the 95-percent confidence level and 3 cm (0.098 ft) relative horizontal accuracy to other connected, adjacent control points at the 95-percent confidence level.

Topographic Survey of Stream Channels and Floodplains

- Coordinate the survey area, units, feature coding, etc. with the designer before surveying.
- Use accepted terrestrial or GPS surveying methods to obtain sufficient topographic detail to ensure accurate mapping of the survey area at 1-foot contour interval. Meet relative positional accuracies that support detailed reclamation design, grading, excavation, roads, culverts, etc.
- Use breaklines to establish correct digital terrain model (DTM) and topographic contours for linear features such as, slope breaks, channels, ditches, berms, roads, etc.
- Collect high points, low points, and spot elevations at sufficient intervals to represent the general character of the terrain.
- Collect stream topography as follows:
    - Thalweg, including at the head of each bed feature (riffle, run, pool, glide) and max depth of each pool. It can also be helpful to survey the mid-point of riffles.
    - Water surface elevation (including at head of each feature)
    - Top of bank, note which is the low bank.
    - Toe of bank
    - Continue survey at least 50 ft above and below the project reach or as directed by the designer
- Collect floodplain topography as follows:
    - Main stem: extend at least 40’ beyond top of banks on both sides of stream channel
    - Tributaries: extend at least 20’ from top of banks on both sides of stream channels
    - Collect topography to at least the floodprone elevation
    - Collect topography of all terraces, drainage features, erosional areas, ponds, spoil piles, etc.
- Field locate all structures, signs, fences, utilities, wells, roads, trails, etc. within survey area.

Provide main floor elevations of buildings.

- Field locate culverts and bridges. Include inverts, dimensions (e.g. diameter, length), materials, and height of cover if applicable.
- Field locate centerline and edge of roads and trails extending approx. 50' each side of crossings (if applicable). Indicate surfacing materials.
- Field locate the perimeter of all transplant source areas, as identified by designer
- Field locate bedrock outcrops, springs, seeps, and other natural features
- Collect location, diameter, and species of trees over specified size, if requested by the designer.
- Indicate observable evidence of recent earth moving work, borrow, fill or buried material.
- Perform quality assurance/quality control before submitting deliverables to designer

Survey Deliverables

- Point, Northing, Easting, Elevation, Description (PNEZD) file, including control points.
- Narrative describing the surveying procedures, equipment used, monument descriptions, and site-specific information. Include any pictures and survey notes with the narrative.
- Drawing file from computer aided drafting and design (CADD) software of the survey points, control points, breaklines, and site features.

Base Map

- Use CADD software to create the project base map from survey data.
    - Meet the United States National CADD Standard.
    - Meet BLM drafting standards and symbols
- Import the survey data including surveyed features, points, linework, breaklines, and symbology.
    - Typically, the stream reclamation design is based on local ground coordinates (i.e. distances on the design plans will equal actual ground distances).
- Create a digital terrain model (DTM) from the survey data.
- Create the topographic base map.
    - Determine the appropriate map scale that clearly shows the topography
    - Show existing ground contour lines
    - Show surveyed topographic features
    - Show control points
    - Annotate map features. Include north arrow and scale.
    - ANSI D sheet size is standard (11" x 17" is half-size)

Appendix F
Bioengineering Specifications and Typical Detail Drawings

Appendix F includes bioengineering specifications and typical detail drawings. The bioengineering specifications have been adapted from the Natural Resources Conservation Service's National Engineering Handbook, Part 654 on Stream Restoration and more specifically from its appendix called Technical Supplement 14I on bioengineering. The specifications provided below have been adapted to better meet the conditions found in Interior Alaska. Plant species suitable for dormant cuttings are provided in Table 9 of the manual along with descriptions supporting the specifications. The manual section number is provided with each bioengineering technique.

The specifications in this appendix focus on using plant material from onsite sources. Therefore, guidance is not provided about how to store and apply dormant cuttings. The Streambank Revegetation and Protection: A Guide for Alaska (Revised 2005) does provide guidance on securing, storing, and then using dormant cuttings. In addition, this guide includes other bioengineering methods that could be more applicable to stream restoration or reclamation sites that are not associated with placer mining.

Bioengineering Specifications

Brush Mattress (Section 12.2.4)

Materials

- Live cuttings, 3/4 to 1 inch in diameter. The cuttings should be as long as possible. This will allow the basal ends to be placed in or at the water table elevation while the tops protect the hillslope. Up to 20 percent of the cuttings can be dead material to add bulk.
- Dead stout stakes—wedge shaped, 1.5 to 4 feet long, depending on soil texture.
- Ties—string, braided manila, sisal or prestretched cotton twine, or non-galvanized wire.
- Tools—machete, shovels, clippers, hammer, sledge hammer, punch bar, saw, and machine to shape the bank
- Fertilizer and other soil amendments

Installation

- Ideally, collect cuttings on the same day that they will be installed. If transplants are being used, the tops of willows can be cut and immediately used. Leave side branches intact.
- If more are being cut than can be installed that day, soak the live cuttings in water for a max of 14 days. Settling ponds can be used to store material. Leave side branches intact.
- Cut a 2- by 4-inch board diagonally and at desired length to create the dead stout stakes.

- Excavate the bank to a slope of 1V:2H or flatter. The distance from the top of the slope to the bottom of the slope is typically 4 to 20 feet. Excavate a 1-foot-wide and 8- to 24-inch-deep trench along the toe.
- Drive the dead stout stakes 1 to 3 feet into the ground up the face of the prepared bank. Space the installation of the dead stout stakes on a grid that is 1.5 to 3 foot square. Start the lowest row of dead stout stakes below bankfull stage or a fourth of the height of the bank. The tops of the dead stout stakes should extend above the ground 6 to 9 inches. Live cuttings may also be mixed with the dead stout stakes, and tamped in between to add deeper initial rooting. However, the live cuttings cannot generally be driven-in as securely as the dead stout stakes and should not be relied upon solely for anchoring the brush mattress.
- Lay the live cuttings up against the face of the bank. The basal ends of the cuttings are installed into the trench with the growing tips oriented upbank. The live cuttings' side branches should be retained and should overlap in a slight crisscross pattern. Depending on the size of the branches, approximately 8 to 15 branches are installed per linear foot of bank.
- Stand on the live cuttings and secure them by tying string, cord, wire, braided manila, sisal, or prestretched cotton twine in a diamond pattern between the dead stout stakes. Short lengths of tying material are preferred over long lengths. In the event of a failure, only a small portion of the treatment would be compromised if short lengths are used. Otherwise, there are risks of losing larger portions of the project if long lengths of tying material are used to anchor the cuttings to the dead stout stakes.
- After tying the string to the stakes, drive the dead stout stakes 2 to 3 inches further into the bank to firmly secure the live cuttings to the bank face. This improves the soil-to-stem contact.
- Wash loose soil into the mattress between and around the live cuttings so that the bottom half of the cuttings is covered with a 3- to 4-inch layer of soil.
- Backfill the trench with soil or a suitable toe protection such as rock or transplants.

Brush Layering (Section 12.2.5)

Materials

- Live cuttings—3/4 to 3 inches in diameter and 3 to 6 feet long or longer.
- Tools—machete, shovels, mattock, clippers, saw, and hammer.
- Fertilizer and other soil amendments
- String, cord, wire, braided manila, sisal, pre-stretched cotton twine or non-galvanized wire

Installation

- Ideally, collect cuttings on the same day that they will be installed. If transplants are being used, the tops of willows can be cut and immediately used. Leave side branches intact.
- If more are being cut than can be installed that day, soak the live cuttings in water for 14 days. Settling ponds can be used to store material. Leave side branches intact.
- Cut a 2- by 4-inch board diagonally and at desired length to create the dead stout stakes.
- Excavate bankfull bench so that the elevation is four inches below grade.
- Drive the dead stout stakes 1 to 3 feet into the ground of the bankfull bench. Space the installation of the dead stout stakes on a grid that is 1.5 to 3 foot square. Live cuttings may also be mixed with the dead stout stakes, and tamped in between to add deeper initial rooting. However, the live cuttings cannot generally be driven-in as securely as the dead stout stakes and should not be relied upon solely for anchoring the brush layer.
- Lay the live cuttings on the bankfull bench. For bankfull bench widths that are less than the cutting lengths, bury the basal end into a trench excavated at the toe of the hillslope. The tops are at or hanging over the streambank. For bench widths that are greater than the cutting length, place cutting as just described. In addition, place cuttings such that the basal end is along the streambank and the tops are facing the hillslope. Overlap these cuttings with cuttings coming from the hillslope. Secure the basal end with transplants or rock.
- The live cuttings' side branches should be retained and should overlap in a slight crisscross pattern. Depending on the size of the branches, approximately 8 to 15 branches are installed per linear foot of bank.
- Stand on the live cuttings and secure them by tying string, cord, wire, braided manila, sisal, pre-stretched cotton twine or non-galvanized wire in a diamond pattern between the dead stout stakes. Short lengths of tying material are preferred over long lengths. In the event of a failure, only a small portion of the treatment would be compromised if short lengths are used. Otherwise, there are risks of losing larger portions of the project if long lengths of tying material are used to anchor the cuttings to the dead stout stakes.
- After tying the string to the stakes, drive the dead stout stakes 2 to 3 inches further into the bank to firmly secure the live cuttings to the bank face. This improves the soil-to-stem contact.
- Wash loose soil into the layer between and around the live cuttings so that the bottom half of the cuttings is covered with a 3- to 4-inch layer of soil.
- Backfill the trench along the hillslope with soil or transplants.

Live Stakes (Section 12.2.6)

Materials

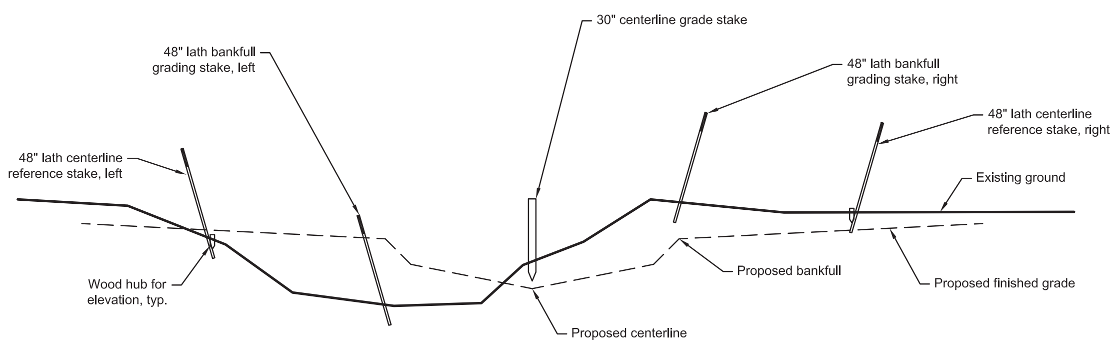
- Live cuttings—3/4 to 3 inches in diameter, 2 to 4 feet long.
- Tools—machete, clippers, dead blow hammer saw, chain saw, loppers, and rebar.

Installation

- Cleanly remove all side branches and the top growth. Cut the basal end to a 45-degree angle or sharpen into a pointed end. The top end should be cut flat. At least two buds or bud scars should be present above the ground in the final installation, depending on the surrounding vegetation height. The live cuttings should be taller than the surrounding vegetation to ensure that they are not shaded.
- Collect and soak the live cuttings for up to 14 days, or preferably, install them the day that they are harvested.
- Use a punch bar or hand auger to create a pilot hole that is perpendicular to the slope. The depth of the hole should be 2/3 to ¾ the length of the live cutting. Make the hole diameter slightly smaller than the live stake to obtain the best soil-to-stem contact. The hole should be deep enough to intercept the lowest water table of the year or a minimum of 2 feet.
- To achieve good soil-to-stem contact, fill the hole around the live stake with a water-and-soil slurry mixture. Add soil around the cutting as the water percolates into the ground and the soil in suspension settles around the cutting. Another method is to tamp soil around the cutting with a rod. Throw a small amount of soil in the hole around the cutting and tamp it down to remove all air pockets.
- Install the live stake into the ground at a right angle to the slope face. Use a dead blow hammer to tap the cutting into the ground. Insert the cutting at a 90-degree angle to the face of the slope. Ensure that the sharpened basal end is installed first.
- Place stakes on 2- to 4-foot spacing in either a random pattern or triangular grid.

Detail Drawings

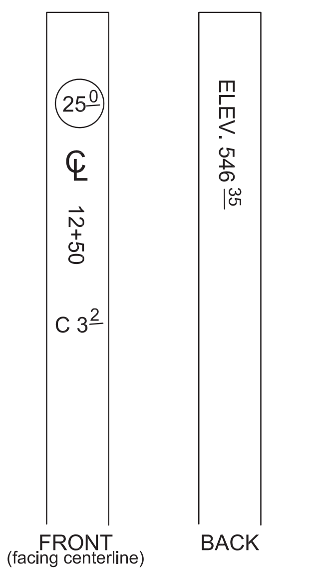
See following pages.



(A) EXAMPLE STREAM CROSS SECTION
Scale: NONE

GENERAL NOTES

1. Establish survey control points before beginning the work.
2. For stream work, stakes are generally placed along the alignment at significant features such as head of riffle, mid-riffle, step, alignment geometry point, etc.
3. Place additional staking as necessary to accomplish the work.



(1) EXAMPLE CENTERLINE REFERENCE STAKE
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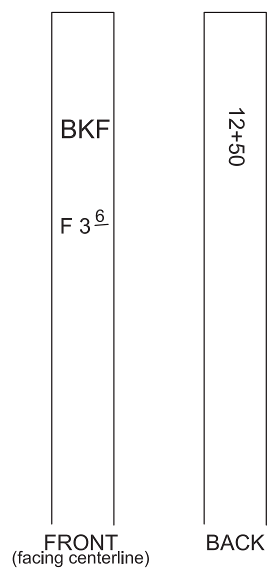

(2) EXAMPLE BANKFULL STAKE
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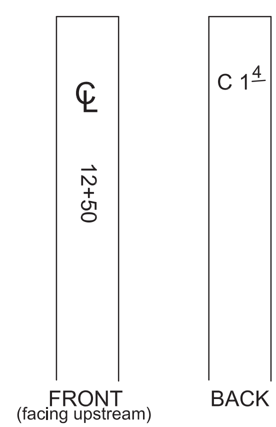

(3) EXAMPLE CENTERLINE STAKE
Scale: NONE

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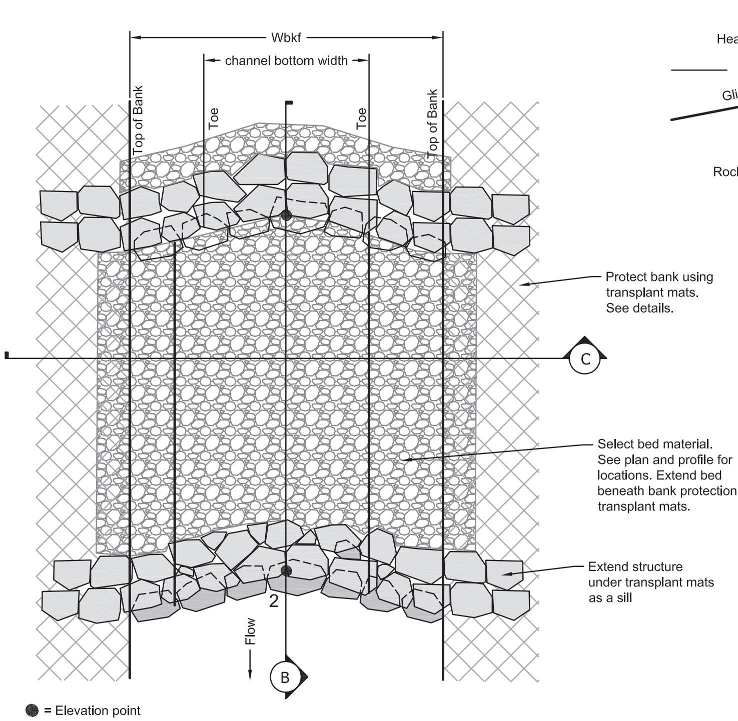
STAKING DETAIL

AK

PROJECT NO:				
DESIGN OFFICE:				
DESIGNED BY:				
DRAWN BY: DM				
CHK'D BY:				
APPROVED BY:				
DATE: 10/22	MARK	DESCRIPTION	DATE	APPROVED

SHEET OF



Ⓐ RIFFLE/CASCADE PLAN
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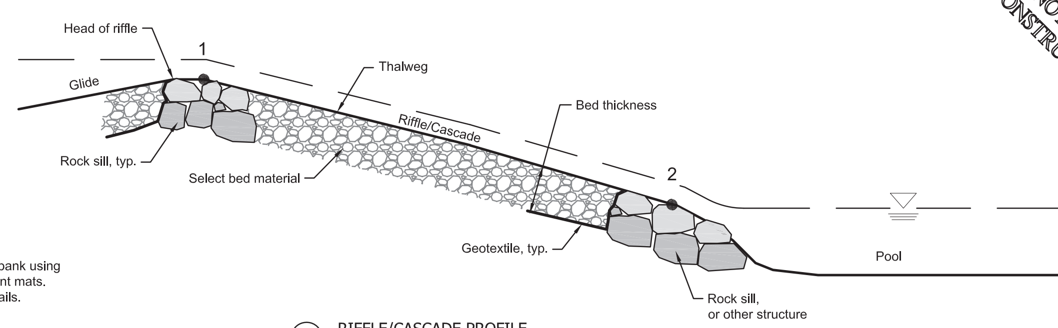
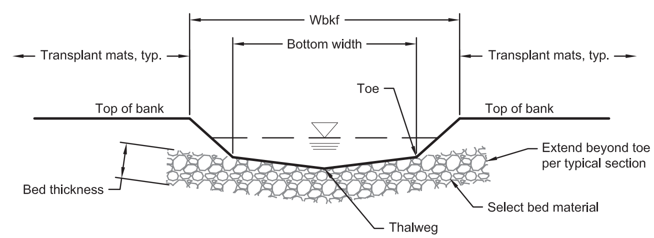


Ⓑ RIFFLE/CASCADE PROFILE
Scale: NONE



Note: Transplant mats not shown for clarity.

