

Stream Design Report

Stibnite Gold Project
Midas Gold Idaho, Inc.



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SECTION 1: INTRODUCTION

1.1 Purpose of Report

The purpose of the Stream Design Report (Design Report) is to summarize field and analytical methods, assumptions, and support rationale for stream design decisions at the Stibnite Gold Project (SGP) in central Idaho. The intent of the Design Report is to support the SGP Conceptual Mitigation Plan.

1.2 Project Background

Figure 1-1 shows the location of the SGP site. The SGP is located in the Stibnite-Yellow Pine Mining District in central Idaho, near the Frank Church River of No Return Wilderness Area. Located in Valley County, the district is characterized by historical mining activities and unpatented (federal land) and patented (private land) mining claims with known deposits of gold, silver, tungsten, and antimony. The Stibnite-Yellow Pine Mining District (the District) is in the Boise National Forest but is administered by the Krassel Ranger District of the Payette National Forest.

Mining began in the District in the late 1800s and continued intermittently through 1997. Beginning in 2009, the Midas Gold group of companies, represented today by the operating company Midas Gold Idaho, Inc. (Midas Gold, a subsidiary of Midas Gold Corporation) began to acquire mining claims throughout the District from prior owners or by staking claims on its own behalf. With federal and state approval, Midas Gold initiated mineral exploration activities in 2009 to better define the mineral deposit potential for the area. Midas Gold also conducted extensive studies to understand the current environmental conditions at the site and designed the SGP to address and repair existing historical legacy issues. The current proposed SGP is described in the Plan of Restoration and Operations (Midas Gold, 2016).

1.2.1 Project Area Description

The SGP site is located along the East Fork of the South Fork of the Salmon River (EFSFSR) and its tributaries approximately 15 miles upstream of the town of Yellow Pine in central Idaho (Figure 1-1). The terrain within the SGP site consists of narrow valleys surrounded by steep mountains. Elevations along valley floors range from 6,000 to 6,600 feet above mean sea level (msl). The surrounding mountains reach elevations over 8,500 feet above msl. The main drainage basin at the SGP site is the EFSFSR.

Stream enhancement and restoration would accompany proposed future mining activities within the SGP site. These affected reaches include the EFSFSR upstream of Sugar Creek and tributaries to the EFSFSR including Meadow Creek, Garnet Creek, Fiddle Creek, Midnight Creek, Hennessy Creek, and West End Creek (a tributary to Sugar Creek, which feeds the EFSFSR at the downstream limit of the project area) (Figure 1-2). Mining activities would also include removal of the existing Spent Ore Disposal Area (SODA), development of the proposed Tailings Storage Facility (TSF), emplacement of proposed Development Rock Storage Facilities (DRSFs), and excavation of three proposed open pits (Figure 1-2).



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Figure 1-1. Vicinity Map.

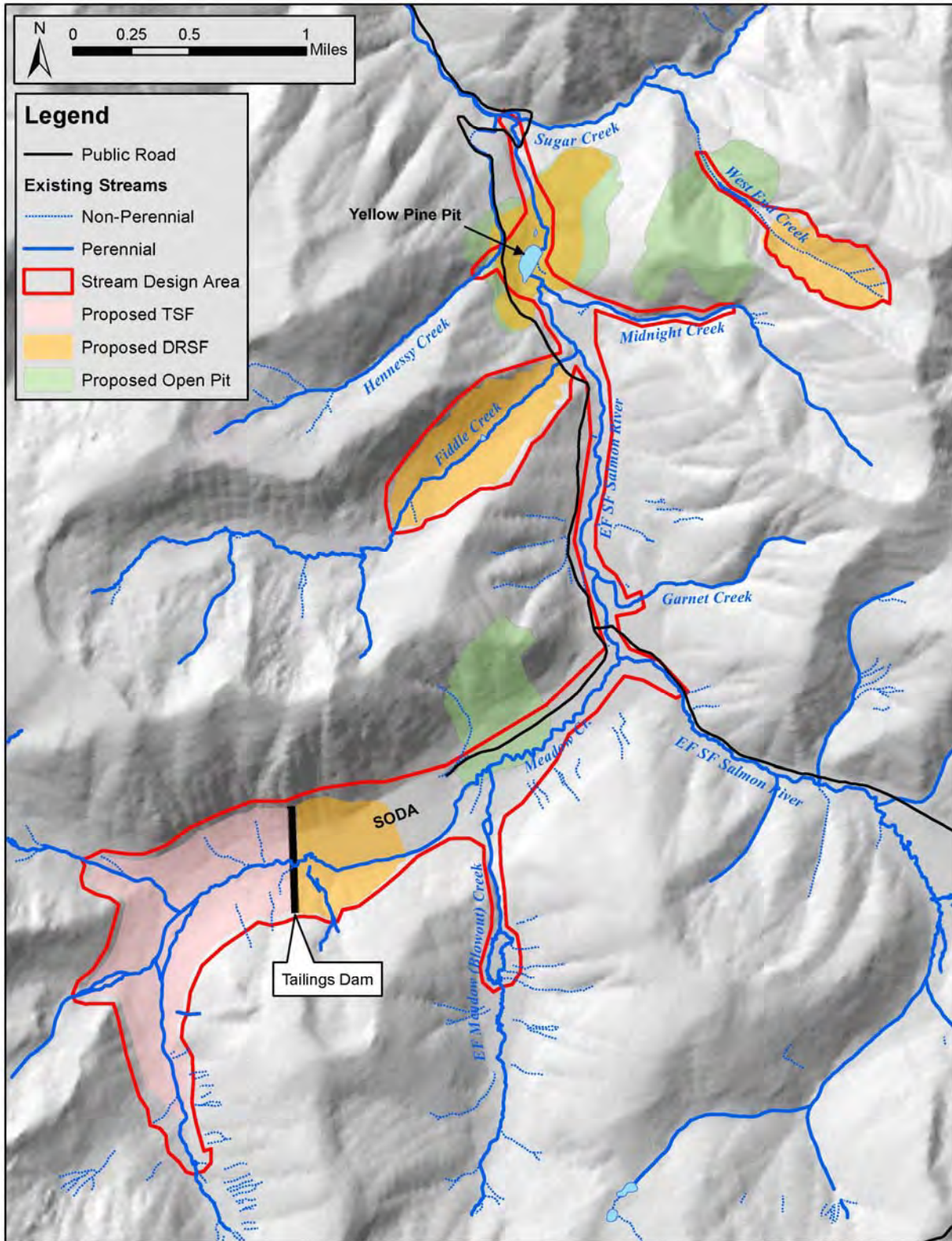


Figure 1-2. Stream Design Project Area Map.

1.3 Project Goals, Objectives and Approach

The primary goals of the project, pertaining to stream design, are to reclaim and/or restore disturbed streams and floodplains from historical and proposed mining activities to improve habitat conditions for aquatic species and mitigate for project impacts.

Stream design objectives have been divided between project-scale and reach-scale. Project-scale objectives are listed below, while reach-scale objectives are outlined on a reach-by-reach basis in Appendix D.

Project-scale objectives:

- Removal of the existing Yellow Pine pit barrier to restore fish passage and make approximately 25,100 linear feet of EFSFSR and 7,300 linear feet of Meadow Creek accessible to fluvial and anadromous fish for the first time since the 1930's.
- Improve habitat for aquatic species by restoring and/or enhancing roughly 10 miles of stream and riparian habitat disturbed by historical or proposed mining or mine-related activities.

The overall stream enhancement and restoration approach is to create fish passage above the existing Yellow Pine pit barrier, restore high-quality stream channels over the top of proposed mine features at closure, and enhance habitat and passage in select streams that would be otherwise unaffected by mining. Fish passage at Yellow Pine pit would initially be provided in a diversion tunnel required for re-mining/expanding the pit, then ultimately by backfilling the expanded pit and building a new stream channel over the top of the backfill, thereby providing permanent fish passage through the area.

As noted above, the stream design approach includes enhancement and restoration of stream reaches disturbed by historical or proposed mining activities. For purposes of this document, and following 33 CFR 332.2, restoration and enhancement are defined as follows (including direct quotes from 33 CFR 332.2 where specified):

Restoration - “the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historical functions to a former or degraded aquatic resource. For the purpose of tracking net gains in aquatic resource area, restoration is divided into two categories: re-establishment and rehabilitation.”

- “**Re-establishment** means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historical functions to a former aquatic resource. Re-establishment results in rebuilding a former aquatic resource and results in a gain in aquatic resource area and functions.”
- “**Rehabilitation** means the manipulation of the physical, chemical, or biological characteristics of a site with the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function, but does not result in a gain in aquatic resource area.”
- Proposed SGP stream restoration (whether considered re-establishment or rehabilitation) would focus on restoring natural function including the creation of a new stream channel where the natural channel has been filled or otherwise altered by mining-related activities. Restored streams will be designed to maximize habitat potential based on species-specific intrinsic potential and geomorphic suitability. Stream designs will target relatively low-gradient, riffle-pool morphology over the short-term suitable for spawning

and rearing meanwhile enabling natural, long-term dynamic response where geomorphically appropriate.

Enhancement – “the manipulation of the physical, chemical, or biological characteristics of an aquatic resource to heighten, intensify, or improve a specific aquatic resource function. Enhancement results in the gain of selected aquatic resource function(s), but may also lead to a decline in other aquatic resource function(s). Enhancement does not result in a gain in aquatic resource area.”

- Enhancement of streams as part of the SGP stream design would include improvements to physical channel processes and habitat largely within the existing stream channel. This would be accomplished by selectively installing large woody debris (LWD) and rock structures, eliminating fish passage barriers, creating pools, enabling improved sediment sorting, and generally increasing hydraulic and habitat diversity. Enhancement efforts may also include floodplain reconnection and reestablishment of riparian vegetation, achieved by excavation of legacy fill material down to bankfull level.

1.4 Organization of Report

- Section 1, the introduction, explains the purpose of the Design Report and provides background information on the project area.
- Section 2 provides an overview of the study area and foundational background information supporting the design.
- Section 3 summarizes the methodologies, assumptions, analyses, and rationale used to develop and support the stream designs.
- Section 4 provides a summary of stream enhancement and restoration sequencing as it relates to the mine operations timeline.
- Section 5 contains references, abbreviations and acronyms.
- Section 6 includes the list of preparers.
- Appendices are included to provide more detailed information regarding:
 - fish biology
 - reference sites
 - project area hydrology
 - reach-scale design summary
 - design sheets (plans)
 - reference reach riparian vegetation data
 - construction quantities
 - design review comment tracking
 - general report limitations and guidelines

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SECTION 2: STREAM DESIGN BACKGROUND

2.1 Description of Stream Design Project Area

The SGP area is located in the Salmon River Mountains, a high-relief mountainous physiographic province in central Idaho. Bedrock in the area consists of pre-Cretaceous metasedimentary “basement” rocks, the Cretaceous Idaho batholith, Tertiary intrusions and volcanics, and Quaternary unconsolidated sediments derived from glaciers and surficial erosion (Midas Gold, 2017).