Ⓒ RIFFLE/CASCADE CROSS SECTION
Scale: NONE

GENERAL NOTES

1. Grade streambed and banks to proposed dimensions per typical cross-section and profile.
2. Construction sequence: 1. Construct sills 2. Place geotextile 3. Place bed material
3. An additional sill may be constructed midway in the riffle/cascade.
4. Wood and select boulders may be added for habitat complexity as directed in the field.
5. Use hand placed stone to fill gaps and voids on upstream side of the header and footer rocks.
6. Place geotextile beginning at the top of the header rocks and extending down to the depth of the footer rocks, then upstream ±10 ft as shown to prevent piping. Trim exposed geotextile.

SPECIFICATIONS

Select bed materail:	Class II Riprap: Hard, durable, angular rock that is resistant to weathering and water action and free of organic or other unsuitable material. Do not use shale, rock with shale seams, or other fissile or fissured rock that may break into smaller pieces in the process of handling and placing. Meet specified quality and gradation requirements. Alluvium alternate: Use grizzly rock screen to create material at project site. Adjust grizzly bars to fit field conditions as directed. Bed material from existing bed shall be screened and the oversize used as select bed material.
Sill and structure rock	Rock diameter as specified. Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Transplant mats	See transplant mat details
Constructed bed Thickness	18 to 24 inches
Geotextile	Class 1, Permanent Erosion Control, meeting AASHTO M288, non-woven. Basis of design: MIRAFE 180N or equal.

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RIFFLE/CASCADE DETAIL

AK

PROJECT NO:	MARK	DESCRIPTION	DATE	APPROVED
DESIGN OFFICE:				
DESIGNED BY:				
DRAWN BY: DM				
CHK'D BY:				
APPROVED BY:				
DATE: 10/22				

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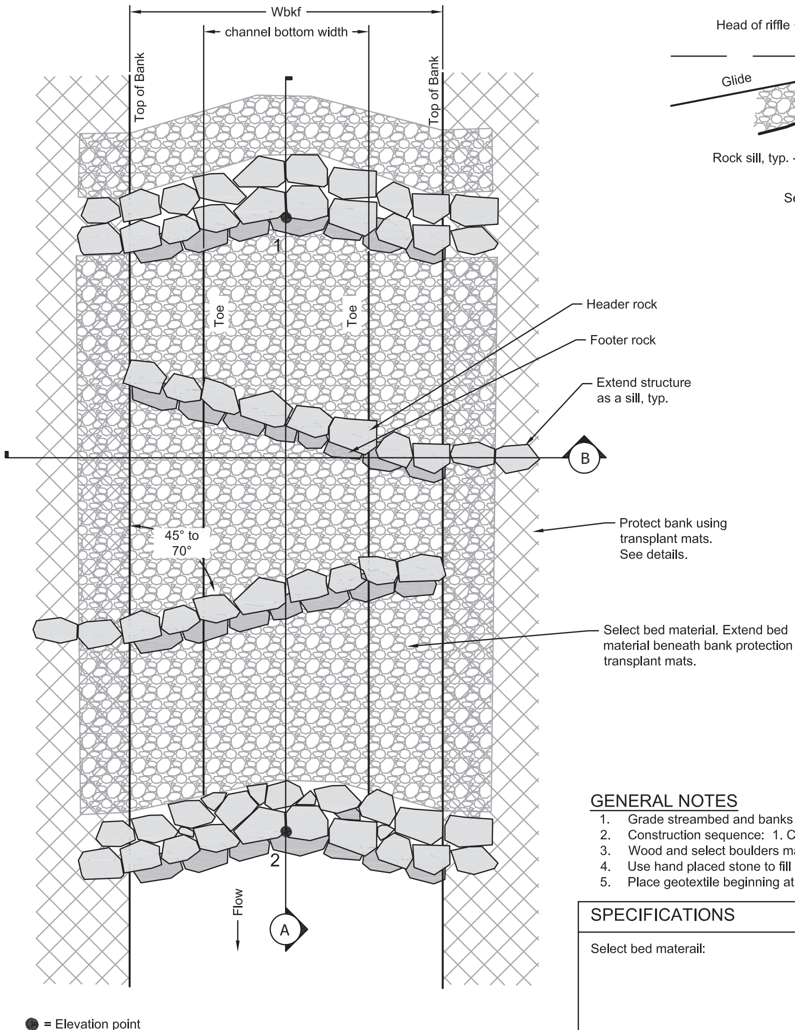

1 RIFFLE/CASCADE PLAN
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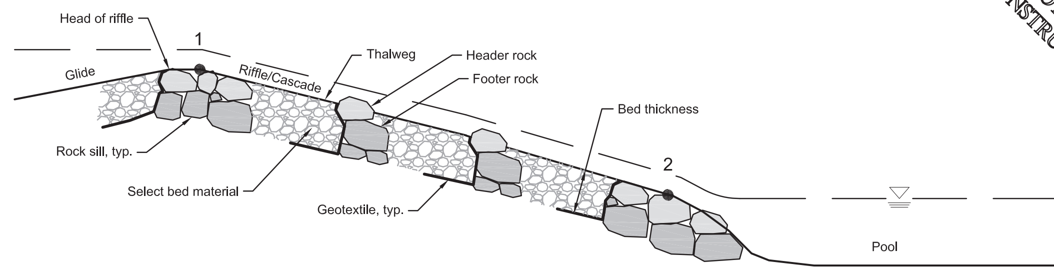
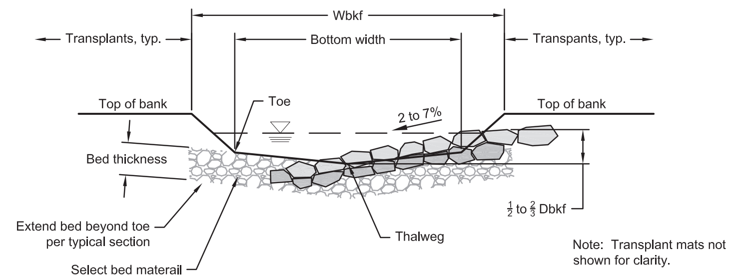


A RIFFLE/CASCADE INVERT PROFILE
Scale: NONE



Note: Transplant mats not shown for clarity.

B RIFFLE/CASCADE SECTION
Scale: NONE

GENERAL NOTES

1. Grade streambed and banks to proposed dimensions per typical cross-section and profile.
2. Construction sequence: 1. Construct sills 2. Place geotextile 3. Place bed material
3. Wood and select boulders may be added for habitat complexity as directed in the field.
4. Use hand placed stone to fill gaps and voids on upstream side of the header and footer rocks.
5. Place geotextile beginning at the top of the header rocks and extending down to the depth of the footer rocks, then upstream ±10 ft as shown to prevent piping. Trim exposed geotextile.

SPECIFICATIONS

Select bed materail:	Class II Riprap: Hard, durable, angular rock that is resistant to weathering and water action and free of organic or other unsuitable material. Do not use shale, rock with shale seams, or other fissile or fissured rock that may break into smaller pieces in the process of handling and placing. Meet specified quality and gradation requirements. Alluvium alternate: Use grizzly rock screen to create material at project site. Adjust grizzly bars to fit field conditions as directed. Bed material from existing bed shall be screened and the oversize used as select bed material.
Sill and structure rock	Rock diameter as specified. Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Transplant mats	See transplant mat details
Riffle/Cascade bed thickness	18 to 24 inches
Geotextile	Class 1, Permanent Erosion Control, meeting AASHTO M288, non-woven. Basis of design: MIRAFE 180N or equal.

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BUREAU OF LAND MANAGEMENT

RIFFLE/CASCADE STAIRCASE DETAIL

AK

PROJECT NO:	MARK	DESCRIPTION	DATE	APPROVED
DESIGN OFFICE:				
DESIGNED BY:				
DRAWN BY: DM				
CHK'D BY:				
APPROVED BY:				
DATE: 10/22				

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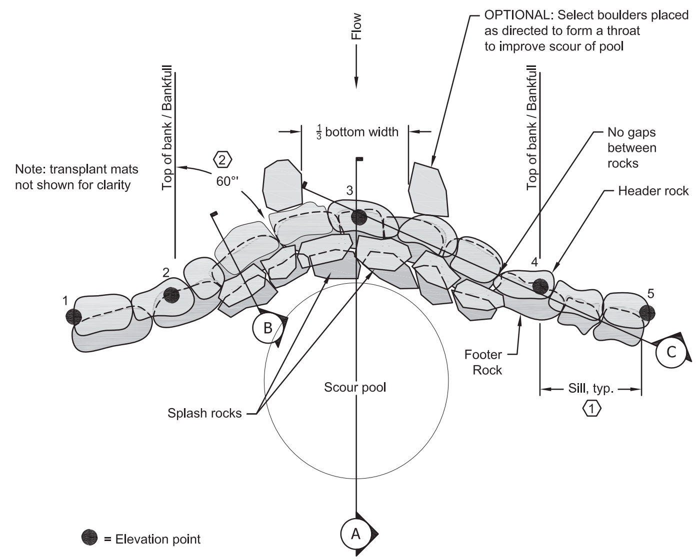
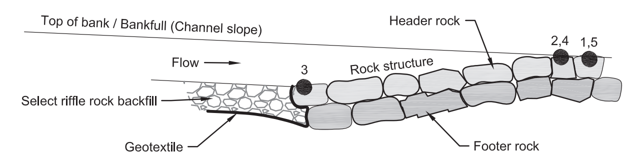
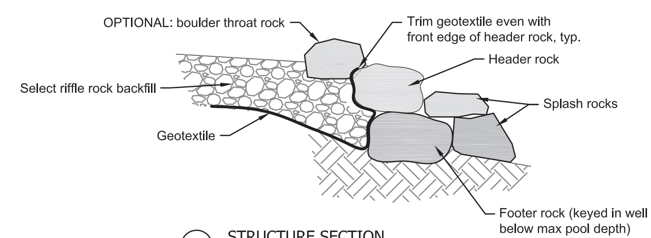


1 ROCK STEP PLAN
Scale: NONE



C SECTION ALONG STRUCTURE
Scale: NONE



B STRUCTURE SECTION
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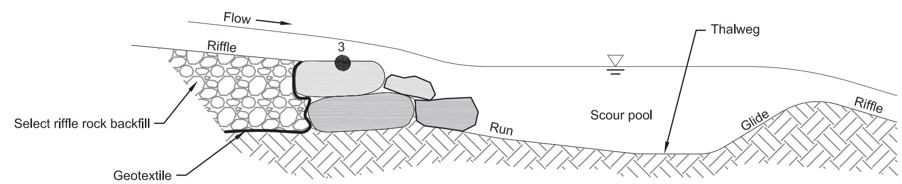

A INVERT AND POOL PROFILE
Scale: NONE

KEYNOTES

1. Select logs (when available) may be used to construct the sill as directed in the field. Extend the sill across floodprone area and/or floodplain to prevent incision as directed.
2. Actual Values may vary based on site conditions.

GENERAL NOTES

1. Dig a trench below the stream bed for footer rocks, header rocks, geotextile, and backfill.
2. Carefully select and place individual footer rocks and then header rocks to achieve design dimensions and elevations. Slight variation in rock sizes, angles, and dimensions will add to the habitat complexity and create a more natural looking result.
3. Place splash rocks downstream of the structure for scour protection as directed.
4. Use hand placed stone to fill gaps and voids on upstream side of the header and footer rocks.
5. Place geotextile beginning at the top of the header rocks and extending down to the depth of the footer rocks, then outward ±10 ft as shown to prevent piping.
6. Install select riffle rock backfill as shown to the elevation of the top of the header rock.

SPECIFICATIONS	
Step Header and Footer Rock	Rock diameter as specified. Select Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Select Riffle Rock:	See riffle / cascade details
Number of Header rows	1
Number of Footer rows	1
Geotextile	Class 1, Permanent Erosion Control, meeting AASHTO M288, non-woven. Basis of design: MIRAFE 180N or equal.

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AK

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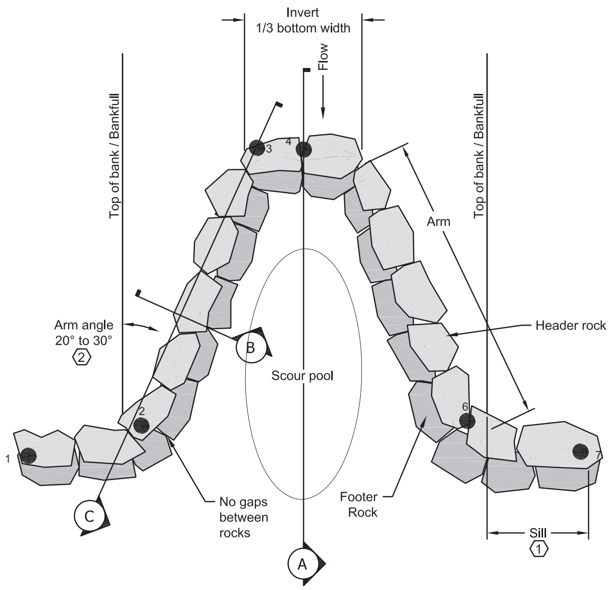
BUREAU OF LAND MANAGEMENT

ROCK STEP DETAIL

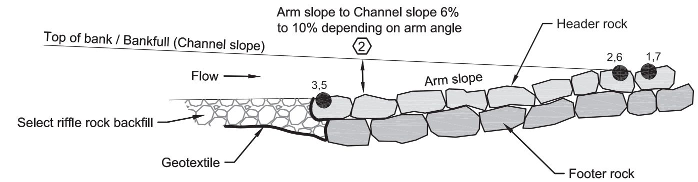
MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

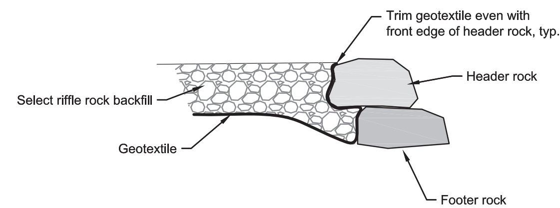
SHEET OF



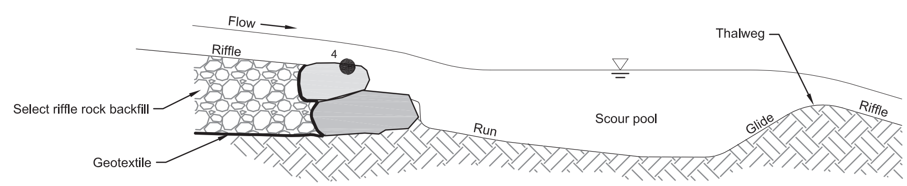
1 ROCK CROSS-VANE
Scale: NONE



C SECTION ALONG ARM
Scale: NONE



B VANE ARM SECTION
Scale: NONE



A INVERT AND POOL PROFILE
Scale: NONE

KEYNOTES

1. Select logs (when available) may also be used to construct the sill as directed in the field. Extend the sill across the floodprone area to prevent incision as directed.
2. Actual values may vary based on site conditions.

GENERAL NOTES

1. Dig a trench below the stream bed for footer rocks, header rocks, geotextile, and backfill.
2. Slight variation in rock sizes, angles, and dimensions will add to the habitat complexity and create a more natural looking result.
3. Place footer rocks and then header rocks to achieve design dimensions and elevations.
4. Use hand placed stone to fill gaps and voids on upstream side of the header and footer rocks.
5. Place geotextile beginning at the top of the header rocks and extending down to the depth of the footer rocks, then outward ±10 ft as shown to prevent piping. Trim exposed geotextile.
6. Install select riffle rock backfill as shown to the elevation of the top of the header rock.

SPECIFICATIONS	
Cross-Vane Header and Footer Rock	Rock diameter as specified. Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Select Riffle Rock:	See riffle / cascade details
Number of Header rows	1
Number of Footer rows	1
Geotextile	Class 1, Permanent Erosion Control, meeting AASHTO M288, non-woven. Basis of design: MIRAFE 180N or equal.

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

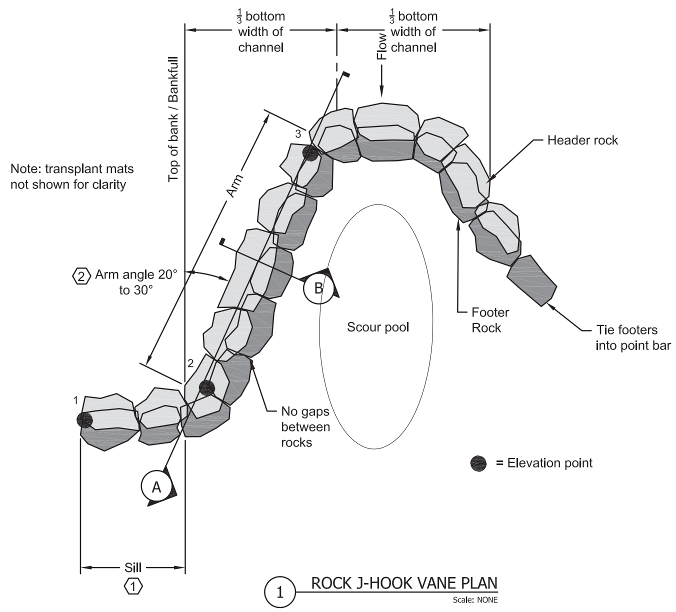
ROCK CROSS—VANE DETAIL

AK

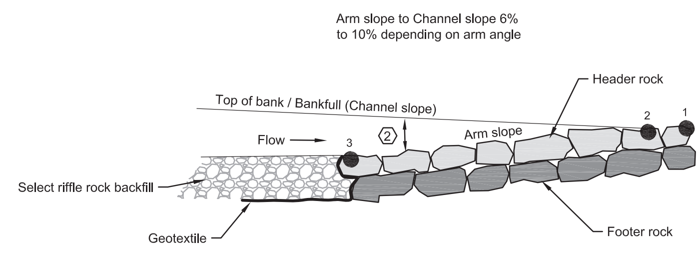
MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

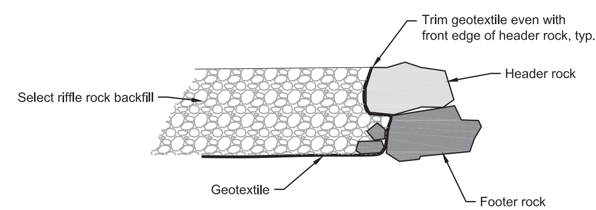
SHEET OF



1 ROCK J-HOOK VANE PLAN
Scale: NONE



A SECTION ALONG ARM
Scale: NONE



B VANE ARM SECTION
Scale: NONE

KEYNOTES

1. Select logs (when available) may also be used to construct the sill as directed in the field. Extend the sill across floodprone area to prevent incision as directed.
2. Actual values may vary based on site conditions.

GENERAL NOTES

1. Dig a trench below the stream bed for footer and header rocks, geotextile, and backfill.
2. Slight variation in rock sizes, angles, and dimensions will add to the habitat complexity and create a more natural looking result.
3. Place footer rocks and then header rocks to achieve design dimensions and elevations.
4. Use hand placed stone to fill gaps and voids on upstream side of the header and footer rocks.
5. Place geotextile beginning at the top of the header rocks and extending down to the depth of the footer rocks, then outward ±10 ft. as shown to prevent piping.
6. Install select riffle rock backfill as shown to the elevation of the top of the header rock.

SPECIFICATIONS	
Vane Header and Footer Rock	Rock size as selected by the designer. Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Select Riffle Rock:	See riffle / cascade details
Number of Header rows	1
Number of Footer rows	1
Geotextile	Class 1, Permanent Erosion Control, meeting AASHTO M288, non-woven. Basis of design: MIRAFE 180N or equal.

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

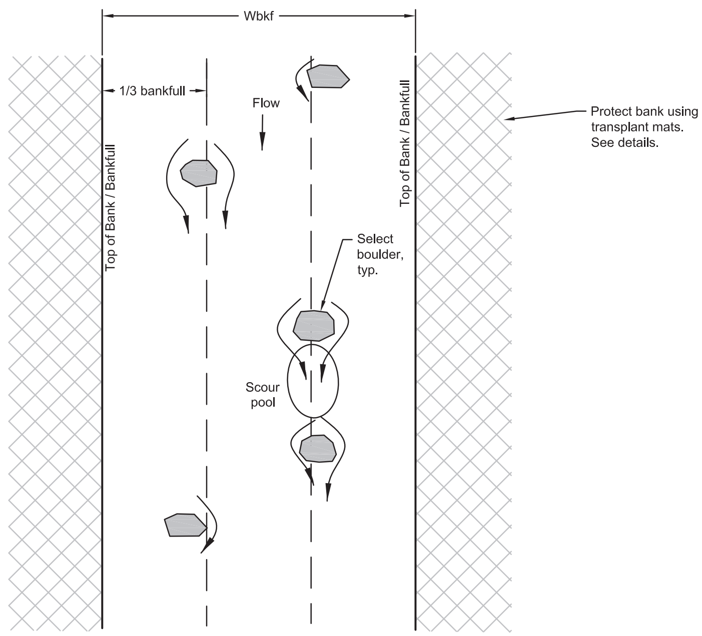
ROCK J HOOK VANE DETAIL

AK

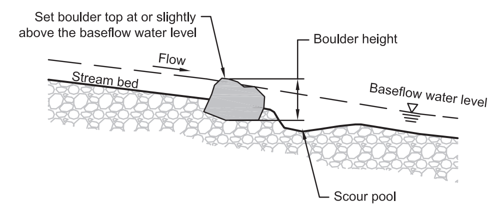
MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

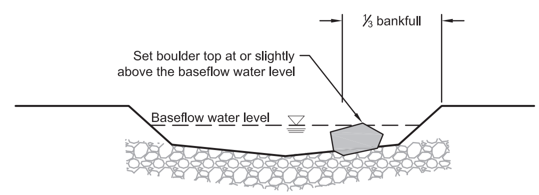
SHEET OF



1 BOULDER CLUSTER PLAN
Scale: NONE



2 BOULDER CLUSTER PROFILE
Scale: NONE



3 BOULDER CLUSTER CROSS SECTION
Scale: NONE

GENERAL NOTES

1. Place boulder groups in the center half of the bankfull channel as directed.
2. Maximum boulder size in longest dimension shall not be greater than 1/5 the bankfull width.
3. Place boulders such that the longest dimension is perpendicular to the stream flow.
4. Place boulders such that the top of the boulder is at or slightly above the baseflow water level.
5. Place groups of 3 to 7 boulders in a staggered pattern so flow around one boulder is deflected into another boulder.

SPECIFICATIONS	
Select Boulder	Min. Size: 4ft x 3ft x 2ft. Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Transplant mats	See transplant mat details

NOT FOR CONSTRUCTION

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

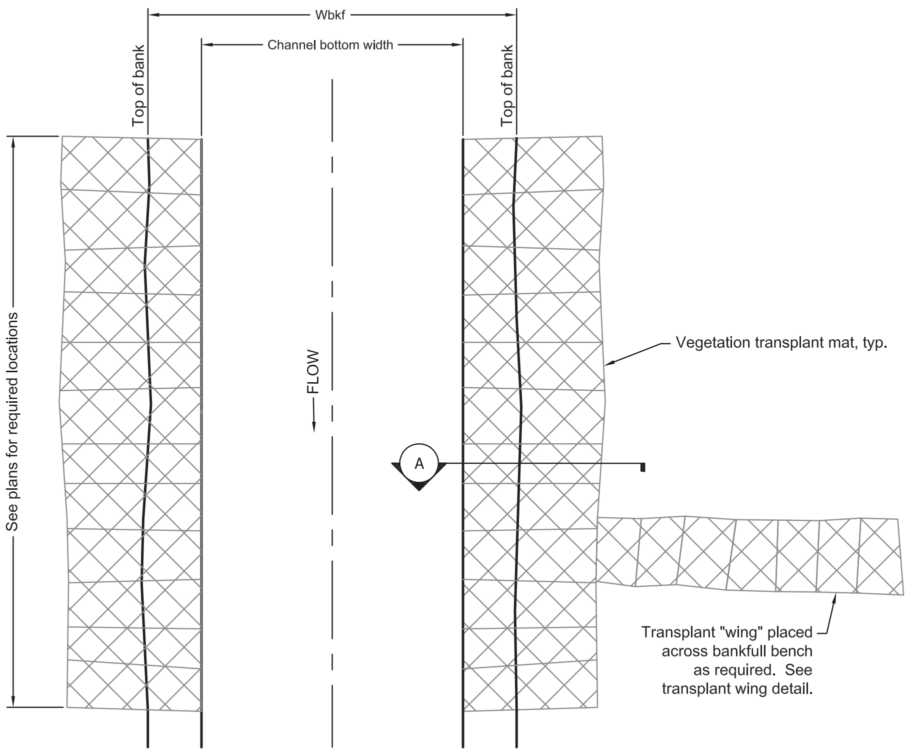
BOULDER CLUSTER DETAIL

AK

MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

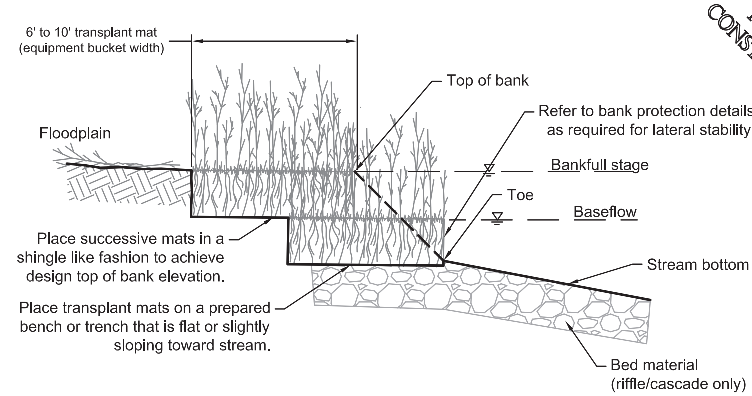
SHEET OF



NOTES
1. Place mats tightly together on a prepared bench or trench.
2. Fill voids between mats with boulders.

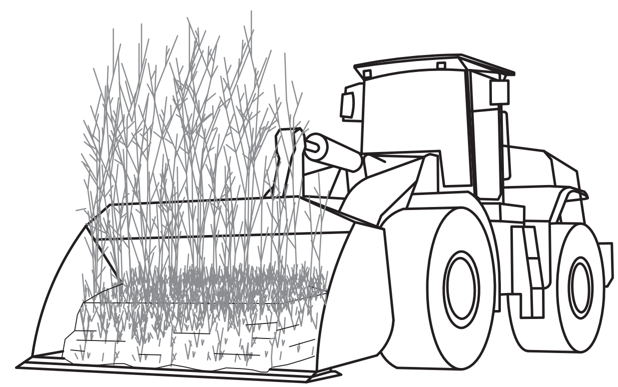
1 VEGETATION TRANSPLANT MAT PLAN
Scale: NONE

SPECIFICATIONS	
Transplant mat	Root mass of woody & herbaceous vegetation of suitable riparian species
Transplant mat depth	12" to 18" typical, depending on rooting depth
Transplant mat length and width	Loader bucket size.



NOTES
1. Adjust bench elevation for transplants depending on transplant mat thickness.
2. Check grade during placement of mats to ensure design elevations are met.
3. Place mats in shingle fashion, with the upper mat sitting on the back of the lower mat as shown.
4. Projects with short banks or sparse transplants, may only require a single row of transplant mats.
5. Backfill the floodplain behind the installed mats leaving the surface rough and gently sloping toward the stream.

A VEGETATION TRANSPLANT MAT SECTION
Scale: NONE



NOTES
1. Source area shall be flagged and approved prior to construction. Harvest transplants near the project site. Maintain vegetation buffer between source area and stream.
2. Use mid-size wheel loader, or similar approved equipment, for excavating, transporting, and placing on-site vegetation transplant mats.
3. Disturb transplant mats as little as possible and maintain soil moisture. Tall vegetation may need trimming to prevent breaking apart the root mass during transport.
4. Typical mat depth is 12 to 18 inches depending upon root depth. Do not cut too far below the root zone, but make sure all of the root zone is acquired.