The stream design project area (See Section 1, Figure 1-2) includes the EFSFSR upstream of its confluence with Sugar Creek to roughly 1,000 feet upstream of its confluence with Meadow Creek. The project area also includes areas within the proposed mine disturbance footprint on all perennial tributaries to the EFSFSR within this reach including Meadow Creek, the East Fork of Meadow Creek (Blowout Creek), Garnet Creek, Fiddle Creek, Midnight Creek, and Hennessy Creek. Additionally, the project area includes upper West End Creek from near its headwaters, downstream to within approximately 2,250 feet of its confluence with Sugar Creek.

2.2 Fish Biology

Baseline studies conducted by MWH, 2017 document fish species within the project area including spring/summer Chinook salmon (*Oncorhynchus tshawytscha*), Snake River Basin steelhead (steelhead; *O. mykiss*), Columbia River bull trout (bull trout; *Salvelinus confluentus*), and Westslope cutthroat trout (*O. clarki lewisi*). Fish habitat requirements, physical habitat criteria, distribution, and periodicity related to these species have been used to inform the stream restoration design. A summary of fish biology as it pertains to the SGP stream design is provided in Appendix A.

2.2.1 Aquatic Habitat Conditions

Recovery planning documents have identified limiting factors and threats to summer Chinook salmon and steelhead at the population level and within bull trout core areas (NMFS, 2016; USFWS, 2015). At the population level, limiting factors identified for steelhead (South Fork Salmon River Population) and spring/summer Chinook salmon (EFSFSR Population) include riparian condition, excess sediment, passage barriers, high water temperatures and lack of instream complexity (NMFS, 2016). Threats identified for bull trout in the South Fork Salmon River Core Area include impaired connectivity, habitat degradation and brook trout (USFWS, 2015).

Reach-scale habitat conditions were developed, in part using Watershed Condition Indicators (WCI) to evaluate these limiting factors and to document baseline habitat conditions within the SGP project area (HDR, 2016; MWH, 2017). Among the stream design objectives is improving habitat conditions as measured by WCI. Several design objectives therefore have been informed by the WCI criteria reported in Appendix B of the Payette National Forest (PNF) Forest Plan (PNF, 2003).

2.3 Reference Conditions

Reference sites in and near the SGP site were selected to provide reference for a broad range of proposed conditions. Individual reference sites include areas that exhibit characteristics (in part or whole) that are useful for evaluation during stream design. Reference sites include individual sub-reaches that are stable or unstable, represent a spectrum of habitat ranging from good to poor, and exhibit complex hydraulic character through simplified character. The goal of evaluating reference conditions was to understand how streams in and near the project area function and provide habitat, rather than record and copy current conditions. The stream designs emulate reference conditions considered positive while avoiding other reference conditions considered negative or detrimental.

Reference site selection and classification generally followed the steps summarized below:

- Reference site evaluation included desktop analysis (geographic information system [GIS] and past reports) of slope, apparent confinement, vegetation class (timber, shrub, meadow, etc.), lithology, soils, hydrology, likely fish use (species, life stage, timing) within and near the project area.
- Evaluation of previously reported reference conditions from Tamarack, Profile, Fourmile, and Goat Creeks (HDR, 2016) and determination of applicability in utilization for stream design reference conditions.
- Located candidate reference sites (20 sites) on a map and categorized them based on hydrology, gradient, confinement, and fish usage to ensure the suite of proposed reference sites provides adequate reference for most of the proposed restoration reaches.
- Field visit by geomorphologist and design engineer to evaluate candidate reference sites based on applicability relative to proposed restoration reaches and based on intrinsic geomorphic character. Identified 8 reference sites for further analysis and documented characteristics to inform the design process for each proposed restoration reach (coarse-scale field data collection).
- Second field visit by geomorphologist, habitat biologist, riparian ecologist, and multiple design engineers to measure reference site physical conditions at select reference sites (8 sites previously identified, 3 additional sites added) that are most representative and/or informative for the proposed stream design.
 - Detailed field measurements included typical cross sections (riffles and pools), longitudinal profile, discharge measurements, observed flow velocities, sediment composition (Wolman pebble counts), and other ocular observations.
 - Identified, photographed, and quantified preferred fish habitat conditions.
 - Identified and quantified riparian plant composition and influence on physical stream characteristics.
 - Evaluated hydrologic influences and interactions between stream, riparian, and connected wetland areas to understand existing wetland character and inform development of appropriate stream/wetland designs.

A detailed summary of measured and observed conditions from reference sites is provided in Appendix B.

SECTION 3: STREAM DESIGN

3.1 Design Summary

The stream design approach has followed a sequence of coarse- to fine-scale development. The coarse-scale analysis initiated with the PRO (Midas Gold, 2016). Midas Gold compiled a stream design team including specialists in engineering, geomorphology, fisheries biology, riparian ecology, and wetland ecology to refine the stream design concepts from the PRO. Each stream within the project areas was divided into design reaches based on proposed valley gradient, fish use, and hydrology. Reference sites were identified and evaluated (as discussed above in Section 2.3). Design criteria, including proposed channel geometries were developed for each reach based on evidence derived from 1) GIS and field measurements from reference sites; 2) empirical formulae developed from local and regional data; and 3) published design guidelines available in the scientific literature. Refinements to post mining-topography (primarily changes to valley slope and width) were made to improve the intrinsic potential and associated habitat conditions within select reaches where possible. The channel geometry and reach-specific design criteria were revised then evaluated using standard at-a-station hydraulic calculations to ensure appropriate sediment transport and physical habitat conditions would be achieved.

The reach-specific design criteria were then applied to a design template illustrating the reach plan view, a representative meander plan and profile, and representative cross sections (see Appendix E – Design Sheets). From these plans, design quantities were calculated to quantify construction costs as well as proposed habitat conditions using WCI for comparison with baseline conditions. Typical bank treatments and in-channel features were developed to support the design criteria, provide habitat diversity, and facilitate bank stabilization until riparian vegetation becomes established. Finally, a generalized revegetation and planting plan was developed for specific riparian, wetland, and upland zones to improve long-term bank stability, woody debris recruitment, overhead cover, shade, and terrestrial/wetland habitat. Please note that the riparian planting plan would need to be field fit upon completion of stream channel and floodplain grading to reflect the actual site conditions. See sheets D1 and D20 in Appendix E – Design Sheets for generalized revegetation plans and planting and seeding schedules.

3.2 Design Reaches

Design reaches were delineated per stream based on hydrology (confluence with major tributary) and significant changes in proposed channel gradient. Each reach is identified in Table 3-1 **Error! Reference source not found.** along with its associated mine feature and action type – restoration versus enhancement. The location of each proposed reach in relation to prominent mine features is shown in Figure 3-1 and includes the proposed fish passage extent for anadromous and resident fish at the end of mining activities. The stream design limits (upstream extent) were determined by the location of the proposed SGP impact area. Around the perimeter of the TSF, the impact area includes different proposed mine-related actions that result in different stream designs summarized below and in Figure 3-2.

- **TSF Limit:** The disturbance area defined by the actual depositional surface of the proposed tailings, associated closure cover (soil/rock/growth media) and stream corridor liner (impermeable barrier separating water from contact with the underlying tailings).

This surface would be relatively low-gradient and includes stream design reaches MC1a through MC1e.

- **TSF Disturbance:** The disturbance area located between the TSF Limit and Maximum Disturbance Limit. This area would be indirectly impacted by the TSF (downgradient) and the diversion channels and access roads (upgradient) associated with the TSF. The stream design in this area includes “transition channels” as described below.
- **Maximum Disturbance Footprint:** The disturbance area including stream channel diversions, perimeter access roads, and associated cuts/fills around the TSF. The stream design in this area includes “transition channels” as described below.

Within the proposed stream design, three channel classes were detailed: perennial, non-perennial¹, and transition channels. Perennial and non-perennial channels have been designed and drawn as shown in Appendix E. Transition channels would be recontoured and replanted to match the existing (pre-disturbance) channel as shown in Appendix E. The transition channels would be recontoured in the area between the Maximum Disturbance Footprint and the TSF Limits to match the upstream existing channel geometry (Figure 3-2). Transition channels have also been identified in the area between the Maximum Disturbance Footprint and the DRSF Limits; in the case of DRSFs, this area is the land lying inside the outermost limit of perimeter diversion cut slopes but outside the limits of the emplaced development rock.

The total existing versus proposed stream length (perennial and non-perennial) is summarized in Table 3-2.

¹ For the SGP stream design non-perennial is used to refer to both ephemeral and intermittent streams. The stream design does not distinguish between the design methods and approach for these two subclasses of non-perennial channels.

Table 3-1. Stibnite Gold Project Conceptual Stream Design Project Reaches.

Stream	Mine Feature	Reach ID	Location	Action Type
Meadow Creek	Tailings Storage Facility	MC1a	Southern-most branch of creek on Tailings Storage Facility (TSF)	Restoration
		MC1b	Middle branch of creek on TSF	Restoration
		MC1c	Northern branch of creek on TSF	Restoration
		MC1d	Trunk stream between middle branch and northern branch on TSF	Restoration
		MC1e	Trunk stream below confluence of northern branch on TSF	Restoration
	Hangar Flats DRSF (top)	MC2	Area on DRSF Upstream of chute	Restoration
	Hangar Flats DRSF (face)	MC3	Chute on face of DRSF	Restoration
	Hangar Flats DRSF (toe)	MC4	Between chute and Hangar Flats pit	Restoration
	Hangar Flats pit	MC5	Outlet channel from Hangar Flats pit	Restoration
Hangar Flats pit	MC6	Enhancement of existing channel below pit	Enhancement	
Blowout Creek	Blowout Creek (Meadow)	BC1	Meadow channel upstream of boulder chute	Enhancement
	Blowout Creek (Boulder Chute)	BC2	Steep channel between meadow and alluvial fan	Restoration
	Hangar Flats Pit	BC3	Channel into Hangar Flats Pit	Restoration
EFSFSR	Processing Facility	EF1	Section upstream of confluence with Meadow Cr.	Enhancement
	Yellow Pine Pit	EF2	Section upstream of Yellow Pine Pit restoration reach	Enhancement
	Yellow Pine pit	EF3	Final stream segment replacing the temporary tunnel	Restoration
	Yellow Pine pit	EF4	Section downstream of Yellow Pine Pit restoration reach	Enhancement
Fiddle Creek	Fiddle DRSF (top)	FC1	Restoration upstream of boulder chute	Restoration
	Fiddle DRSF (face)	FC2	Chute on face of DRSF	Restoration
Midnight Creek	Yellow Pine pit	MNC1	Steep reach above EFSFSR floodplain	Restoration
	Yellow Pine pit	MNC2	Channel on top of EFSFSR floodplain	Restoration
Hennessy Creek	Yellow Pine pit	HC1	Cascade over Yellow Pine Pit highwall	Restoration
	Yellow Pine pit	HC2	Channel on top of EFSFSR floodplain	Restoration
Garnet Creek	Processing Facility	GC1	Upstream of confluence with EFSFSR	Restoration
West End Creek	West End DRSF (top)	WE1	Restoration on top of the West End DRSF	Restoration
	West End pit (face)	WE2	Chute on face of DRSF	Restoration
	West End pit (lower)	WE3	Downstream of West End Pit within mining disturbance area	Restoration

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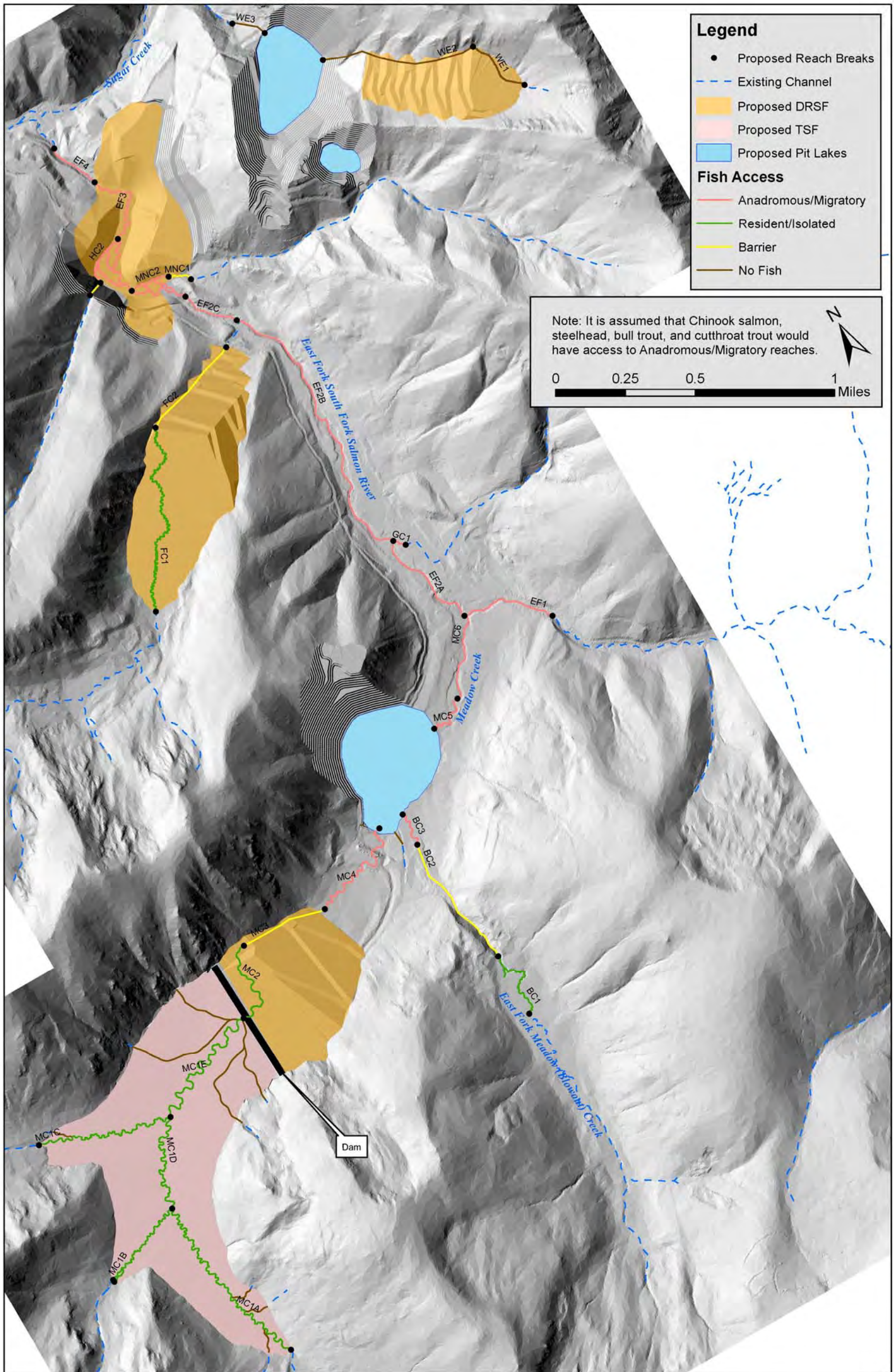


Figure 3-1. Proposed Stream Design Reaches at Mine Closure.

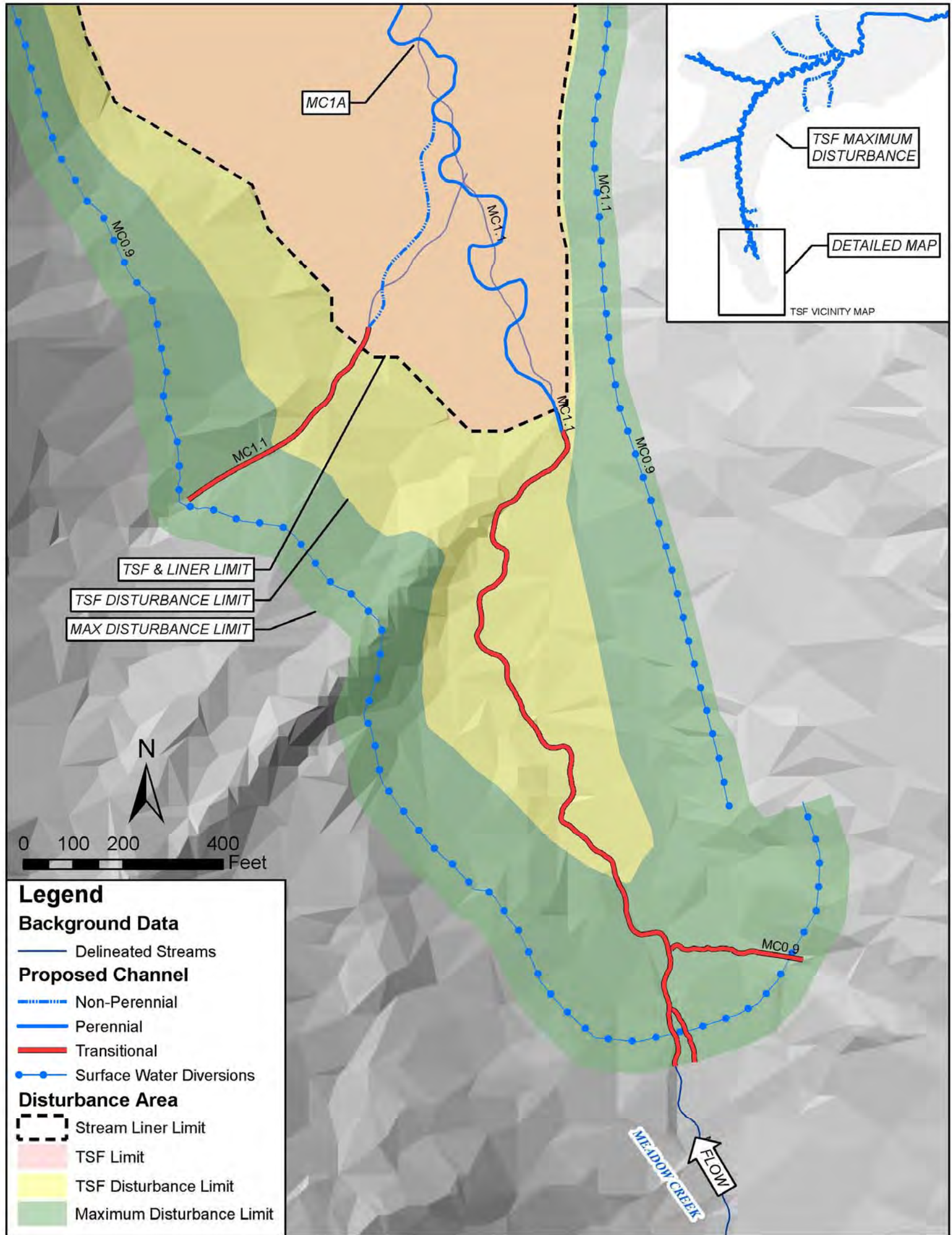


Figure 3-2. Proposed disturbance areas and stream channel classes associated with the TSF.

Table 3-2. Existing Vs. Proposed Stream Lengths

Reach ID	Existing		Proposed (Enhanced and Restored)	
	Perennial Stream Length (ft)	Non-perennial Stream Length (ft)	Perennial Stream Length (ft)	Non-perennial Stream Length (ft)
Meadow Creek				
MC1A	4,492	819	5,581	1,423
MC1B	2,927	0	2,828	0
MC1C	2,692	616	3,716	417
MC1D	3,833	0	3,002	0
MC1E	3,280	4,608	4,164	7,172
MC2	852	62	2,108	0
MC3	4,107	0	1,693	0
MC4	2,291	1,488	2,843	180
MC5	3,362	3,147	450	0
MC6	2,357	0	2,357	0
Transitional	2,124	1,195	2,124	1,262
Total	32,317	11,935	30,866	10,454
Blowout Creek				
BC1	2,105	0	2,012	0
BC2	3,480	0	2,670	0
BC3	924	0	822	0
Total	6,509	0	5,504	0
East Fork South Fork Salmon River				
EF1	1,918	1,119	1,897	0
EF2	9,256	4,501	9,118	0
EF3	2,817	493	4,606	2,011
EF4	2,265	0	2,143	0
Total	16,255	6,113	17,764	2,011
Fiddle Creek				
FC1	4,244	589	5,860	0
FC2	2,386	0	2,216	0
Transitional	175	0	176	0
Total	6,805	589	8,252	0
Midnight Creek				
MNC1	446	0	468	0
MNC2	152	0	893	0
Transitional	2,124	427	2,098	427
Total	2,722	427	3,459	427
Hennessy Creek				
HC1	328	0	287	0
HC2	3,683	475	1,193	0
Transitional	246	0	246	0
Total	4,258	475	1,726	0
Garnet Creek				
GC1	239	0	285	0
Total	239	0	285	0
West End Creek				
WE1	0	1,911	0	1,456
WE2	0	2,922	0	2,923
WE3	0	2,052	0	678
Total	0	6,884	0	5,057
Grand Total				
Total	69,105	26,423	67,763	17,948

Notes:

- A. Existing stream length does not include stream length through the existing Yellow Pine pit lake.
 B. Proposed stream length does not include stream length through the proposed Hangar Flats pit lake or West End pit lake.

3.3 Analysis

Initial stream channel conceptual designs from the PRO were refined on a reach-by-reach basis according to measurements from reference sites, empirical formulae, and published design guidelines. Design criteria were refined in each reach to maximize physical habitat objectives given site constraints. Various technical analyses were performed to develop and evaluate the specific design criteria and to evaluate the proposed physical conditions for geomorphic suitability and engineering feasibility.

A summary of the analyses, methods, assumptions, and conclusions for the project site are listed below, while results from additional reach-specific analyses can be found in Appendix D.

3.3.1 Physical Habitat

The PRO identified that the overall purpose of restoration and reclamation is to restore (rehabilitate) prioritized areas impacted by historical mining activities as well as to return newly impacted areas to stable and productive conditions (Midas Gold, 2016). Midas Gold recognizes that to achieve functional watershed conditions, fish passage must be reestablished upstream of the Yellow Pine pit and that the habitat conditions upstream and atop the Yellow Pine pit backfill are adequate to support anadromous and migratory salmonids. Elimination of the fish passage barrier and implementation of the stream restoration identified in the PRO are the types of habitat actions that contribute to recovery of steelhead, Chinook salmon, and bull trout (NMFS, 2016; USFWS, 2015). Therefore, the goals of the restoration and mitigation plan are to restore fish passage, improve fish habitat for spawning and rearing, and provide early and sustainable on-site mitigation for stream and wetland impacts. On balance, the plan seeks to provide a net ecological benefit relative to current conditions.