2 VEGETATION TRANSPLANT MAT HARVESTING DETAIL
Scale: NONE

NOT FOR CONSTRUCTION

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

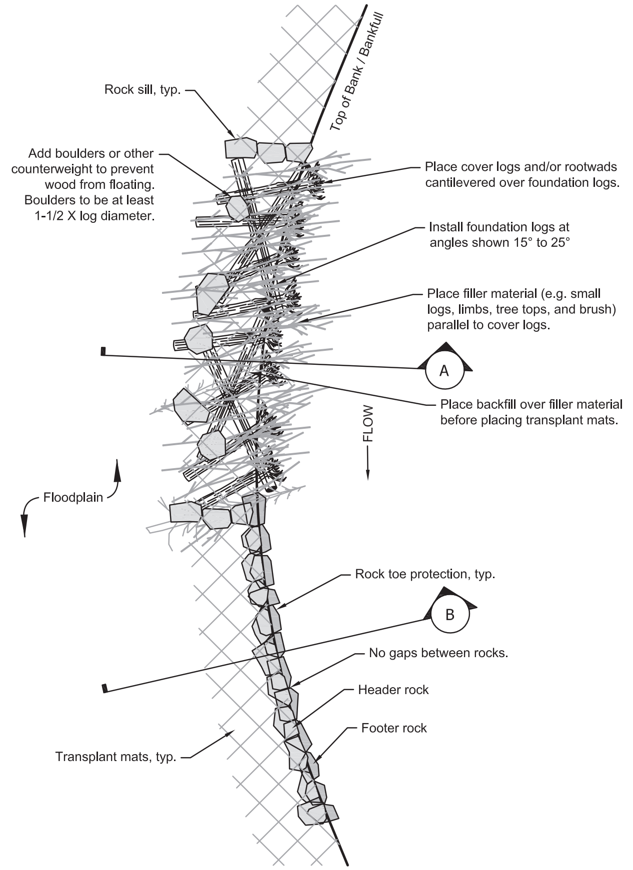
TRANSPLANT MAT DETAIL

AK

MARK	DESCRIPTION	DATE	APPROVED

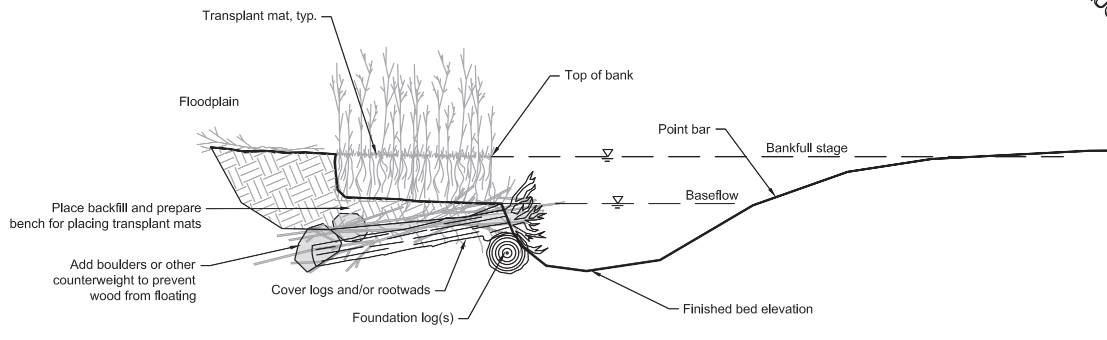
PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

SHEET OF

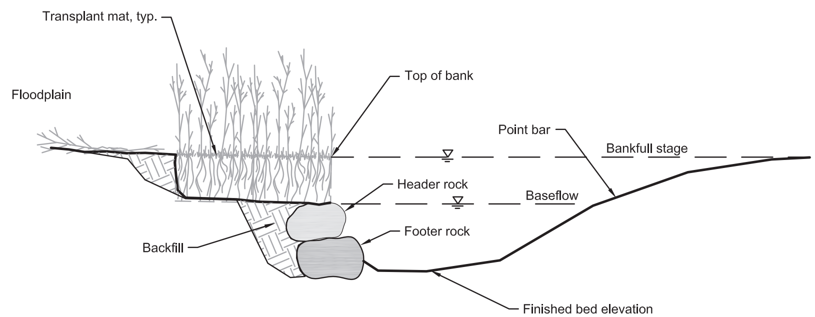


NOTES
1. Log toe and boulder toe locations shall be according to the plans or as determined at the time of construction and staked in the field.
2. Log sill may also be used in place of rock sill.

1 BANK PROTECTION PLAN VIEW
Scale: NONE



A LOG TOE SECTION
Scale: NONE



B ROCK TOE SECTION
Scale: NONE

SPECIFICATIONS	
Boulder	Rock diameter as specified. Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Logs	Size determined by designer. Straight, not rotten.
Transplant mat	See transplant mat details

NOT FOR CONSTRUCTION

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

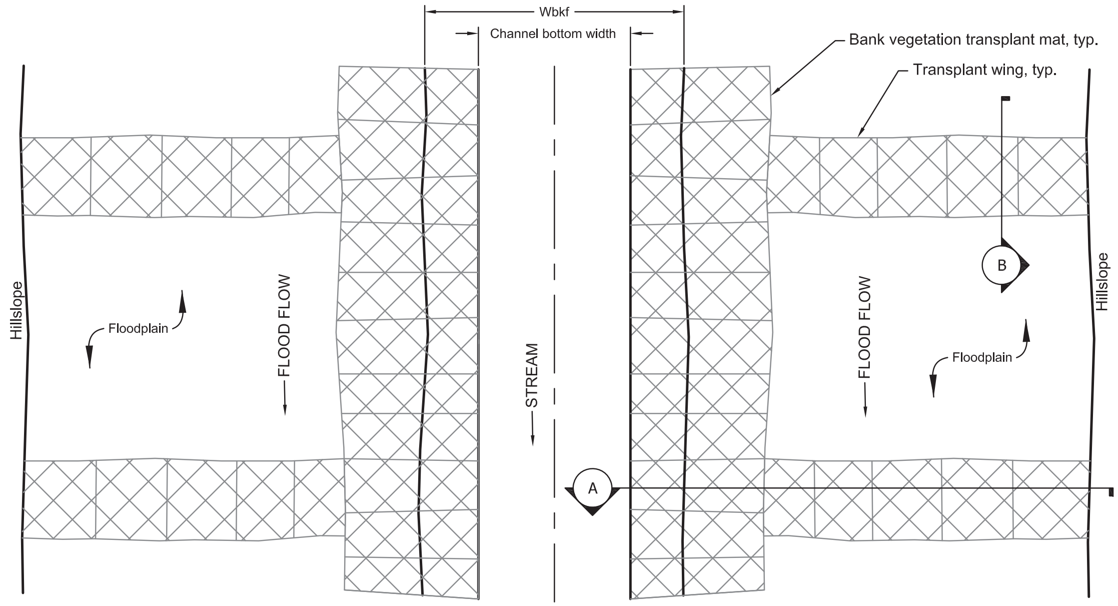
BANK PROTECTION DETAIL

AK

MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

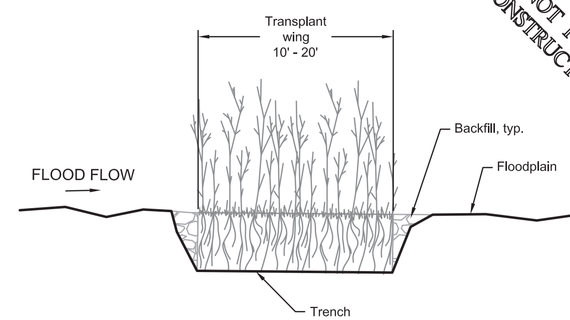
SHEET OF



NOTES

1. Transplant wing spacing should not exceed two times the bankfull width.

(1) TRANSPLANT WING PLAN
Scale: NONE

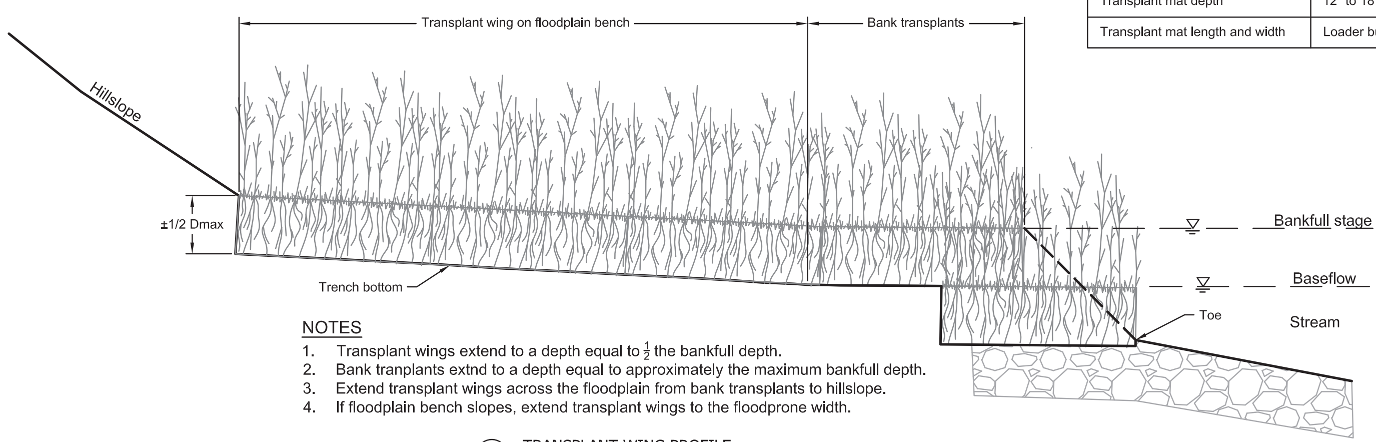


(B) TRANSPLANT WING SECTION
Scale: NONE

GENERAL NOTES

1. Place transplant mats in excavated trench so that top surface of mat is flush with surrounding ground elevations. Adjust trench depth to match transplant mat thickness (±1/2 Dmax).
2. Backfill any gaps around and between mats with suitable coarse backfill material.

SPECIFICATIONS	
Transplant mat	Root mass of woody & herbaceous vegetation of suitable riparian species
Transplant mat depth	12" to 18" typical, depending on rooting depth
Transplant mat length and width	Loader bucket size.



NOTES

1. Transplant wings extend to a depth equal to $\frac{1}{2}$ the bankfull depth.
2. Bank tranplants extnd to a depth equal to approximately the maximum bankfull depth.
3. Extend transplant wings across the floodplain from bank transplants to hillslope.
4. If floodplain bench slopes, extend transplant wings to the floodprone width.

(A) TRANSPLANT WING PROFILE
Scale: NONE

NOT FOR CONSTRUCTION

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

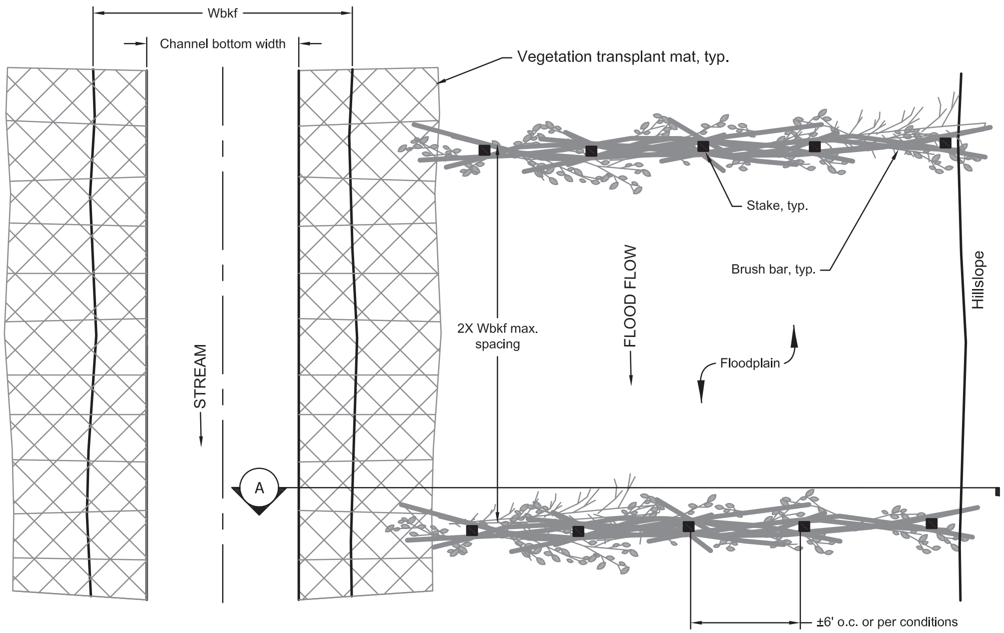
TRANSPLANT WING DETAIL

AK

MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

SHEET OF

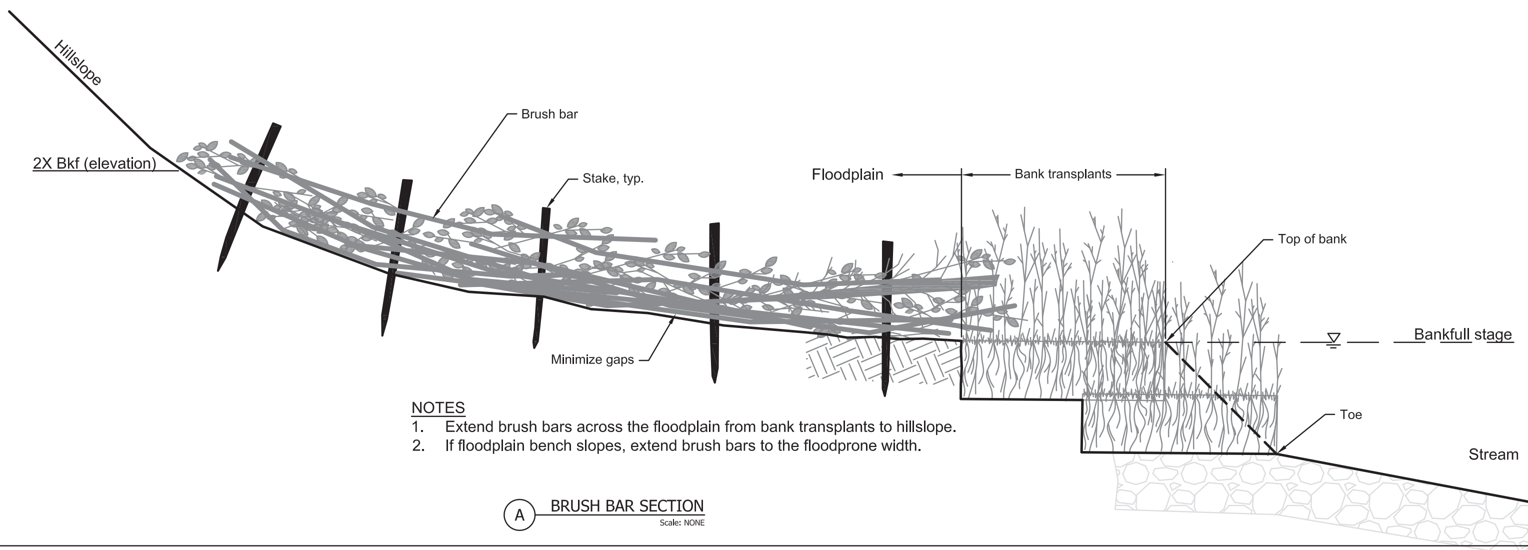


1 BRUSH BAR PLAN
Scale: NONE

GENERAL NOTES

1. Prepare slope to receive brush bar to a uniform grade clear of debris to prevent gaps between brush bar and underlying soil.
2. Harvest a mix of live and dead cuttings to construct the brush bar.
3. Use 2"x2" wood stakes or cutting stakes at least 2" in diameter to securely hold the brush bar in place. Drive stakes at a spacing that securely holds brush stems that are woven alternately in front and behind stakes. Additionally, brush may be secured to stakes with cord. Place additional stakes as needed to wedge brush together and prevent them from rafting up and floating away during flood flows.

SPECIFICATIONS	
Transplant mats	See transplant mat details
Brush mattress cuttings	Long cuttings of suitable species with branches. Approximately 1" diameter or larger.
Stakes	Stout dead wood stakes of suitable length depending on soil conditions. Stout cutting stakes may be used to supplement.
Cord	Natural biodegradable jute twine or similar.



NOTES
1. Extend brush bars across the floodplain from bank transplants to hillslope.
2. If floodplain bench slopes, extend brush bars to the floodprone width.