To provide the anticipated net ecological benefits, stream restoration concept designs were generated based on a three-step process to help assess and ultimately assign appropriate biological objectives within each reach of the project area:

1. Develop design targets
 - a. Determine species use based on post-mining passage conditions and current use;
 - b. Determine post-mining physical design criteria (valley gradient, valley width, channel slope, sinuosity) based on reference conditions, empirical formulae, and published design guidelines (final design criteria listed below in Section 3.4 and per reach in Appendix D).
2. Assign biological objectives based on intrinsic potential for anadromous areas and on anticipated fish use in areas isolated above barriers.
3. Refine physical design criteria to maximize habitat based on biological objectives
 - a. Refine physical criteria listed above;
 - b. Develop design criteria for bankfull width (BFW), depth, meander wavelength, meander amplitude, bend radii, meander belt width, and floodplain width (FPW) (final design criteria listed below in Section 3.4 and per reach in Appendix D).

Intrinsic potential for Chinook salmon and steelhead, access, and spawning and rearing habitat preferences for salmonids provided the template for assigning biological objectives. For Chinook

salmon and steelhead, a basic assessment of intrinsic potential (Cooney and Holzer, 2006) was used for selected reaches based on channel slope (gradient), BFW and the ratio of FPW to BFW (Tables 3-3 and 3-4) (Cooney and Holzer, 2006). Current fish use is based on recent sampling to describe baseline conditions (MWH, 2017). However, it should be noted that the presence of juvenile Chinook salmon noted within the reaches upstream from the Yellow Pine pit are the result of successful adult Chinook salmon outplants (i.e. trap and haul program). The observed adult Chinook salmon spawned and produced juvenile fish that were noted during subsequent baseline surveys.

Table 3-3. Relative intrinsic potential for Interior Columbia Basin Spring/Summer Chinook salmon spawning and initial rearing.

Chinook salmon relative potential for spawning and initial rearing				
Stream width / Gradient Categories		Valley Width Ratio (ratio of valley width to bankfull stream width)		
Bankfull Width (ft)	Gradient (%)	Confined ($\leq 4 \times$ BFW)	Moderately Confined (4 to 20 x BFW)	Unconfined ($> 20 \times$ BFW)
BFW <12.1	≥ 0.0	None	None	None
BFW 12.1 to 82	0.0 - 0.5	Medium	High	High
	0.5 - 1.5	Low	Medium	High
	1.5 - 4.0	Low	Low	Medium
	4.0 - 7.0	Negligible	Low	Low
	>7.0	None	None	None
BFW 82-164	0.0 - 0.5	None	Medium	Medium
	0.5 -10.0	None	None	None
	≥ 10.0	None	None	None
BFW > 164	≥ 0.0	None	None	None

Note: Intrinsic potential categories (i.e., none - high) were assessed for potential anadromous reaches in Meadow Creek and EFSFSR. Intrinsic potential categories were based on proposed bankfull width (BFW), gradient (%), and the ratio of floodplain width (FPW) to bankfull width (FPW/BFW). For example, streams with a BFW from 12.1 to 82 feet, a gradient from 0.0%-0.5% and confinement ratio greater than 20 (i.e., unconfined) were considered to have a high intrinsic potential for Chinook salmon. BFW = Bankfull stream width. After Cooney and Holzer 2006.

Table 3-4. Relative intrinsic potential for interior Columbia Basin summer steelhead spawning and initial rearing.

Steelhead relative potential for spawning and initial rearing				
Stream width / Gradient Categories		Valley Width Ratio (ratio of valley width to bankfull stream width)		
Bankfull Width (ft)	Gradient (%)	Confined (≤ 4 x BFW)	Moderately Confined (4 to 20 x BFW)	Unconfined (> 20 x BFW)
BFW <12.5	≥ 0.0	None	None	None
BFW 12.5 - 82	0.0 - 0.5	None	Medium	Medium
	0.5 - 4.0	Low	High	High
	4.0 - 7.0	None	Low	Low
	> 7.0	None	None	None
BFW 82 - 164	0.0 - 4.0	Low	Medium	Medium
	> 4.0	None	None	None
BFW > 164	≥ 0.0	None	Low	Low

Note: Intrinsic potential categories (i.e., none - high) were assessed for potential anadromous reaches of the aquatic resource area. Intrinsic potential categories were based on proposed bankfull width (BFW), gradient (%), and the ratio of floodplain width (FPW) to bankfull width (FPW/BFW). For example, streams with a BFW from 12.5 to 82 feet, a gradient from 0.0%-0.5% and confinement ratio greater than 20 (i.e., unconfined) were considered to have a medium intrinsic potential for steelhead. BFW = Bankfull stream width. After Cooney and Holzer 2006.

3.3.2 Geomorphology

Geomorphology includes the understanding of how and why stream-related physical conditions formed and changed over time. This understanding is then used to develop future target conditions for restoration and enhancement.

Historical Conditions: A combination of data were used to evaluate historical conditions within the SGP area including historical photos, previously developed scientific literature, geologic maps, detailed surface topography (LiDAR), and field observations. The Geological Baseline Study (Midas Gold, 2017) identified that over 20,000 years ago glaciers occupied several valleys within the project area including Meadow Creek and the upper reaches of Hennessy and Fiddle Creeks. Research from the Sawtooth Range to the southeast of the project area suggests that most valley glaciers retreated from the mountains of Idaho roughly 11,000 years ago (Breckenridge, et al., 1988). Glaciers generally carve valleys on a larger scale than streams, resulting in broad, deep, U-shaped valleys as opposed to narrow, V-shaped valleys. Modern streams flowing in these broad valleys are “underfit” meaning the stream is too small to be correlated to the much larger valley geometry previously formed by a glacier. Often underfit streams have established an appropriately sized inset floodplain bound by terraces that together fill the valley bottom (Figure 3-2). Although the valley bottom has been reworked by historical mining activities, it is highly likely that lower Meadow Creek, in the vicinity of the existing SODA continuing downstream to the confluence with the EFSFSR, was historically characterized by an inset floodplain with broad terraces.

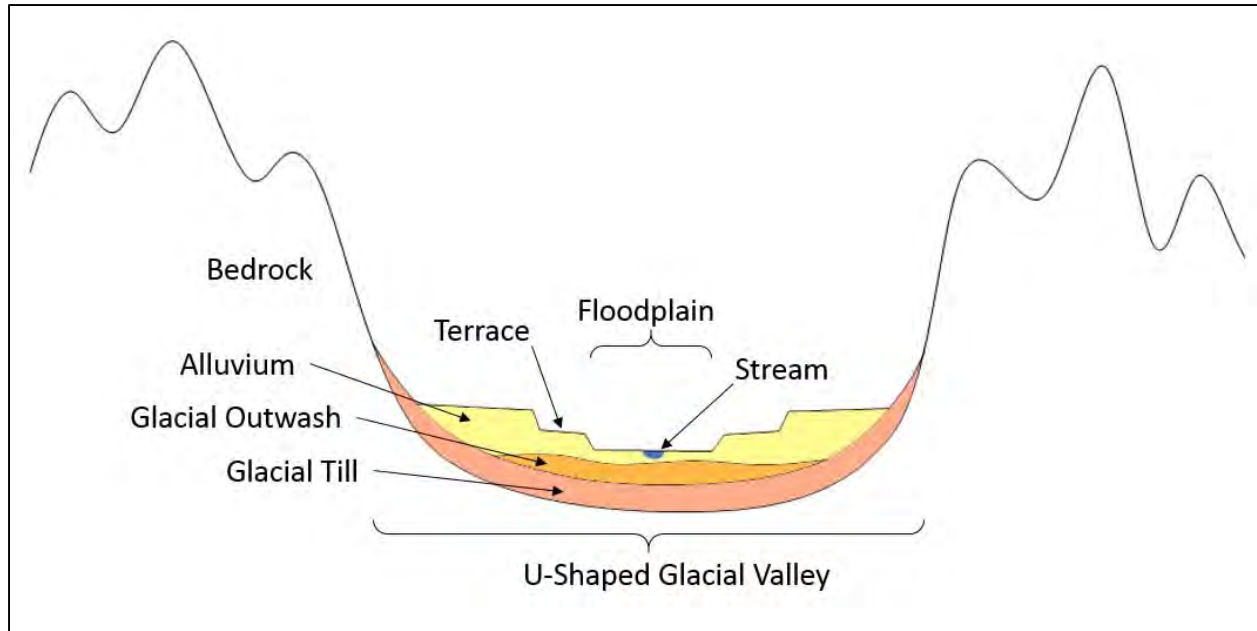


Figure 3-2. Glacial Valley with Underfit Stream and Inset Floodplain (Cross-Section).

Tributaries to the glacially carved U-shaped valleys often have not been carved as deeply as the main valleys, resulting in a perched or “hanging valley” orientation. The tributary streams occupying these hanging valleys are commonly characterized by a sharp break in topographic slope at the point where the hanging valley intersects the larger U-shaped valley. Such slope breaks can result in cascades and may represent natural barriers to fish passage. Numerous hanging valleys are found in the project area including the upper reaches of East Fork of Meadow Creek (Blowout Creek) and Fiddle Creek.

As valley glaciers advance, the underlying rock material scoured from the valley bottom and deposited beneath the glacier is known as “glacial till.” Glacial till consists of unsorted grain sizes ranging from clay to boulder size all mixed together without layering. Glacial till and other sediments that are transported to glacial margins are deposited in terminal and lateral moraines. These moraines can temporarily dam stream flow and commonly provide long-term grade control for modern streams. The existing meadow on Blowout Creek (at the site of the former reservoir impoundment) was likely formed when streamflow from Blowout Creek was dammed by the right-lateral glacial moraine from the Meadow Creek valley glacier (Figure 3-3). Following glacial retreat, the coarse material comprising the lateral glacial moraine created a long-term grade control that maintained the relatively flat meadow upstream of the relatively steep cascade marking the edge of the hanging valley.