A BRUSH BAR SECTION
Scale: NONE

NOT FOR CONSTRUCTION

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

BRUSH BAR DETAIL

AK

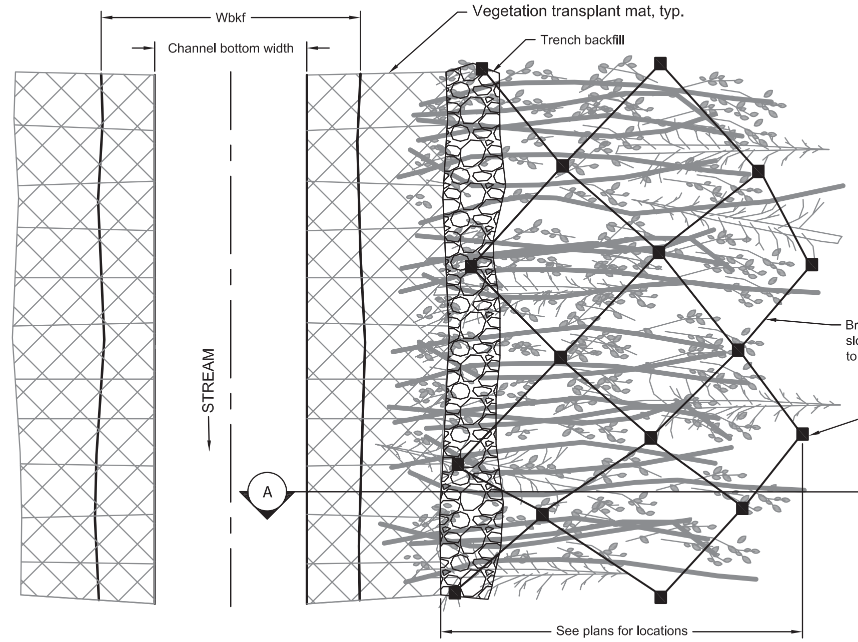
PROJECT NO:	MARK	DESCRIPTION	DATE	APPROVED
DESIGN OFFICE:				
DESIGNED BY:				
DRAWN BY: DM				
CHK'D BY:				
APPROVED BY:				
DATE: 10/22				

SHEET OF

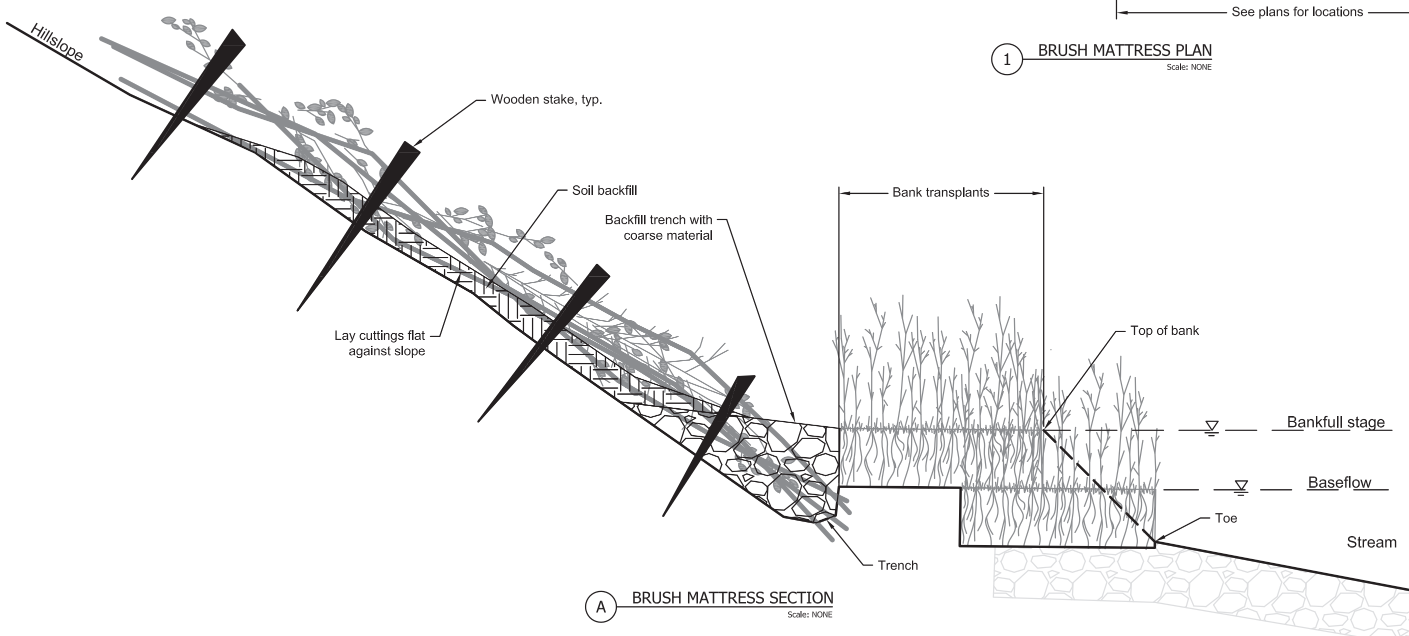
GENERAL NOTES

1. Prepare slope, clear debris, grade so cuttings lay flat against the soil without large air pockets.
2. Excavate trench at hillside toe, sufficiently deep so that butt ends of cuttings are below mean low water level.
3. Harvest cuttings and install them the same day or soak them for up to 14 days.
4. Lay cuttings flat against slope, slightly criss-cross, with basal end placed deeply into trench. Install approximately 8 to 15 branches per lineal foot of bank.
5. Place grid of dead stout wood stakes for securing mattress to the slope. Leave 6 to 9 inches of stake extended above the ground.
6. Secure mattress to stakes using cord tied with clove hitches in diamond pattern between each row of stakes.
7. After securing cord to the stakes, drive the stakes farther to compress mattress tightly against slope to improve the soil-to-stem contact.
8. Backfill around and in between branches, lightly tamp, and use water to wash soil down amongst stems. Bury the mattress so that the bottom half of the cuttings is covered with a 3 to 4 inch layer of soil.
9. Anchor the bottom portion of the brush mattress into the trench by backfilling with suitable toe protection, such as rock or transplants. Ensure the basal ends of the live cuttings are securely held into the bank.

SPECIFICATIONS	
Transplant mats	See transplant mat details
Brush mattress cuttings	Long cuttings of suitable species with branches, 2 to 3 years old, approximately 3/4" to 1" in diameter. Up to 20% can be dead material to add bulk.
Stakes	Stout dead wood stakes, wedge shaped, 1.5 to 4 ft long depending on soil texture.
Cord	Natural biodegradable jute twine or similar.



1 BRUSH MATTRESS PLAN
Scale: NONE



A BRUSH MATTRESS SECTION
Scale: NONE

NOT FOR CONSTRUCTION

NATIONAL SYSTEM OF PUBLIC LANDS
U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

BRUSH MATTRESS DETAIL

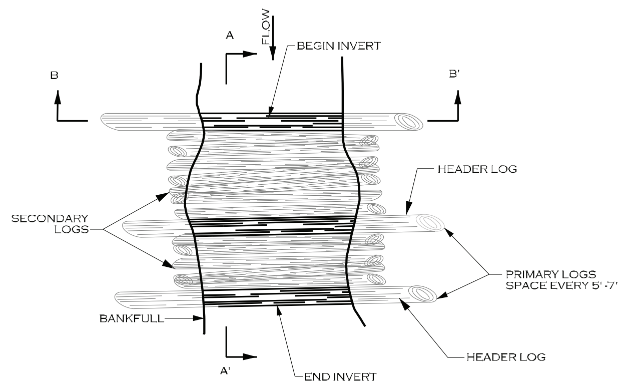
AK

MARK	DESCRIPTION	DATE	APPROVED

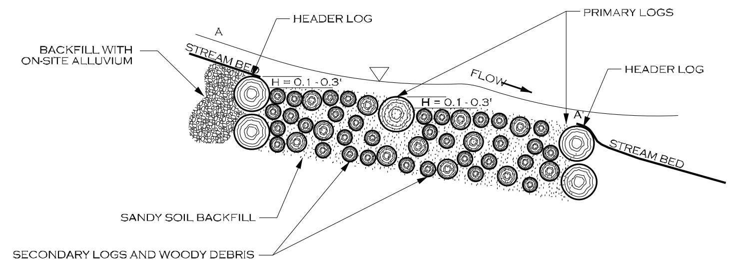
PROJECT NO:
DESIGN OFFICE:
DESIGNED BY:
DRAWN BY: DM
CHK'D BY:
APPROVED BY:
DATE: 10/22

SHEET OF

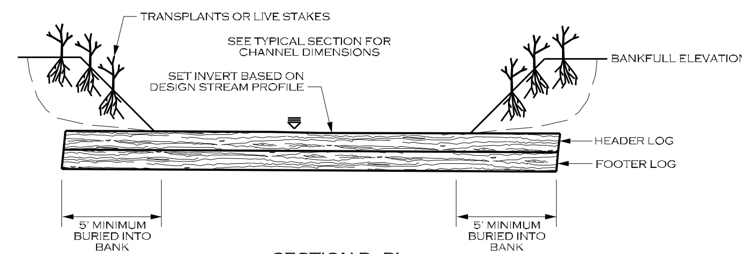
GRADE CONTROL WOODY RIFFLE (WR)



PLAN VIEW



SECTION A - A'



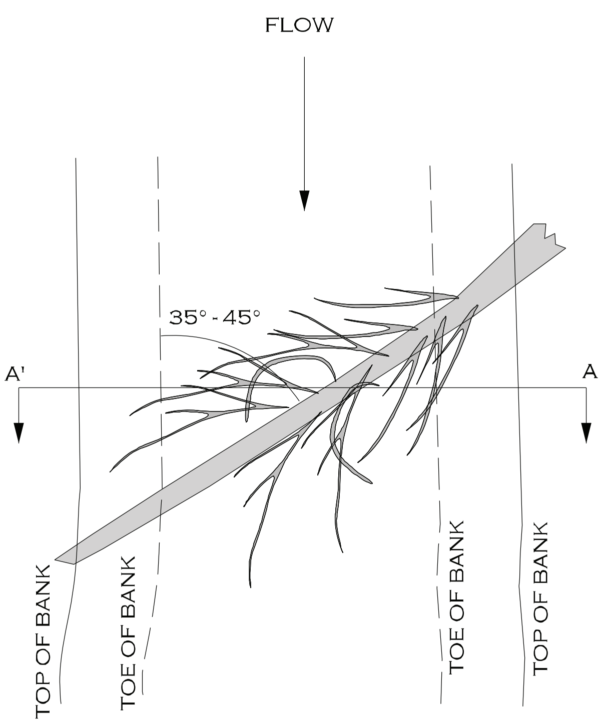
SECTION B - B'

NOTES:

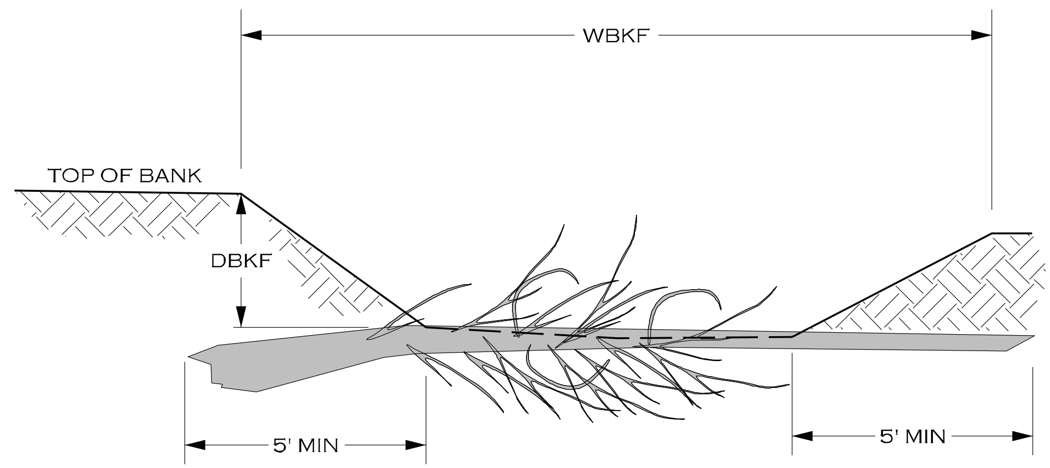
1. PRIMARY LOGS SHOULD BE AT LEAST 10" OR MORE IN DIAMETER, RELATIVELY STRAIGHT, AND RECENTLY HARVESTED AND EXTENDING INTO THE BANK 5' ON EACH SIDE.
2. SECONDARY LOGS SHOULD BE AT LEAST 1" IN DIAMETER AND NO LARGER THAN 10", AND EXTEND INTO THE BANK 2 FEET ON EACH SIDE. WOOD MATERIAL SHALL BE VARYING DIAMETER TO ALLOW MATERIAL TO BE COMPACTED.
3. ROOTWADS AND COIR FIBER MATTING CAN BE USED INSTEAD OF TRANSPLANTS OR LIVE STAKES, PER DIRECTION OF ENGINEER.
4. AFTER TRENCH HAS BEEN EXCAVATED A LAYER OF SECONDARY LOGS AND WOODY DEBRIS SHOULD BE PLACED WITH MINIMAL GAPS. A LAYER OF ON-SITE ALLUVIUM SHOULD BE APPLIED TO FILL VOIDS BETWEEN SECONDARY LOGS BEFORE ADDITIONAL LAYERS ARE PLACED.

GRADE CONTROL WOODY RIFFLE

DEBRIS JAM
TYPE 1



PLAN VIEW

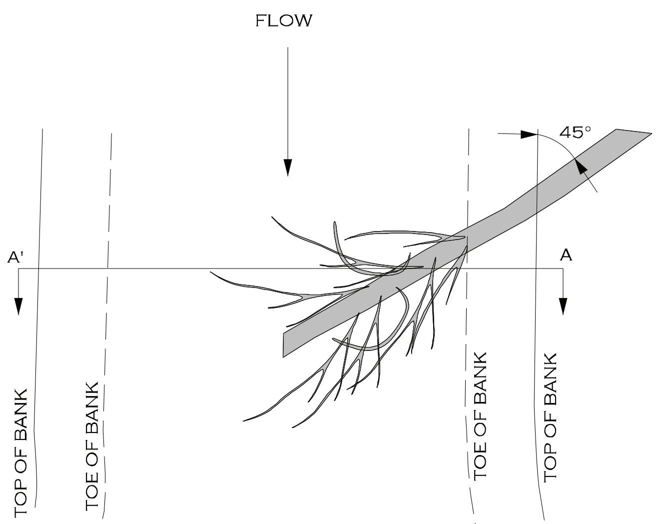


SECTION A - A'

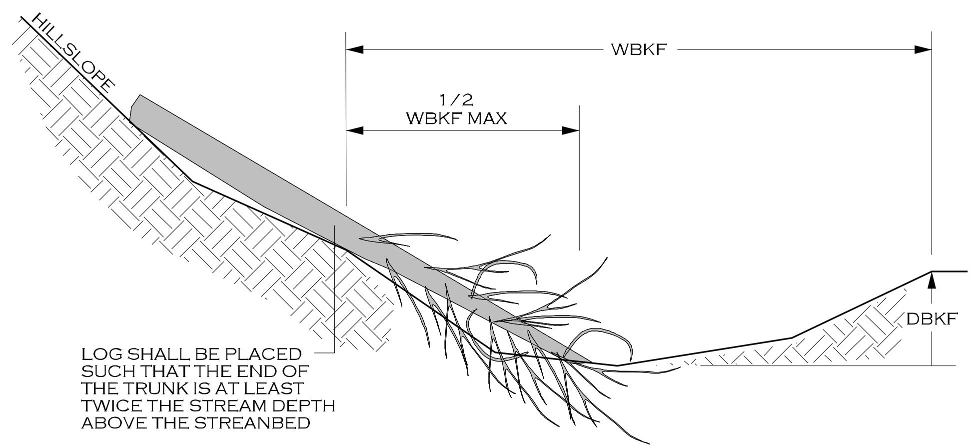
DEBRIS JAM TYPE 1

1. DEBRIS JAM TYPE 1 INSTALLATIONS SHALL BE PLACED WITHIN STREAM RIFFLES TO TRAP DETRITUS AND ORGANIC MATTER AND KEEP IT IN CONTACT WITH FLOWING, AERATED WATER.
2. TREE SHALL BE ANY NON-EVERGREEN TREE WITH BRANCHES, AT LEAST 8 INCHES DIAMETER, AND NOT ROTTEN.
3. TREE SHALL HAVE CONSIDERABLE NUMBER OF BRANCHES THAT REMAIN EXPOSED AFTER INSTALLATION AND IN CONTACT WITH THE STREAM FLOW TO TRAP LEAVES AND DETRITUS FROM STREAM FLOW.
4. TREE SHALL BE INSTALLED SO THAT THE TRUNK IS LEVEL WITH THE BED ELEVATION OF THE STREAM, SUCH THAT THE TRUNK DOES NOT POOL WATER IN FRONT OF THE STRUCTURE. BACKFULL AND COMPACT AROUND THE TRUNK AND INSTALLED TREE TO MINIMIZE VOIDS.