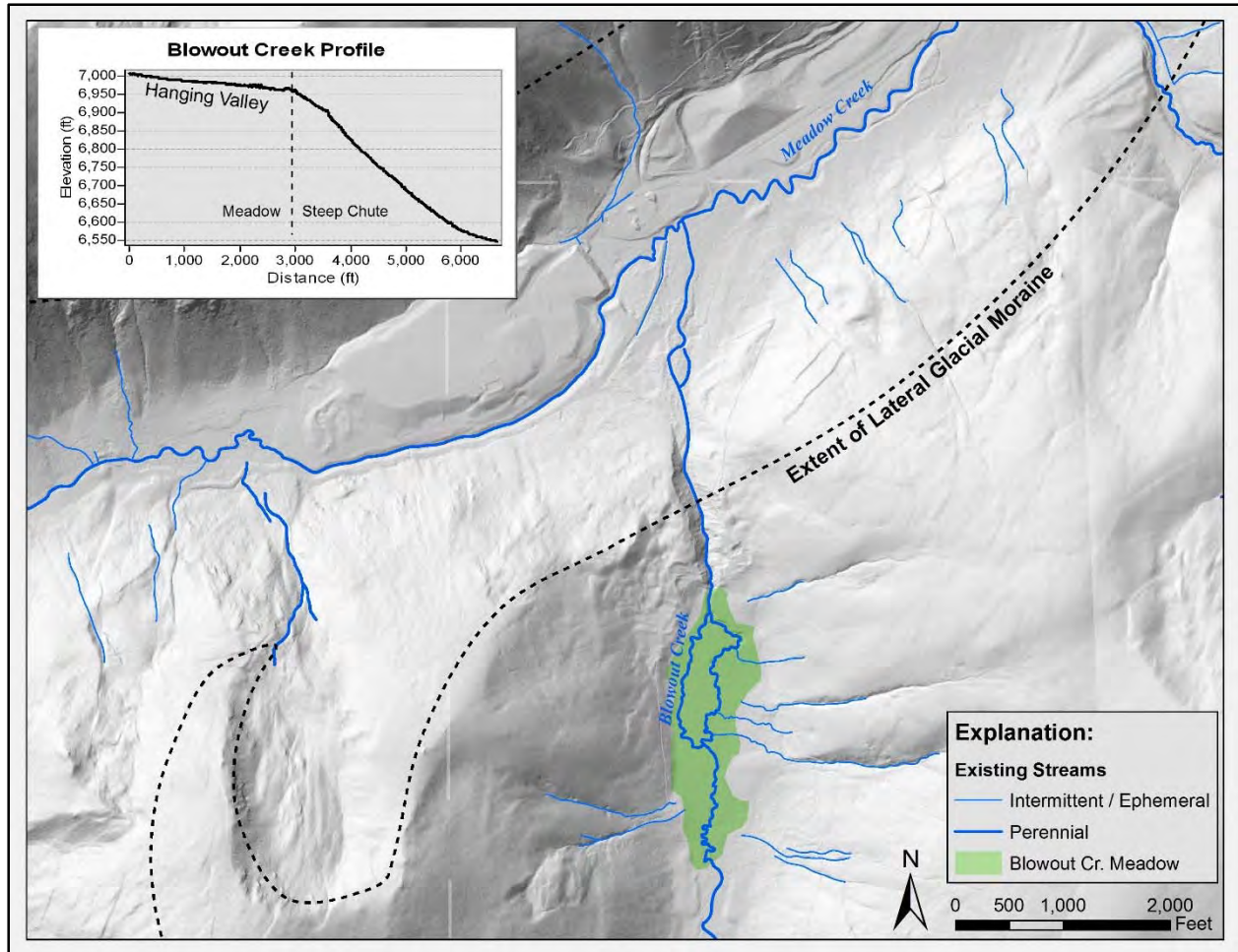


Figure 3-3. Blowout Creek Meadow and Lateral Moraine.

As glaciers receded during the last ice age, the melted ice contributed substantially to the hydrology of the basin, greatly increasing the volume of stream discharge per unit area compared to existing conditions. The result was a much larger stream capable of transporting larger grain



Photo 3-1. EFSFSR Armored Bed Composed of Glacial Till and Outwash.

sizes that were deposited as glacial outwash. Modern streams have cut into and flow over these historical glacial till and outwash deposits winnowing away relatively fine material, while coarse boulders incapable of transport by the modern stream remain. The EFSFSR exhibits this trait through the project area where the stream bed is armored by very large boulders originally deposited as glacial till and/or outwash (Photo 3-1).

The glacial history of the project area helped shape the pre-disturbance, “natural” conditions upon which the ecosystem formed and evolved. Over

the past 100 years, these natural conditions have been impacted by human-related activities, especially mining. Much of the valley-bottom sediments in Meadow Creek and the EFSFSR have been reworked by historical mining operations creating a variety of unnatural channel conditions. In addition to the existing open pit mine creating a small lake that traps sediment and creates a fish passage barrier on the EFSFSR, much of the valley bottom has been filled with relic mine development (including both tailings and development rock dumps) confining the channel such that all but the largest floods are contained within the banks.

Historical stream impacts: Anthropogenic and natural historical stream impacts have significantly influenced the modern character of the SGP area. A summary of significant stream impacts and associated channel response is listed below.

- Sediment releases from mining activities, human-related slope failures, and forest fires result in sediment deposition and aggradation of low-gradient, unconfined response reaches.
 - Nearby reference reaches in Sugar Creek (Photo 3-2) and Profile Creek exhibiting evidence of recent large-scale sediment deposition were also characterized by the greatest amounts of hydraulic and habitat diversity among the reference reaches observed. Sediment commonly drives channel processes, including migration and avulsion that recruits woody debris, forces flow convergence, scour pools, and sorts sediment, all of which contribute to high-quality habitat (based on WCI criteria).



Photo 3-2. Sugar Creek Reference Site.

Note: Sediment deposition has driven channel response resulting in diverse habitat including pools, riffles, woody debris, split flow, off-channel habitat, and a broad floodplain.

- Filling the valley bottom has resulted in a straightened, over-steepened, and confined channel. Such conditions have resulted in concentrated flood flow and excessive sediment transport capacity contributing to the formation of a relatively homogenous, armored bed.
 - Portions of Meadow Creek, EFSFSR, and Sugar Creek.
- Stream channels have been relocated into unnatural or geomorphically inappropriate channels, ditches, or rock drains. Such channels have been engineered for the sake of water management, as opposed to habitat, and are typically designed to be very stable with minimal habitat or hydraulic diversity and little to no dynamic variability resulting from natural geomorphic processes.

- Roughly 4,400 feet of Meadow Creek is contained within a rock-lined channel around the SODA (Photo 3-3).
- Portions of Midnight Creek and Garnet Creek.
- West End Creek is routed twice through rock drains and/or culverts (now failed) at the base of development rock dumps, each drain spanning over 1,000 feet in length.
-
- Hennessy Creek routed around and partially through relic development rock dumps.
- Midnight Creek diverted into the Yellow Pine Pit.



Photo 3-3. Rock-Lined Reach of Meadow Creek Around the SODA.

- Dams that have collected sediment and/or failed catastrophically releasing the sediment and/or destabilizing slopes that have subsequently released sediment.
 - Blowout Creek dam.
 - Fiddle Creek dam.

Proposed alterations to streams: Future mine activities would result in many proposed impacts which would be offset by restoration and enhancement actions.

- Create a passage barrier on Meadow Creek – Impact.
 - The barrier would block upstream passage to upper Meadow Creek (much smaller drainage basin than the area blocked by the Yellow Pine Pit) isolating a small population of resident fish above the proposed Hangar Flats DRSF.
- Elongate the existing fish passage barriers on Fiddle Creek and West End Creek by filling the valley with development rock – Impact.
 - The Fiddle and West End DRSFs would elongate the existing passage barriers on Fiddle and West End Creeks.
- Fill valleys with development rock and tailings requiring a channel and floodplain built atop an impermeable liner² to separate the restored stream from the underlying materials – Impact.

² The need for a liner underneath stream corridors atop the TSF and DRSFs was determined based on limited assumptions regarding geochemistry and groundwater. Geochemistry and groundwater analyses are being conducted concurrently with the stream design. As new information becomes available (pending finalized reports), the need for an impermeable liner will be reevaluated.

- Upper Meadow Creek would be filled with tailings and development rock.
- Fiddle and West End Creeks would be filled with development rock.
- The expanded Yellow Pine Pit would be backfilled with development rock upon which the EFSFSR and lower Hennessy and Midnight Creeks would flow.
- Remove the passage barrier at the existing Yellow Pine Pit – Restoration.
 - Principal habitat improvement to offset negative impacts associated with mine actions.
 - Extends migratory fish access upstream to all naturally accessible portions of the EFSFSR, lower Meadow Creek (to the upstream extent of Reach MC3), and small portions of Hennessy, Midnight, Garnet, and Blowout Creeks.
- Increase habitat quantity and quality through enhancement actions along the EFSFSR and Meadow Creek – Enhancement.
 - Changes to channel form (plan and profile) along with additions of in-stream and off-channel habitat structures are proposed to improve habitat conditions for salmonids within reaches that are not otherwise directly impacted by proposed mine actions.
- Restore impacted stream corridors on Meadow, Fiddle, Garnet, Midnight, Hennessy, West End Creeks and the EFSFSR – Restoration.
 - Rebuild streams with enhanced habitat within reaches that would be directly impacted by proposed mine actions.

Proposed geomorphic targets: All of the stream reaches within the project area have proposed geomorphic targets for restoration or enhancement.

- Isolated areas atop DRSF or TSF surfaces would target highly sinuous, low-gradient, meadow-like conditions with the potential for significant beaver influence. The restored channel would be dynamic and occupy a broad floodplain designed to be approximately 1.25-times wider than the minimum meander beltwidth required for channel migration.
- Maximize valuable low-gradient habitat by increasing the slope and decreasing the length of high-gradient reaches forming a series of steps rather than a singular moderate gradient slope. Low-gradient streams have greater intrinsic potential for habitat than do similar high-gradient streams (See Section 3.3.1).
- Increase in-stream hydraulic and habitat diversity by adding rock and/or woody debris structure. Increasing hydraulic diversity would create many areas of flow convergence to scour pools and flow divergence to sort and deposit sediment enabling the creation and enhancement of spawning and rearing habitat within the same general area.
- It is assumed that low-gradient spawning and rearing habitat is less common and more valuable than similar high-gradient habitat. Geomorphic targets have been developed, taking advantage of lower-gradient valley segments and/or increasing the sinuosity in many reaches, thereby reducing channel slope in an effort to gain more low-gradient, high intrinsic potential habitat.
- Existing, isolated fish passage barriers will be identified along the EFSFSR within the project area and removed where possible.

Alluvial fans: Several existing alluvial fans have formed along the margins of Meadow Creek, EFSFSR, and Blowout Creek valleys. Alluvial fans are convex, depositional landforms that often

take the shape of a fan or cone spread over a relatively flat surface. Alluvial fans are generally formed in places where confined flow can spread out to the point where the increasing width of the channel decreases its competence to the point that it is no longer able to transport its sediment load resulting in deposition. Within the project area, observed fans have developed onto post-glacial surfaces (areas previously occupied by glaciers), suggesting each alluvial fan has been accumulating sediment since glaciers retreated in this area – assumed to be 11,000 years ago (Breckenridge, et. al., 1988). Existing fans contribute to the morphology of the valley and can force or obstruct channel migration. Understanding historical alluvial fan development in the SGP area can help predict future alluvial fan formation in support of proposed stream designs.

Morphologies were measured from 10 existing alluvial fans along the margins of Meadow Creek, EFSFSR, and Blowout Creek to determine characteristic fan shape and to estimate potential future fan formation along proposed TSF and DRSF surfaces (Figure 3-4). Measurements were taken in GIS from fans and their associated drainage basins to identify any correlative or possibly predictive relationships (Table 3-5). No correlation was identified between measured fan dimensions and basin variables. Estimates of potential future fan formation and size have therefore been based on maximum measured morphologies from those fans identified within the project area. It is assumed that future spatial and temporal fan development would occur similar to that of existing fans. In other words, new fans of comparable size to existing fans would take thousands of years to form. The range of existing alluvial fan morphologies is shown in Table 3.6.