DEBRIS JAM
TYPE 2



PLAN VIEW

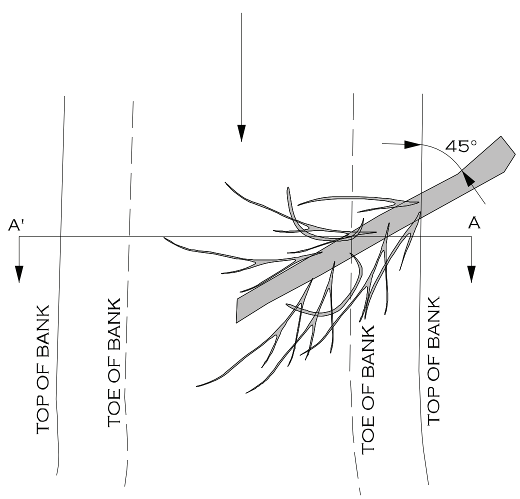


SECTION A - A'

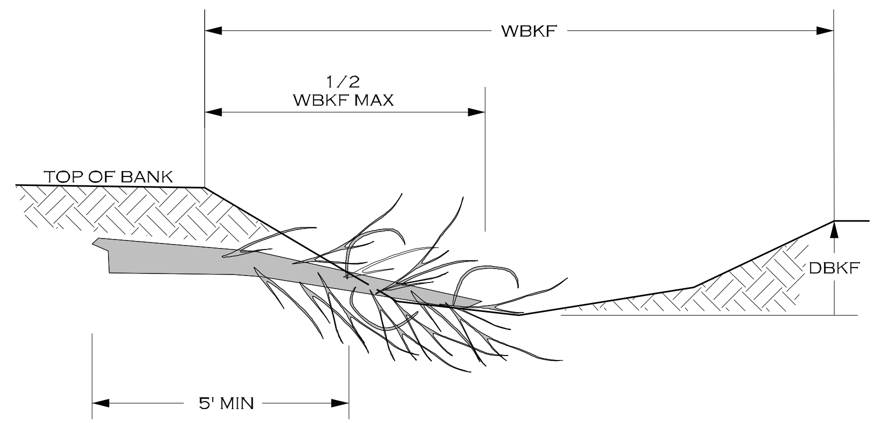
DEBRIS JAM TYPE 2

1. DEBRIS JAM TYPE 2 INSTALLATIONS SHALL BE PLACED AREAS WHERE THE STREAM FLOWS AGAINST A STEEP SLOPE. A TREE IS INSTALLED AS SHOWN TO CATCH DETRITUS AND ORGANIC MATTER AND KEEP IT IN CONTACT WITH STREAM FLOWS. THIS DEBRIS JAM MAY BE INSTALLED IN RIFFLE OR POOL LOCATIONS.
2. TREE SHALL BE ANY NON-EVERGREEN TREE WITH BRANCHES, AT LEAST 8 INCHES DIAMETER, AND NOT ROTTEN.
3. TREE SHALL HAVE CONSIDERABLE NUMBER OF BRANCHES THAT REMAIN EXPOSED AND IN CONTACT WITH THE STREAM FLOW AFTER INSTALLATION TO TRAP LEAVES AND DETRITUS FROM STREAM FLOW.
4. TREE SHALL BE INSTALLED SO THAT THE TRUNK LIES UPON THE HILLSLOPE, AND IS ANCHORED TO THE HILLSLOPE TO PREVENT MOVEMENT DURING LARGE STREAM FLOWS. TREE SHALL BE CABLED TO A FRESHLY CUT STUMP OR ANOTHER LIVE TREE OF AT LEAST THE SAME SIZE.

DEBRIS JAM
TYPE 3



PLAN VIEW

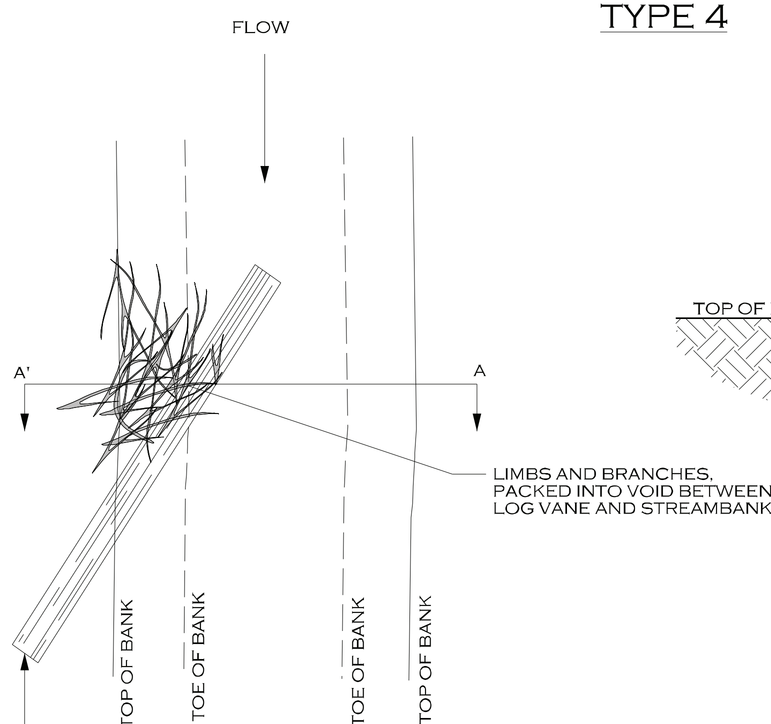


SECTION A - A'

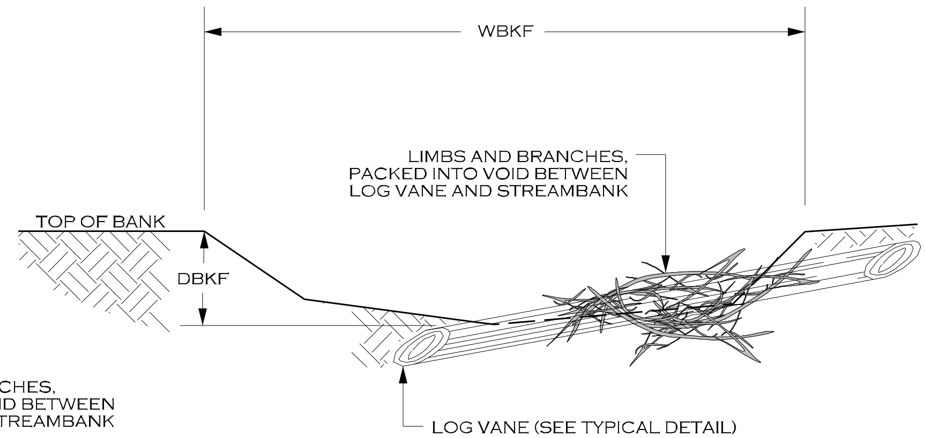
DEBRIS JAM TYPE 3

1. DEBRIS JAM TYPE 3 INSTALLATIONS SHALL BE PLACED WITHIN STREAM RIFFLES OR POOLS TO TRAP DETRITUS AND ORGANIC MATTER AND KEEP IT IN CONTACT WITH FLOWING WATER.
2. TREE SHALL BE ANY NON-EVERGREEN TREE WITH BRANCHES, AT LEAST 8 INCHES DIAMETER, AND NOT ROTTEN.
3. TREE SHALL HAVE CONSIDERABLE NUMBER OF BRANCHES THAT REMAIN EXPOSED AFTER INSTALLATION AND IN CONTACT WITH THE STREAM FLOW TO TRAP LEAVES AND DETRITUS FROM STREAM FLOW.
4. TREE SHALL BE INSTALLED SO THAT THE TRUNK IS IN CONTACT WITH THE STREAM BED. BACKFULL AND COMPACT AROUND THE TRUNK AND INSTALLED TREE TO MINIMIZE VOIDS.

DEBRIS JAM TYPE 4



PLAN VIEW

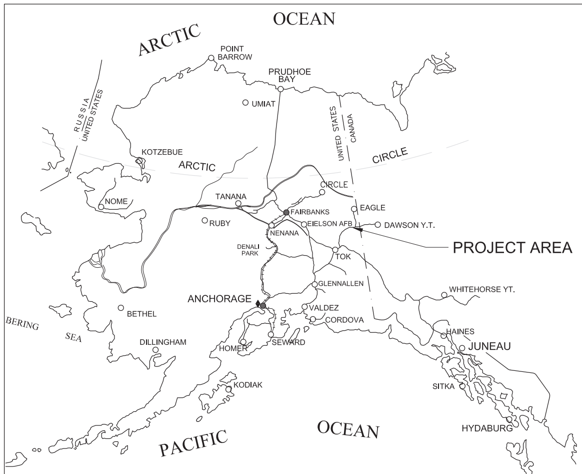


SECTION A - A'

DEBRIS JAM TYPE 4

1. DEBRIS JAM TYPE 4 INSTALLATIONS SHALL BE INSTALLED IN ASSOCIATION WITH LOG VANE INSTALLATIONS (SEE TYPICAL DETAIL FOR LOG VANE).
2. LIMBS AND BRANCHES THAT FORM THE DEBRIS JAM SHALL VARY IN DIAMETER, BUT SHALL BE AT LEAST 3 FEET LONG WITH MULTIPLE BRANCHES TO PROMOTE ENTANGLING WHEN PACKED TOGETHER. LIMBS AND BRANCHES SHOULD BE A MIXTURE (APPROX. 50/50) OF RECENTLY CUT BRANCHES AND DEAD/DECAYING BRANCHES.
3. PREPARE THE EXCAVATION FOR THE LOG VANE, THEN PLACE THE DEBRIS JAM PRIOR TO PLACING AND INSTALLING THE LOG VANE.
4. WHEN INSTALLED, THE LOG VANE SHOULD PIN THE DEBRIS JAM TO THE STEAM BED AND BANK AND PREVENT EASY MOVEMENT DURING HIGH FLOW EVENTS.
5. AFTER INSTALLATION, STREAM FLOW SHOULD BE IN CONTACT WITH THE DEBRIS JAM, IN ORDER TO TRAP ADDITIONAL DEBRIS AND ORGANIC MATTER.

Appendix G
Example Plan Set



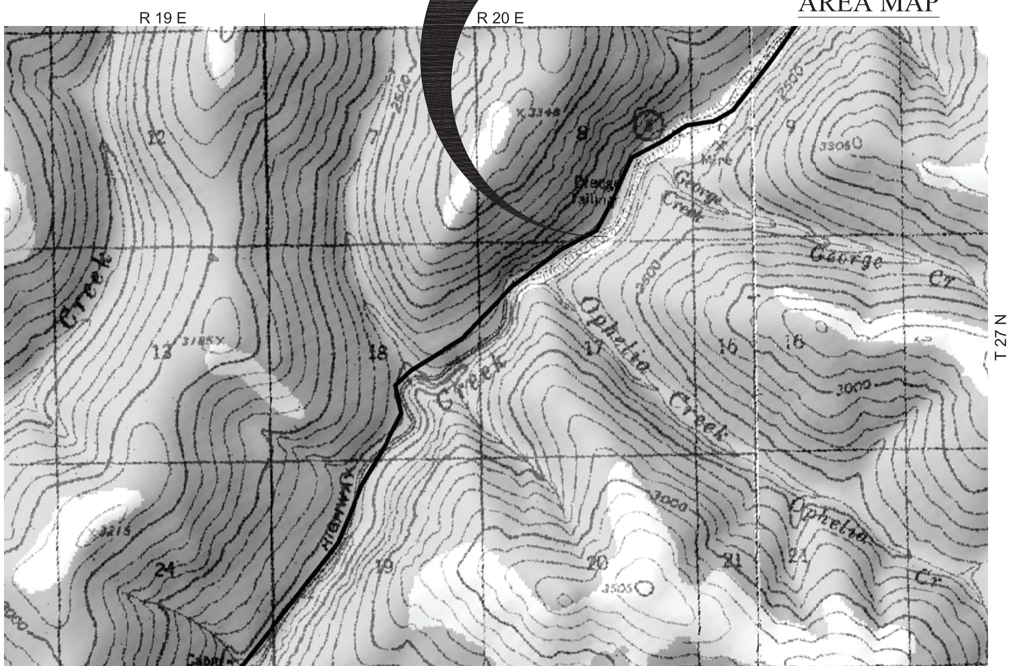
ALASKA KEY MAP

CITY
BLM DISTRICT OFFICE
BLM STATE OFFICE

JACK WADE CREEK
STREAM RESTORATION
20 MILES E OF CHICKEN, AK

THIS PROJECT
MILEPOST 87 TAYLOR HIGHWAY

AREA MAP



SHEET INDEX

1 TITLE SHEET
2 SITE PLAN, NOTES, & QUANTITIES
3 TYPICAL SECTIONS
4 PLAN & PROFILE
5 CONSTRUCTED RIFFLE DETAIL
6 ROCK STEP (CROSS VANE) DETAIL
7 LOG ROLLER DETAIL

DESIGN DATA

Drainage area	28.45 sqmi
Stream type	B4c
Qbkf	358 cfs
Vbkf	5.27 ft/sec
Abkf	66.98 sqft
Wbkf	33.5 feet
Dbkf	2.0 feet
Wbkf pool	43.6 feet
Dpoolmax	6.0 feet
Width/Depth ratio	17.0
Bank Height Ratio	1.0
Entrenchment ratio	1.8

PROJECT LENGTHS

Existing stream length	910 feet
Proposed stream length	838 feet
Length of riffles	673 feet
Length of pools	165 feet
Riffle percentage	80%
Pool percentage	20%

11"X17" SHEETS ARE HALF SIZED

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

JACK WADE CREEK STREAM RESTORATION

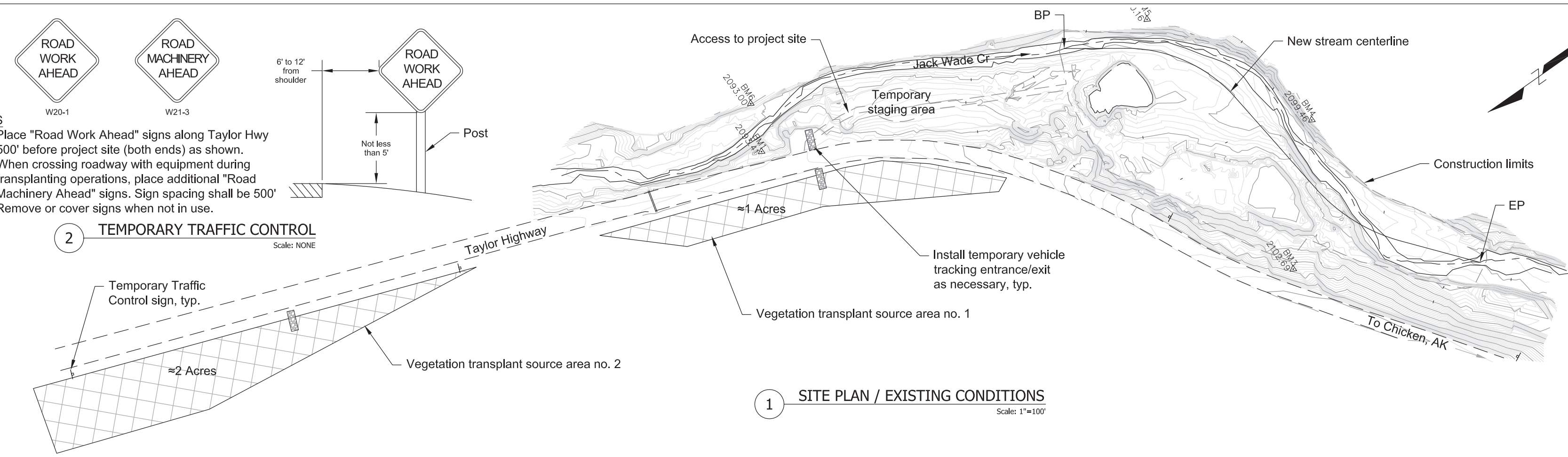
MILEPOST 87 TAYLOR HIGHWAY

FAIRBANKS DISTRICT OFFICE AK

MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE: AK953
DESIGNED BY: MV,DM
DRAWN BY: DM
CHK'D BY: DM
APPROVED BY: AC
DATE: 04/24/2018

TITLE
SHEET 1 OF 7



NOTES
1. Place "Road Work Ahead" signs along Taylor Hwy 500' before project site (both ends) as shown.
2. When crossing roadway with equipment during transplanting operations, place additional "Road Machinery Ahead" signs. Sign spacing shall be 500'
3. Remove or cover signs when not in use.