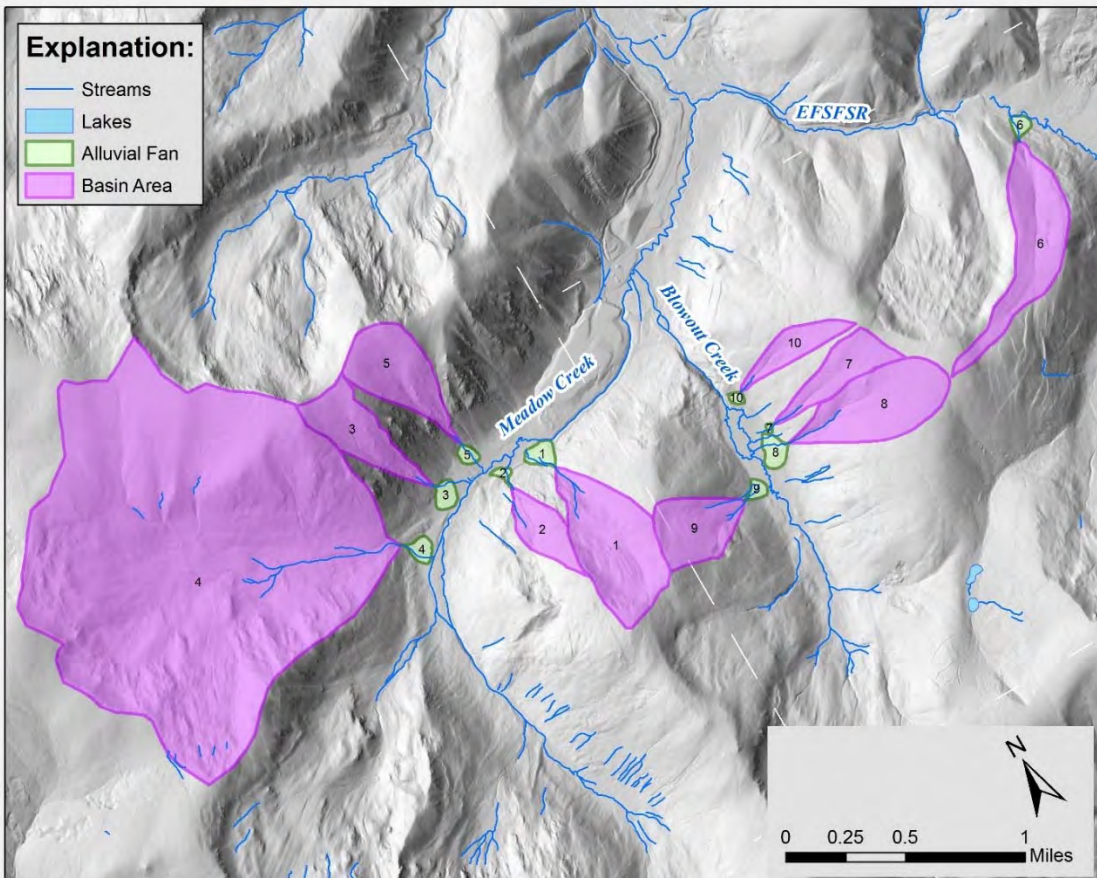


Figure 3-4. Existing Alluvial Fans and Associated Drainage Basins Measured.**Table 3-5. Alluvial Fan Morphology Measurements.**

Measurement	Definition / Methodology
Basin Area	2-dimensional square foot basin area manually measured in GIS from 2009 LiDAR
Basin Max Flow Length	Manually measured length from max elevation point to min elevation point following topographic low (valley)
Basin Elevation	Min and Max elevations manually measured in GIS from 2009 LiDAR
Avg. Basin Slope	$(\text{Max elevation} - \text{Min elevation}) / \text{Max Flow Length} * 100$
Basin Ruggedness	Melton Ruggedness Number (Melton 1965) $(\text{Max elevation} - \text{Min elevation}) / \text{sqrt}(\text{Basin Area})$
Basin Aspect	Manually determined from 2009 LiDAR
Fan Width	Max width of alluvial fan manually measured from 2009 LiDAR
Fan Thickness	Estimate of fan height by subtracting elevation of fan surface from elevation of adjacent valley floor at a cross section location near the center of the fan
Fan Area	Square Feet measured in GIS from polygon outline manually drawn following 2009 LiDAR topography break interpreted by geomorphologist
Fan Slope	$(\text{Max fan elevation} - \text{Min fan elevation}) / \text{Max flow length} * 100$

Table 3-6. Existing Alluvial Fan Morphology.

Fan #	Basin Area (ac)	Max Flow Length (ft)	Avg Basin Slope (%)	Basin Ruggedness (ft)	Fan Width (ft)	Fan Length (ft)	Fan Thickness (ft)	Fan Area (sq ft)	Fan Slope (%)
1	114	4,558	33.2%	0.68	752	675	24	294,434	26.2%
2	32	2,600	48.3%	1.06	460	470	10.25	89,310	9.2%
3	57	3,548	51.1%	1.15	690	645	26	259,613	16.6%
4	1,128	1,0086	15.7%	0.23	610	708	12	236,738	12.8%
5	70	3,342	52.0%	0.99	440	520	17	148,258	22.1%
6	93	5,959	22.5%	0.66	500	545	15.5	158,378	20.0%
7	42	3,368	33.4%	0.83	245	202	9	27,607	22.3%
8	93	3,912	31.7%	0.62	820	583	15.5	329,912	14.1%
9	54	2,446	42.1%	0.67	485	565	15.5	147,370	21.1%
10	28	3,068	35.2%	0.97	400	280	10.5	74,454	13.6%
Max	1,128	10,086	52%	1.15	820	708	26	329,912	26%
Avg	171	4,289	37%	0.79	540	519	16	176,607	18%
Min	28	2,446	16%	0.23	245	202	9	27,607	9%

Note: Fan numbering corresponds with fans illustrated above in Figure 3-4.

3.3.3 Hydrology

This EFSFSR basin is approximately 25 square miles in size with elevations ranging from 9,220 feet to 5,930 feet with a south to north flow direction. The basin averages 32.7 inches of annual precipitation, with the dominant form of precipitation occurring as snow in the winter months (United States Geological Survey [USGS], 2017a). The watershed's stream network is largely dominated by snow and snowmelt processes resulting in peak runoff in May and June with base flows typically occurring in September through March.

For the proposed restoration designs, two important hydrologic conditions include: 1) peak flood flow frequencies to assess channel and floodplain stability; and 2) daily exceedance discharges at varying time intervals based on fish species and life stage of interest to assess fish passage design criteria and associated aquatic habitat for all reaches, identified species, and life stages. These metrics were quantified at select locations using USGS stream gage data. Regression equations were developed to estimate these metrics anywhere within the mine site proper project area. This historical information was used in the development of proposed hydrologic scenarios and to assess potential climate change trends. A summary of the project area hydrology is provided below, with detailed descriptions of methods, data, results, and conclusions provided in Appendix C.

The majority of peak flow events at the project site occur as a result of snowmelt runoff during spring and early summer – April (6%), May (56%) and June (39%). There are six stream gages, maintained by the USGS, near the project area that are collecting, or have historically collected, water stage and discharge data (Table 3-7). Historical streamflow records from the stream gages were utilized to aid in the quantification of hydrological statistics and to estimate probabilistic discharges throughout the project area. Peak flood flow discharges for select recurrence intervals are displayed in Table 3-8 while daily flow exceedance values for various fish species and fish use periods are shown in Table 3-9.

Table 3-7. USGS Gaging Station Summary.

Gage Number	Description	Latitude	Longitude	Period of Record	Years of Record
13310850	Meadow Creek Near Stibnite, ID	44.88953	115.36022	2012-2017	6
13310800	EFSF Salmon Above Meadow Creek Near Stibnite, ID	44.90225	115.32567	2012-2017	6
13311450	Sugar Creek Near Stibnite, ID	44.93636	115.33722	2012-2017	6
13311000	EFSF Salmon at Stibnite, ID	44.90572	115.32950	1929-1942, 1983-1997,	36
13311250	EFSF Salmon Above Sugar Creek Near Stibnite, ID	44.93478	115.33669	2012-2017	6
13311500	EFSF Salmon Downstream of Sugar Creek Near Stibnite, ID (offsite)	44.93639	115.33944	1929-1941	13
13313000	Johnson Creek at Yellow Pine, ID (offsite)	44.96167	115.50000	1928-2017	89

Note: Source is USGS website (USGS, 2017b).

Table 3-8. Peak Flood Discharge (CFS) at Select Recurrence Intervals for Project Reaches.

Annual Exceedance Probability		0.6667	0.5	0.2	0.1	0.04	0.02	0.01	0.002
Recurrence Interval (Years)		1.5	2	5	10	25	50	100	500
Reach	MC1A	41	46	58	65	73	78	83	93
	MC1B	19	21	25	27	30	32	33	37
	MC1C	30	33	42	46	51	55	58	65
	MC1D	44	52	70	81	93	101	109	125
	MC1E	67	79	106	123	141	154	166	190
	MC2	84	99	133	154	177	193	208	238
	MC3	84	99	133	154	177	193	208	238
	MC4	89	105	143	166	192	211	227	262
	MC5	108	130	182	213	250	276	300	351
	MC6	111	134	188	221	260	288	313	367
	BC1	33	37	46	51	57	61	65	73
	BC2	37	42	53	60	67	72	76	86
	BC3	38	43	55	61	69	74	78	88
	EF1	83	97	130	149	172	187	201	230
	EF2A	175	216	317	380	455	508	558	667
	EF2B	191	235	341	406	484	539	590	701
	EF2C	214	261	373	442	524	580	633	747
	EF3A	215	263	376	445	526	583	636	750
	EF3B	227	276	392	462	546	604	657	773
	EF3C	234	285	405	479	566	626	682	803
	EF4	236	288	409	483	572	633	690	812
	FC1	14	16	20	22	24	26	27	30
	FC2	16	18	23	26	28	30	32	35
	MNC1	9	10	12	13	14	15	15	16
	MNC2	9	10	12	13	14	15	15	16
	HC1	6	6	7	8	8	9	9	10
	HC2	6	6	7	8	8	9	9	10
	GC1	5	6	7	7	8	8	8	9
	WE1	0.7	0.8	1.2	1.5	1.8	2.1	2.4	3.0
	WE2	1.7	2.1	3.2	3.9	4.8	5.4	6.1	7.6
WE3	5.6	7.0	10.6	13	16	18	20	25	

Table 3-9. 5% and 95% Annual Daily Exceedance Discharge (CFS) for Select Salmonid Species for Project Reaches.

Reach	Juvenile Salmonids		Adult Chinook Salmon		Adult Steelhead		Bull Trout		Westslope Cutthroat Trout	
	5%	95%	5%	95%	5%	95%	5%	95%	5%	95%
MC1A	14	0.6	13	0.8	21	0.6	12	0.7	19	0.7
MC1B	6.0	0.3	5.3	0.3	8.9	0.2	5.0	0.3	8.1	0.3
MC1C	11	0.5	9.8	0.6	16	0.5	9.2	0.6	15	0.5
MC1D	29	0.8	30	1.2	44	1.2	28	1.1	43	1.1
MC1E	45	1.3	47	1.9	69	1.9	44	1.8	68	1.8
MC2	49	1.4	51	2.1	75	2.1	48	2.0	74	2.0
MC3	51	1.6	53	2.3	78	2.3	49	2.2	77	2.2
MC4	53	1.7	55	2.5	81	2.5	51	2.4	81	2.4
MC5	69	2.8	70	4.0	103	4.1	65	3.8	108	3.8
MC6	72	3.0	73	4.3	107	4.3	68	4.1	113	4.0
BC1	12	0.5	11	0.7	18	0.5	9.9	0.6	16	0.6
BC2	15	0.7	13	0.9	22	0.6	12	0.8	20	0.7
BC3	15	0.7	14	0.9	23	0.6	13	0.8	21	0.7
EF1	43	2.4	41	4.0	72	2.0	37	3.8	71	2.5
EF2A	125	6.7	123	9.4	183	9.5	114	8.9	204	8.8
EF2B	131	6.9	127	9.7	199	9.2	118	9.1	210	8.6
EF2C	140	7.2	133	10	222	8.9	123	9.4	219	8.4
EF3A	141	7.2	134	10	223	8.9	123	9.4	220	8.4
EF3B	145	7.4	137	10	234	8.7	126	9.6	224	8.2
EF3C	149	7.6	141	11	242	9.1	130	10	233	8.6
EF4	150	7.7	143	11	245	9.3	131	10	235	8.7
FC1	7.6	0.3	6.7	0.6	11	0.3	6.3	0.5	10	0.4
FC2	9.3	0.4	8.3	0.7	14	0.4	7.8	0.6	13	0.4
MNC1	4.4	0.2	3.9	0.3	6.5	0.2	3.6	0.3	5.9	0.2
MNC2	4.4	0.2	3.9	0.3	6.5	0.2	3.6	0.3	5.9	0.2
HC1	3.3	0.1	2.9	0.3	4.9	0.1	2.7	0.3	4.4	0.1
HC2	3.3	0.1	2.9	0.3	4.9	0.1	2.7	0.3	4.4	0.1
GC1	2.3	0.1	2.1	0.2	3.5	0.1	2.0	0.2	3.2	0.1
WE1	0.3	0.0	0.2	0.0	0.4	0.0	0.2	0.0	0.4	0.0
WE2	0.8	0.0	0.7	0.1	1.1	0.0	0.6	0.0	1.0	0.0
WE3	2.8	0.1	2.5	0.2	4.1	0.1	2.3	0.2	3.8	0.1

Notes:

1. Juvenile Salmonids are within the system year-round.
2. Adult Chinook salmon are assumed to be within the system from mid-June through Mid-September.
3. Adult steelhead are assumed to be within the system from April through May.
4. Bull trout are assumed to be within the system from mid-June through September.
5. Westslope cutthroat trout are assumed to be in the system from mid-March through Mid-July.

3.3.4 Hydraulics

3.3.4.1 Roughness Analysis

Hydraulic roughness was estimated for a wide range of discharges at each of the five USGS gage locations to inform the design of proposed channels. Available field measurements collected to develop discharge – stage rating curves (USGS, 2017b) were obtained from USGS. These data include stage, discharge, channel width, and channel area. Assuming a rectangular channel cross section, depth, wetted perimeter, and hydraulic radius was calculated. Channel slope was approximated from 2010 LiDAR data (provided by Midas Gold) assuming a 200-foot reach length centered at the gage site. Assuming normal depth conditions, the Manning’s equation (Equation 3-1) was used to estimate the channel roughness. Figure 3-5 shows the variation in n-value as a function of stage for USGS Gage 13311000.

$$n = \frac{1.49}{Q} AR^{2/3} S^{1/2} \quad \text{Equation 3-1}$$

Where:

- n is the Manning’s roughness value
- Q is the discharge (cfs),
- A is the channel cross sectional area (ft²),
- R is the hydraulic radius (ft), and
- S is the channel slope (ft/ft)

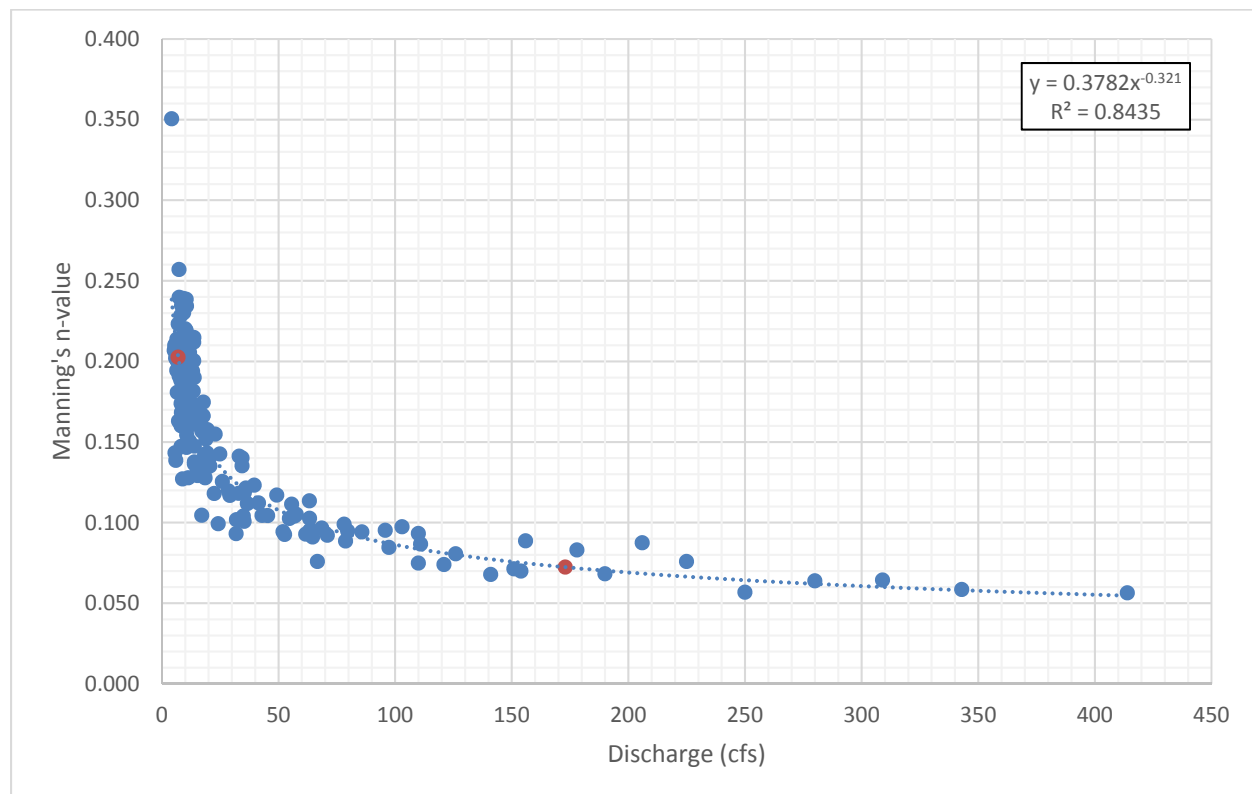


Figure 3-5. Manning’s n-value Estimation at USGS Gage 13311000 in Relation to Discharge (Red Dots Are Associated with the 1.5-Year Peak Flow (Channel Forming) and the 95% Annual Daily Exceedance Flow (Low Flow)).

The n-values associated with the 1.5-year return flow (channel forming) and low flow (95% annual exceedance flow) from the five USGS gages located on or near the project site were analyzed to determine the degree of correlation. Typically, bed roughness is related to sediment size in flatter gradient systems as developed with Limerinos' equation (USGS, 1970). Since slope is proportional to shear, which is used to estimate the average piece of sediment size mobilized at certain flows, slope was selected as the most significant variable (Leopold et al., 1964). This information was used to develop a regression equation for existing roughness values at low flow and bankfull flow based on channel slope for existing conditions. It is assumed that the proposed channels would consist of similar sediment (size and shape) to existing conditions, so these values were utilized as initial n-value estimates in proposed conditions hydraulic calculations. The relationships for low flow and high flow channel roughness (Manning's n-value) relative to channel bed slope are shown in Figure 3-6.

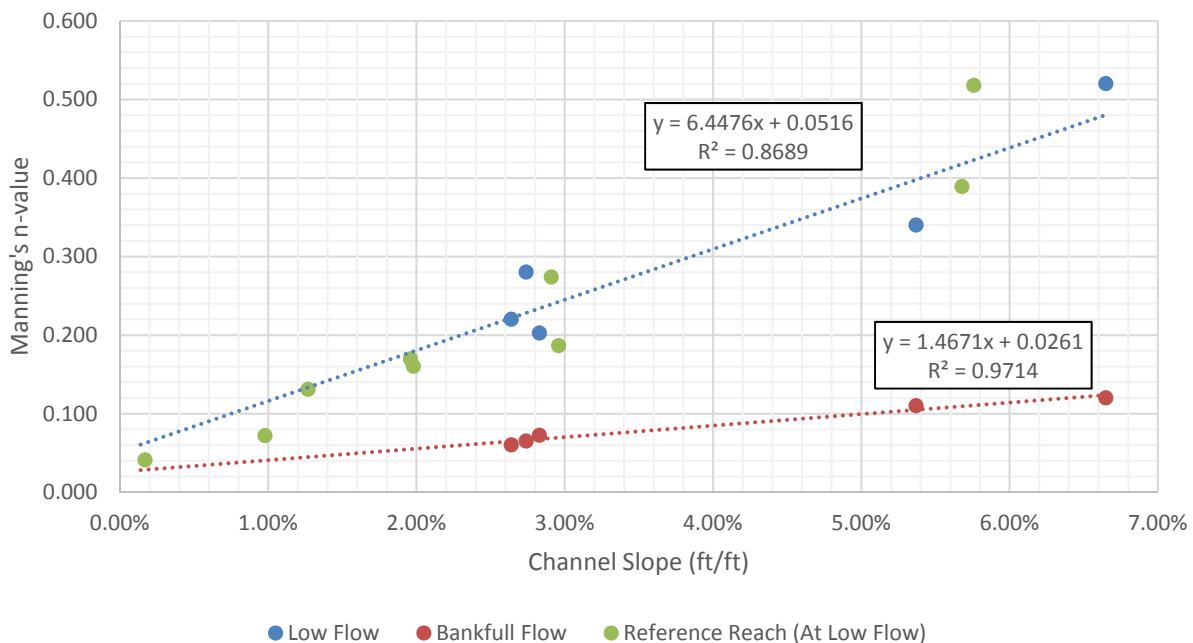


Figure 3-6. Manning's n-value Estimation for the Project Site Based On Channel Slope At Both Low Flow and Channel Forming Flow.

Note: Reference reach data are plotted for comparison purposes only, since they were not measured at specifically the 95% annual exceedance flow as were the USGS gaging sites. These values were not used in the development of the trendline and regression equation for estimating low flow channel roughness.

3.3.4.2 Proposed Conditions

Proposed hydraulic conditions were analyzed using at-a-station hydraulic calculations assuming normal depth at one typical section per design reach (example cross section illustrated in Figure 3-7). These sections were analyzed at the 95% annual exceedance discharge, the 1.5-year recurrence peak flood, and the 100-year recurrence peak flood. Hydraulic characteristics analyzed from these calculations include channel velocity, channel shear, and sediment size mobilized. Channel velocity was reviewed for acceptability and will be used to assess validity of bank treatments and potential revegetation efforts in future design phases. Channel shear was used to assess sediment transport competency at the previously selected flow events to estimate mobile bed material, suitability for potential spawning activity, bed stability, and channel substrate design. For all at-a-station calculations it was assumed that proposed slopes would

exhibit similar roughness as existing slopes based on the regression equation obtained from the USGS gaging stations (see Figure 3-5 above). Figure 3-7 below shows representative normal depth calculations for the proposed restored Meadow Creek, Reach MC6.