2 TEMPORARY TRAFFIC CONTROL
Scale: NONE

1 SITE PLAN / EXISTING CONDITIONS
Scale: 1"=100'

SHEET NOTES
1. Site Plan: Existing contours shown.
2. Site plan is intended to show general conditions, project access, traffic control, and relationship of staging and transplant source areas to the project area. Vegetation transplant source area boundaries are not shown to scale: flag limits prior to use.

GENERAL NOTES
1. Comply with all applicable Federal, State, and local laws and regulations. Meet project permit requirements.
2. Follow approved SWPPP, HMCP, and SPCC plan for the work (when required).
3. Implement the TCP and maintain traffic control devices per the Alaska Traffic Manual (ATM). Submit revised TCP for approval when necessary. All signs installed in State rights of way shall be fabricated, located and installed in conformance with the Alaska Traffic Manual (ATM) and Alaska Sign Design Specifications (ASDS). Provide emergency vehicle access at all times.
4. Obtain any utility locates prior to construction. The Contractor shall be responsible for the repair of any utilities damaged during construction.
5. Wash all vehicles and equipment at point of departure before arriving at work site. Provide materials that are free of weeds and weed seed. Coordinate inspections of equipment and materials with BLM prior to arriving at work site.
6. Temporary staging area shall be established as shown on the plans. Maintain 50' clear to Taylor Hwy centerline for all equipment and materials. Provide and maintain temporary toilet(s) at staging area for project duration. When no longer needed, restore temporary staging area to a smooth and stable condition free of depressions, debris, compacted soil, and excess material.
7. Provide and maintain solid waste container(s). Ensure the project is free of trash and leftover materials prior to moving equipment from the work site.
8. Minimize disturbed area and protect natural features and vegetation whenever possible.
9. Upon discovery of any archaeological or paleontological resource, avoid impacting the location and materials, and immediately notify the BLM.
10. Construct / Improve construction project access at locations shown as necessary for the work. Remove access improvements when no longer needed and restore contours to natural conditions.
11. Construct and maintain vehicle tracking entrance/exits as shown. Remove any mud, soil, or debris tracked, spilled, or deposited onto the Taylor Highway within 24 hours. Remove tracking pad improvements when no longer needed and restore contours to original or natural conditions.
12. Excavate the proposed channel "in the dry" whenever possible by leaving water flowing through the existing channel or by creating a temporary diversion channel as directed. Water shall not be diverted into the new channel until that section has been excavated and stabilized with transplants and structures including constructed riffles, rock steps, and log rollers.
13. For sections where the proposed channel and existing channel share the same alignment, limit excavation by the length that can be stabilized with transplants and structures in one day.
14. Grade the floodplain and upland disturbed areas to minimize flow velocities. Uniformly spread salvaged fine soil material over floodplain grading to support vegetation growth. Provide surface roughening (cat-tracking) immediately following final grading.
15. When transplant areas are no longer needed, grade the disturbed areas to match existing slopes and provide surface roughening.
16. Other than the proposed improvements shown, maintain existing area drainage patterns.
17. When construction disturbance is complete, seed, fertilize, and mulch disturbed areas (except stream channels or other bodies of water). Planting season is June 1 - August 15. Seed and mulch materials to be certified weed free.

SURVEY NOTES
1. The digital terrain model (DTM) used to develop this project is based on contour information obtained by gps topography survey in August 2017. The cross sections and quantities are derived using this surface model.
2. Survey grid coordinates have been converted to ground coordinates using the Average Combined Factor of 0.99950706574. All coordinates and distances shown on these plans are ground coordinates.
3. Existing survey monuments shall be referenced prior to construction, and any monuments that are disturbed shall be replaced.
4. These drawings do not depict boundary information, easement information, or utility information.
5. All units are U.S. survey feet.
6. Vertical Datum: gps derived NAVD88 (GEOID 12A)
7. Horizontal Datum: gps derived NAD83 State Plane

ABBREVIATIONS

BKF	bankfull
BP	begin project
cfs	cubic feet per second
CL	centerline
cp	control point
cuyd	cubic yard
EP	end project
ft	feet
HMCP	Hazardous Materials Control Plan
lb	pound
PLS	pure live seed
R/W	right-of-way
s	second
SPCC	Spill Prevention Control & Countermeasure
sqmi	square mile
sqft	square feet
ss	stainless steel
SWPPP	Storm Water Pollution Prevention Plan
TCP	Traffic Control Plan
TW	thalweg
typ.	typical

VIEWS & SECTIONS

A / 3 — letters for sections — to sheet

1 — sheet note

1 / 3 — numbers for details — to sheet

ESTIMATED QUANTITIES

AREAS	
Project area of disturbance (does not include transplant source areas)	3.6 acres
Area of vegetation transplant mats	0.6 acres (in place)
Seed Fertilizer & Mulch (does not include transplant source areas)	2.8 acres
EARTHWORK (unadjusted)	
Cut	8198 cuyd (in place)
Fill	4093 cuyd (in place)
SELECT RIFFLE ROCK	325 cuyd (in place)
LOGS	10 to 15
ROCK FOR STRUCTURES	130 cuyd (in place)
GEOTEXTILE	1 roll
Nails for geotextile	10 lb
SEED	
Wainwright Slender Wheatgrass (*Elymus trachycaulus*):	8.5 lb PLS/acre
Arctared Red Fescue (*Festuca rubra*):	7.5 lb PLS/acre
Tufted Hairgrass (*Deschampsia caespitosa*):	2.0 lb PLS/acre
Alpine Bluegrass (*Poa alpina*):	3.5 lb PLS/acre
Bluejoint reedgrass (*Calamagrostis canadensis*):	0.33 lb PLS/acre
Total	20.8 lb PLS/acre
FERTILIZER	
60-60-30-10 NPKS	160 lb per acre (or as directed)
STRAW MULCH	3200 lb per acre (or as directed)

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UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT

JACK WADE CREEK STREAM RESTORATION

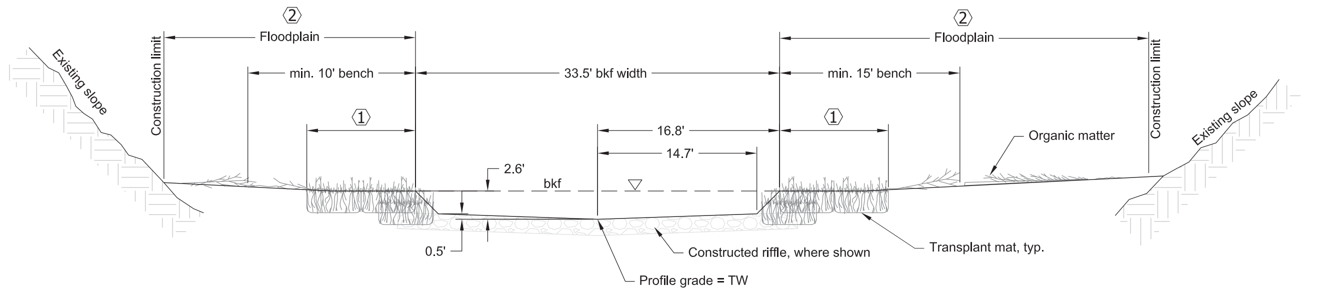
MILEPOST 87 TAYLOR HIGHWAY

FAIRBANKS DISTRICT OFFICE AK

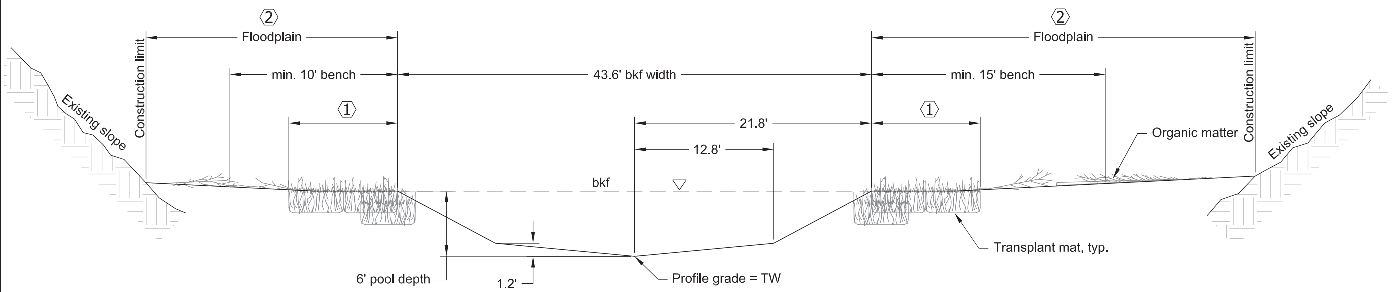
MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE: AK953
DESIGNED BY: MV,DM
DRAWN BY: DM
CHK'D BY: DM
APPROVED BY: AC
DATE: 04/24/2018

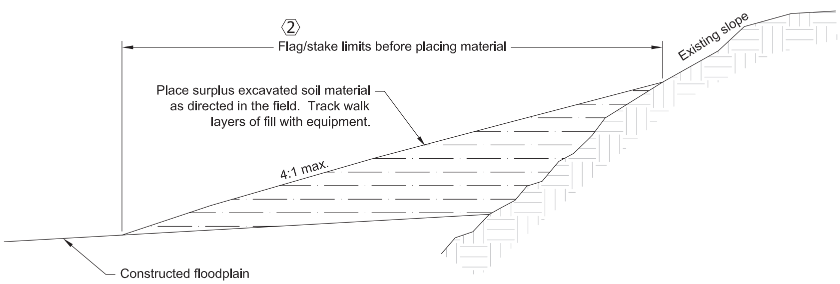
SITE/NOTES
SHEET 2 OF 7



3 TYPICAL SECTION NO. 1 - RIFFLE
Scale: NONE



4 TYPICAL SECTION NO. 2 - POOL
Scale: NONE

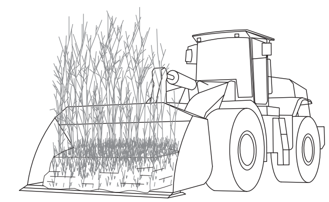


A SURPLUS EXCAVATED MATERIAL SECTION
Scale: NONE

SHEET NOTES

1. 6' to 10' transplant mats at 0% grade. Transplant mats approximately 2.0' in depth, with roots below streambed. See details.

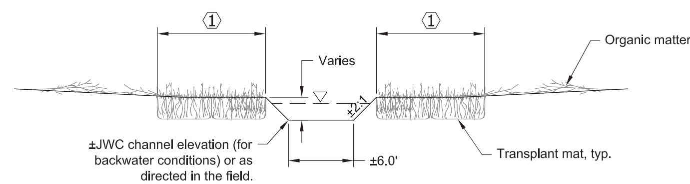
2. Grade at 5% away from stream except where otherwise shown in cross sections or directed in the field. Continue grading to valley limits where possible. Use approved straw mulch and vegetation material from source area as organic matter and roughness on the floodplain. After the floodplain grading is complete, incorporate the organic material into the first few inches of "soil" by cat-tracking. Cat-track parallel with slope. Seed, fertilize, and mulch floodplain and other disturbed areas above bankful with approved materials.



NOTES

1. Transplant source areas shall be flagged and approved prior to construction.
2. Use full-size wheel loader, or similar approved equipment, for excavating, transporting, and placing on-site vegetation transplant mats.
3. Disturb transplant mats as little as possible and maintain soil moisture.
4. Trim transplant vegetation as needed to keep mat intact while transporting.
5. Average mat depth is 2ft.

5 TRANSPLANT MAT
Scale: NONE



6 TYPICAL SECTION NO. 3 - ACCESSORY CHANNEL
Scale: NONE

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MILEPOST 87 TAYLOR HIGHWAY

FAIRBANKS DISTRICT OFFICE

AK

MARK	DESCRIPTION	DATE	APPROVED

PROJECT NO:
DESIGN OFFICE: AK953
DESIGNED BY: DM,MV
DRAWN BY: DM
CHK'D BY: DM
APPROVED BY: AC
DATE: 04/24/2018

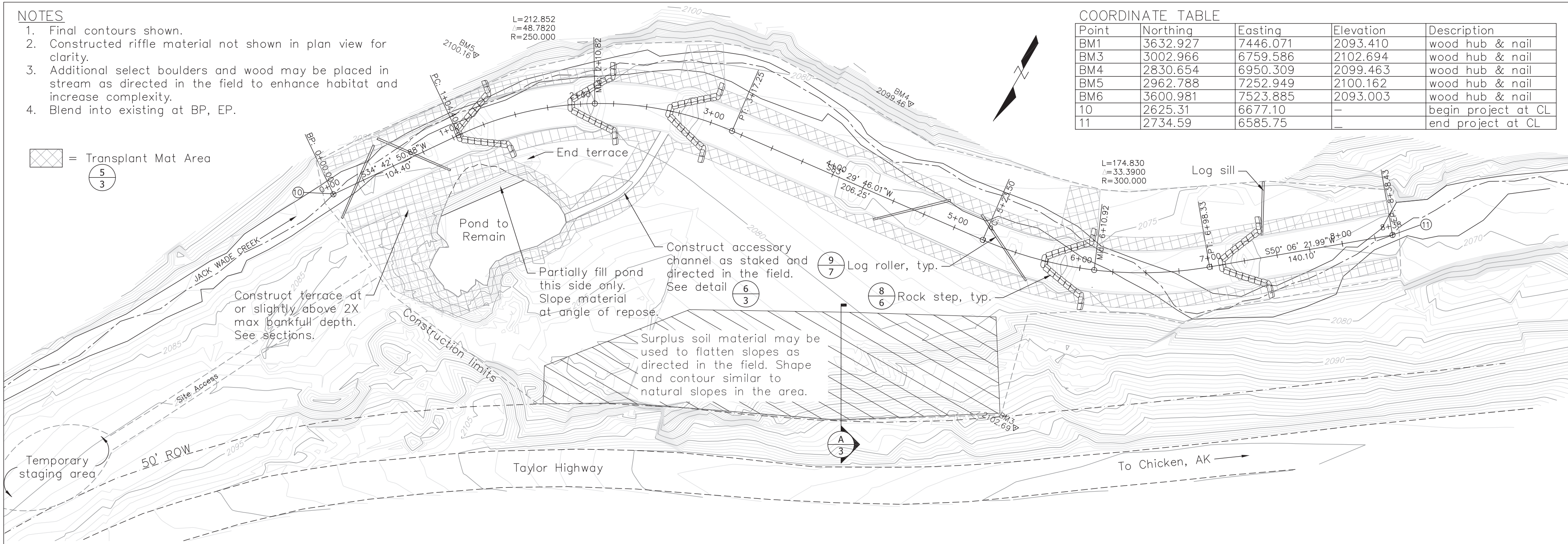
TYP SECTIONS
SHEET 3 OF 7

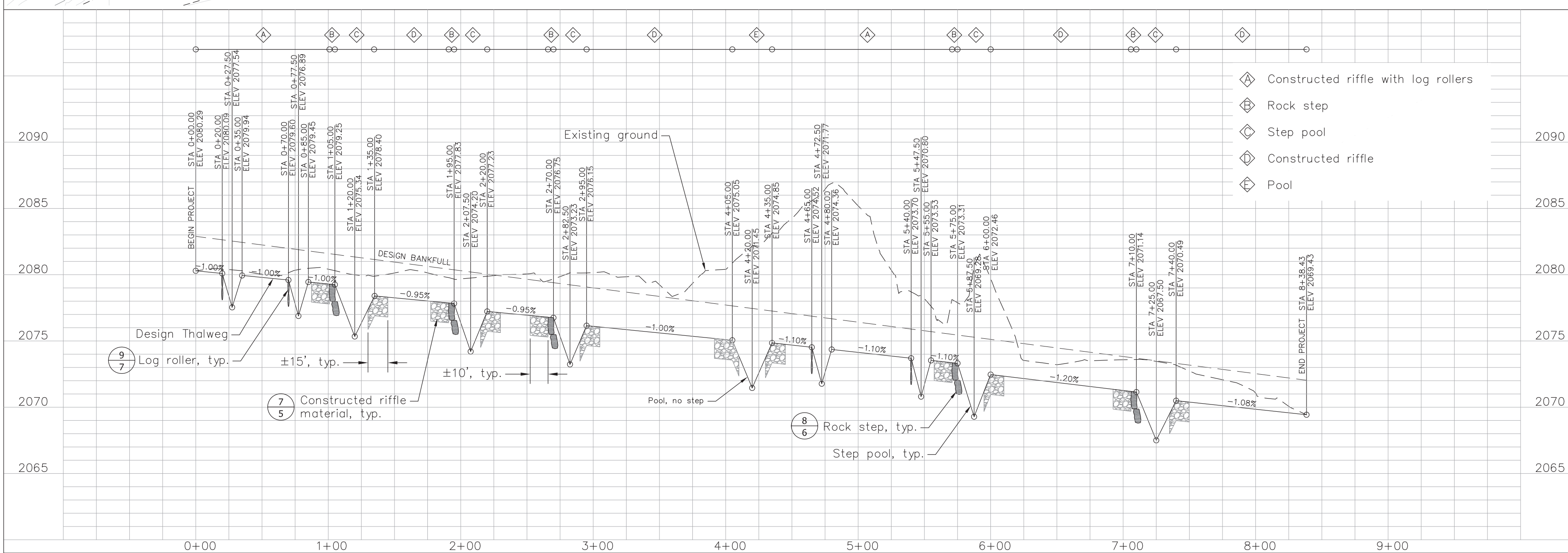
NOTES
1. Final contours shown.
2. Constructed riffle material not shown in plan view for clarity.
3. Additional select boulders and wood may be placed in stream as directed in the field to enhance habitat and increase complexity.
4. Blend into existing at BP, EP.

= Transplant Mat Area (5/3)

COORDINATE TABLE

Point	Northing	Easting	Elevation	Description
BM1	3632.927	7446.071	2093.410	wood hub & nail
BM3	3002.966	6759.586	2102.694	wood hub & nail
BM4	2830.654	6950.309	2099.463	wood hub & nail
BM5	2962.788	7252.949	2100.162	wood hub & nail
BM6	3600.981	7523.885	2093.003	wood hub & nail
10	2625.31	6677.10	–	begin project at CL
11	2734.59	6585.75	–	end project at CL





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JACK WADE CREEK STREAM RESTORATION

MILEPOST 87 TAYLOR HIGHWAY

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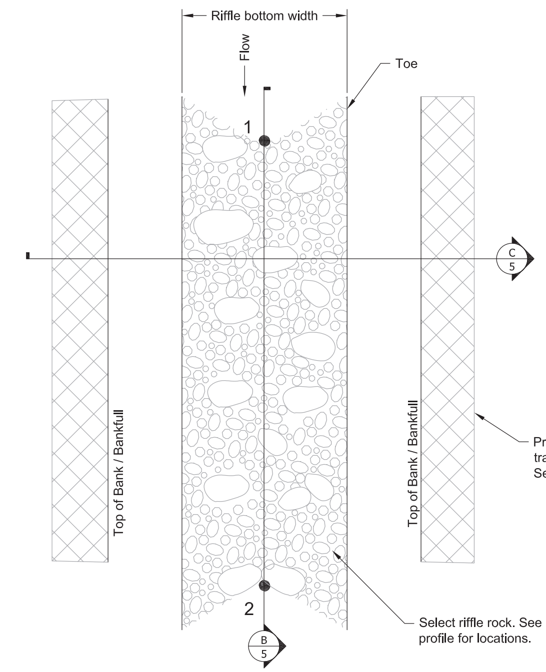
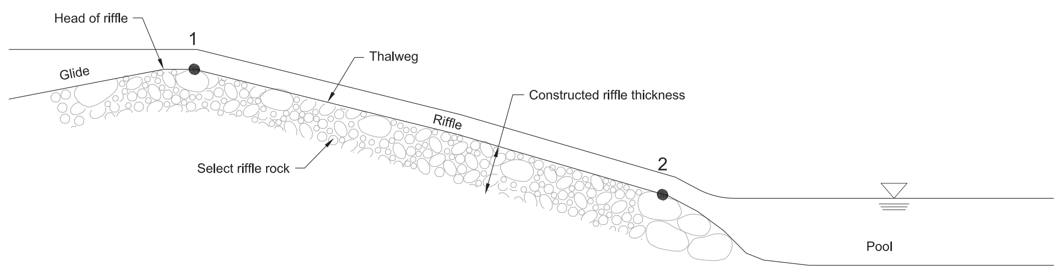
PROJECT NO:
DESIGN OFFICE: AK953
DESIGNED BY: DM,MV
DRAWN BY: DM
CHK'D BY: DM
APPROVED BY: AC
DATE: 04/30/2018

PLAN&PRO
SHEET 4 OF 7

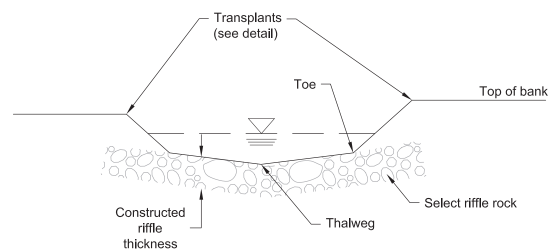


● = Elevation point

7 CONSTRUCTED RIFFLE
Scale: NONE



B RIFFLE INVERT SECTION
Scale: NONE



C RIFFLE CROSS SECTION
Scale: NONE

GENERAL NOTES

1. Grade streambed and banks to proposed dimensions per typical cross-section and profile.
2. Wood and select boulders may be added for habitat complexity as directed in the field.

SPECIFICATIONS

Select Riffle Rock:	OFFSITE: Class II Riprap Hard, durable, angular rock that is resistant to weathering and water action and free of organic or other unsuitable material. Do not use shale, rock with shale seams, or other fissile or fissured rock that may break into smaller pieces in the process of handling and placing. Conform to the quality and gradation requirements of the latest addition of Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects. ONSITE: Alternate: Use grizzly rock screen to create material at project site. Adjust grizzly bars to fit field condtions as directed. Bed material from existing riffles shall be screened and the oversize used as select riffle rock.
Transplant mats	See transplant mat details
Constructed Riffle Thickness	18"

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DRAWN BY: DM
CHK'D BY: DM
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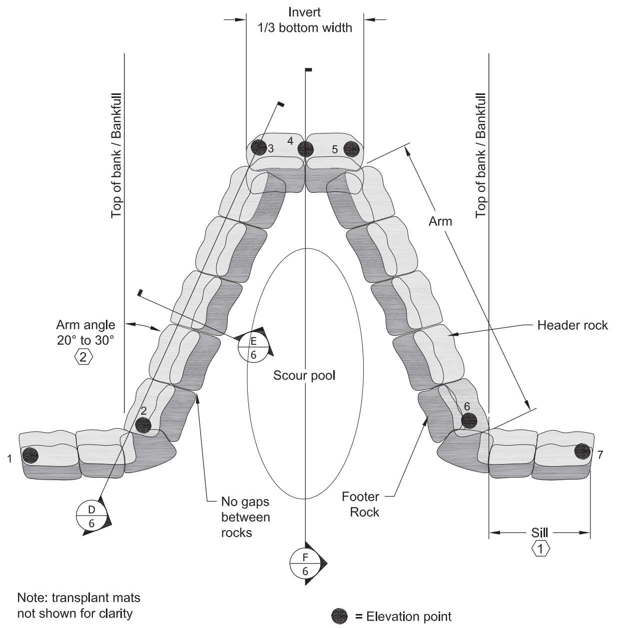
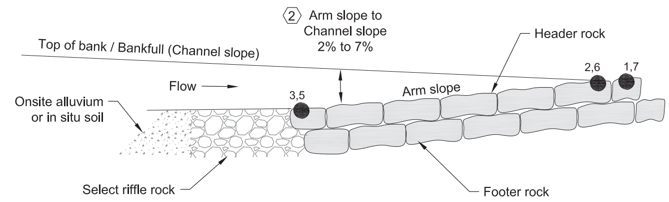
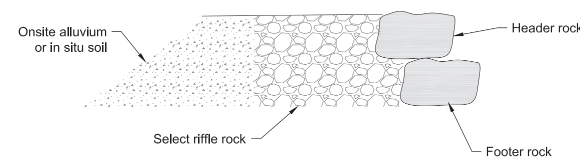
DETAILS
SHEET 5 OF 7



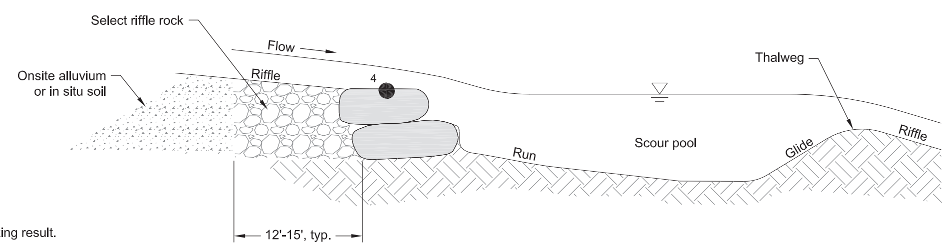
8 ROCK STEP (CROSS-VANE)
Scale: NONE



D SECTION ALONG ARM
Scale: NONE



E VANE ARM SECTION
Scale: NONE



F INVERT AND POOL SECTION
Scale: NONE

KEYNOTES

1. Logs may be used to construct the sill as directed in the field.
2. Actual values may vary based on site conditions.

GENERAL NOTES

1. Dig a trench below the stream bed for footer and header rocks and backfill.
2. Slight variation in rock sizes, angles, and dimensions will add to the habitat complexity and create a more natural looking result.
3. Place footer rocks and then header rocks to achieve design dimensions and elevations.
4. Use hand placed stone to fill gaps and voids on upstream side of he header and footer rocks.
5. Install select riffle rock and onsite alluvium as shown. Fill to the elevation of the top of the header rock.

SPECIFICATIONS

Cross-Vane Header and Footer Rock	Range of Intermediate Dimensions: 12" - 48" Angular Stone that is hard, durable, resistant to abrasion and weathering, and that is free of weak cleavages that may cause the rock to disintegrate during handling and placing.
Select Riffle Rock:	Class II Riprap Hard, durable, angular rock that is resistant to weathering and water action and free of organic or other unsuitable material. Do not use shale, rock with shale seams, or other fissile or fissured rock that may break into smaller pieces in the process of handling and placing. Conform to the quality and gradation requirements of the latest addition of Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects. Alternate: Use grizzly rock screen to create material at project site. Adjust grizzly bars to fit field condtions as directed. Bed material from existing riffles shall be screened and the oversize used as select riffle rock.
Number of Header rows	1
Number of Footer rows	1

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FAIRBANKS DISTRICT OFFICE

AK

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PROJECT NO:
DESIGN OFFICE: AK953
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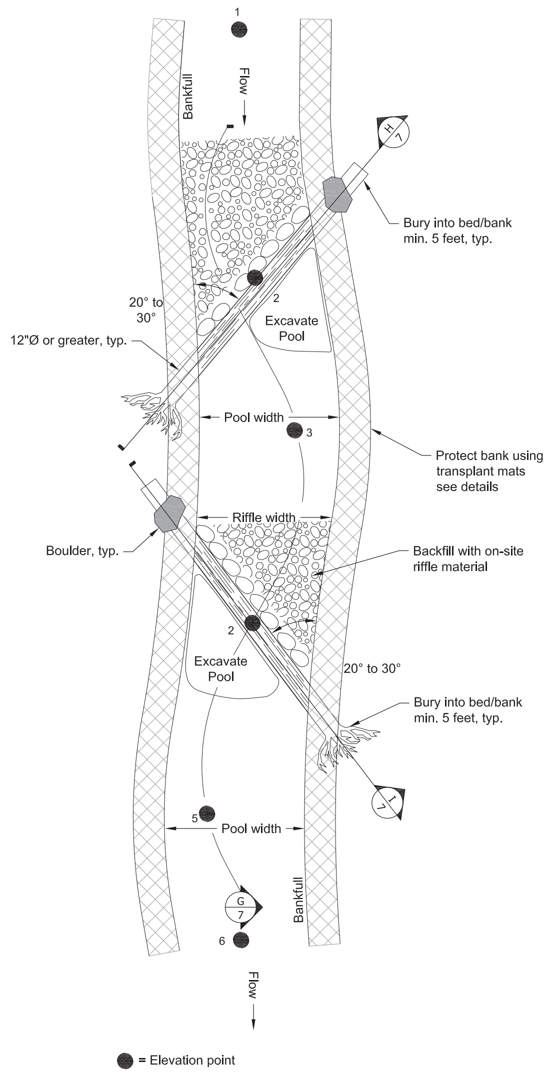
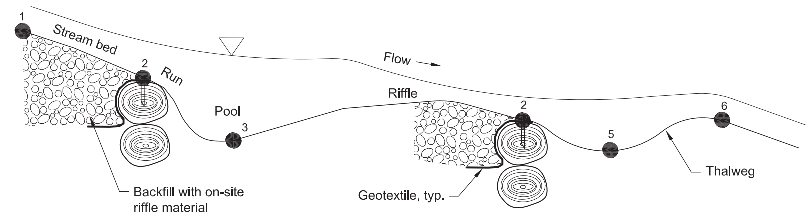
DRAWN BY: DM
CHK'D BY: DM
APPROVED BY: AC
DATE: 04/24/2018

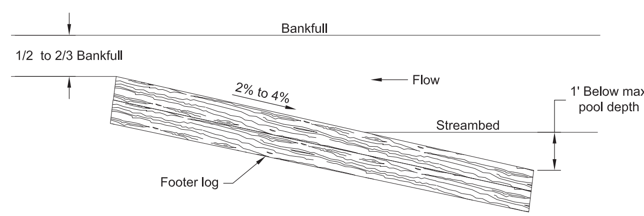
DETAILS
SHEET 6 OF 7



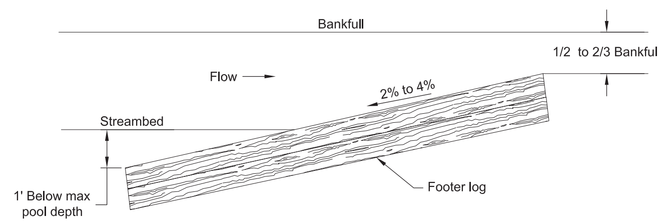
9 LOG ROLLER PLAN VIEW
Scale: NONE



G LOG ROLLER PROFILE
Scale: NONE



H LOG ROLLER SECTION
Scale: NONE



I LOG ROLLER SECTION
Scale: NONE

GENERAL NOTES

1. Compact soil well around buried portions of logs.
2. Place boulder of sufficient size on top of header log for anchoring.
3. Nail geotextile to logs before backfilling.
4. Transplants may be used instead of rootwads as directed in the field.

SPECIFICATIONS

Logs	70' long, 12" diameter min. Straight, not rotten
Geotextile	Class I permanent erosion control (AASHTO M288), non-woven
Nails	10d min., with plastic cap washers

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DETAILS
SHEET 7 OF 7

Technical 65 Report