Design Guidelines / Input		Calculated Design Estimates			
Input	Explanation	Q ₉₅	Q _{BF}	Q _{100-YR}	Explanation
Reach Characteristics	9.82 = DA = Drainage Area (mi ²)	0.0199	0.0199	0.0228	= S = Existing Slope (ft/ft)
	2057 = L _v = Valley Length (ft)	3	111	313	= Required Discharge (cfs)
	2357 = L _c = Channel Length (ft)	0.7	1.9	0.4	= D _{max} = Max Water Depth (ft)
	6533 = ELEV _{US} = Upstream Elevation (ft)	14.5	18.1	248.5	= W _t = Top Width (ft)
	6486 = ELEV _{DS} = Downstream Elevation (ft)	14.57	14.57	244.00	= W _b = Bottom Width (ft)
	1.15 = K = Sinuosity (ft/ft)	5.15	24.53	135.02	= A = Cross-Sectional Area (ft)
	0.0228 = S _v = Existing Valley Slope (ft/ft)	14.62	18.89	249.36	= P = Wetted Perimeter (ft)
	0.0199 = S _c = Existing Channel Slope (ft/ft)	0.35	1.30	0.54	= R = Hydraulic Radius (ft)
	244 = W _{FP} = Average Floodplain Width (ft)	0.58	4.53	5.48	= V _{ch} = Channel Velocity (ft/s)
	Hydrology	3 = Q ₉₅ = 95% Annual Exceedance Flow (cfs)	NA	NA	1.31
111 = Q _{BF} = Bankfull Discharge (cfs)		0.44	1.62	2.15	= τ _{ch} = Channel Shear Stress (lbs/ft ²)
313 = Q _{100-YR} = 100-Year Discharge (cfs)		NA	NA	0.63	= τ _{fp} = Floodplain Shear Stress (lbs/ft ²)
Channel Characteristics	18 = W _{BF} = Estimated Bankfull Width (ft)	3.0	111	313	= Q = Resulting Discharge (cfs)
	9.5 = W/D _{max} = Width/Max Depth Ratio (ft/ft)	0.17	0.69	0.55	= Froude Number
	10 = z _c = Channel Bottom Side-Slopes (H:1V)	0.4	1.4	0.5	= D _{ave} = Average Depth (ft)
	1.5 = z _b = Bank Side-Slopes (H:1V)	NA	13.4	NA	= W/D = Width to Depth Ratio (ft/ft)
	5 = z _{fp} = Floodplain Side-Slopes (H:1V)	26	96	127	= D ₅₀ = Uniform Mobile Sediment (mm)
	0.180 = n _{low} = Manning's n Value (Baseflow)	33	129	173	= D ₈₄ = D ₈₄ Mobile Sediment (mm)
	0.055 = n _b = Manning's n Value (Bankfull)				
	0.1 = n _{fp} = Manning's n Value (Floodplain)				

Note: Design estimates are targets for only certain enhancement elements - some design estimates may not be appropriate depending on the type of enhancement work.

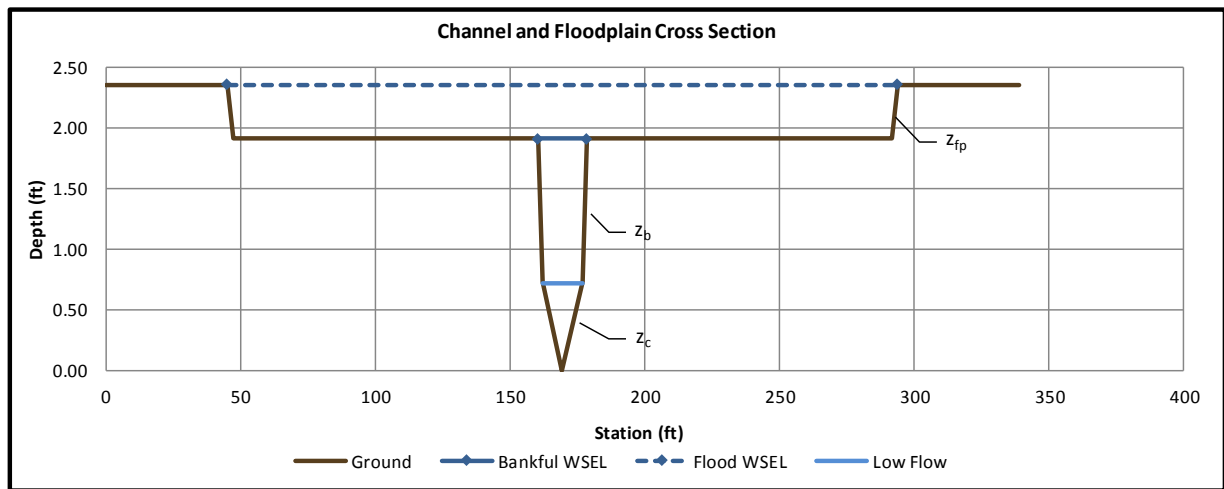


Figure 3-7. Sample Normal Depth at-a-Station Hydraulic Calculation Workbook (Reach MC6).

3.3.5 Sediment Transport

Sediment size data representing the mobile bed material was collected at multiple sites throughout the SGP site and associated offsite reference reach locations. Sediment data was collected using Wolman pebble count methodology (Wolman, 1954). From these pebble counts we utilized the Hydraulic Toolbox program developed by the Federal Highway Administration (FHWA) to estimate the material gradation of the sediment data including the D₅₀, which is the particle size for which 50% of the material is smaller (FHWA 2004). Table 3-10 below shows the D₁₆, D₅₀ and D₈₄ for the locations within or adjacent to the SGP site where we obtained sediment data during summer 2017.

Table 3-10. Estimated Material Gradation of Mobile Sediment Pebble Count Data Collected at Reference Sites.

Reference Reach #	Reference Reach	D ₁₆	D ₅₀	D ₈₄
		(mm)		
11	Sugar Creek	35	67	111
12	EFSF Salmon River	21	57	108
13	EFSF Salmon River	3	14	59
21	Meadow Creek (Upper)	4	19	74
22	Meadow Creek (Lower)	16	26	41
23	EFSF Salmon River (Below Existing Man Camp)	22	84	189
NA	EFSF Salmon River (Yellow Pine Pit Delta)	16	43	112

Proposed conditions at-a-station calculations were evaluated for sediment competency (incipient motion) to assess sediment transport continuity and likelihood of retaining spawning size material. Sediment transport continuity assesses competency along a constant channel slope to evaluate the likelihood of aggradation or incision based on existing or anticipated sediment gradations. The combination of channel slope and sediment gradation establishes the likely bed material which can then be compared with spawning material preferences for target species to evaluate likely spawning habitat. Sediment competency was assessed using two equations that utilize shear outputs from the at-a-station calculations. The first equation, developed by the United States Army Corps of Engineers (USACE), utilizes shear to estimate the D₅₀ as seen in Equation 3-2 (Fischenich, 2001). The second equation utilizes shear to estimate the D₈₄ as seen in Equation 3-3 (Leopold, et al., 1964).

$$D_{50} = \frac{\tau}{0.06\gamma(G_s - G_w)\tan\phi} \quad \text{Equation 3-2}$$

Where:

- D₅₀ is the average sediment particle size
- τ is the average shear stress in the channel
- γ is the unit weight of water,
- G_s is the specific gravity of the sediment
- G_w is the specific gravity of water, and
- φ is the angle of internal friction of the sediment

$$D_{84} = 77.966\tau^{1.042} \quad \text{Equation 3-3}$$

Where:

- D₈₄ is the sediment particle size that 84% is passing (mm)
- τ is the average shear stress in the channel (lb/ft²)

Equations 3-2 and 3-3 were used to appropriately size and develop gradations for streambed material in proposed channels. Assuming channel shear stress at the 1.5-year flood event (assumed to be at or near the channel forming flow), the equations provide an estimate of grain sizes that are expected to be mobile on a relatively regular basis thereby allowing the channel to

function similarly to a natural alluvial system. Sizing and development of streambed material gradation is discussed in more detail in subsequent sections.

3.3.6 Engineering Stability Analysis

The following sections outline proposed engineering stability analysis methodologies to be conducted in future design phases. The following list of stability analyses will be considered for each individual restored or enhanced stream reach:

- Streambed, bank, and riffle material sizing;
- Selection of appropriate bioengineered bank treatments;
- Rock armor scour countermeasures for impervious liner system;
- Rock grade control structure material sizing;
- Energy dissipation pool material sizing;
- LWD and Engineered Log Jam Structures.

3.3.6.1 Meadow Reaches

Meadow reaches within the SGP site are characterized as alluvial, meandering, equi-width or pool-riffle streams with low to moderate gradient (less than 3%) and relatively high sinuosity (greater than 1.3). Engineering stability analyses associated with meadow reaches are expected to include sizing of streambed material, riffle material, and bank material and/or bank treatments to withstand the expected hydraulic conditions under proposed conditions. Materials used to construct meadow reaches will be sized such that bed and bank sediment would begin to mobilize around a 1.5-year bankfull discharge. Therefore, streambed material, riffle material, and bank material for meadow reaches will be sized using incipient motion equations (Equations 3-2 and 3-3) opposed to threshold channel design methods where movement of sediment is negligible during the design flow. Material used for the construction of channels is expected to consist of rounded to angular material.

The design streambed material gradation may be further developed based on target rock size ratios per Washington Department of Fish and Wildlife stream crossing design guidelines (Barnard et al., 2013). For example, equations 3-4 to 3-6 may be used to determine material gradation based on preferred rock size(s) determined from incipient motion calculations. The exact ratios for generating a material gradation may vary reach to reach and will be refined as designs progress and will consider habitat goals, available materials, sediment transport regime, and reference reach conditions (if available) so that the resulting material gradation would function as intended and be geomorphically appropriate for a given reach.

$$D_{84}/D_{16} = 8 \quad \text{Equation 3-4}$$

$$D_{84}/D_{50} = 2.5 \quad \text{Equation 3-5}$$

$$D_{84}/D_{100} = 0.4 \quad \text{Equation 3-6}$$

Selection of appropriate bank treatment types (e.g. fabric encapsulated soil lift, native material, riprap, vegetated bank, etc.) will be performed by comparing hydraulic parameters (depth, velocity, and shear stress) with permissible values of various bank treatment types which are designed to have varying degrees of hydraulic performance, as well as function and habitat

value. For example, fabric encapsulated soil lift bank treatment has a relatively high permissible shear stress, approximately 5 pounds per square feet (Manufacturer Specification – Rolanka International Incorporated, BioD Mat-90 coconut fiber erosion control fabric). Therefore, this bank treatment type will be considered for stream bank locations where shear stress is not expected to exceed the permissible shear stress and where high habitat value is needed. Permissible characteristics of each bank treatment type will be determined in future design phases after the conceptual design concepts have undergone agency review.

The proposed method for sizing stable riffle material includes evaluating incipient motion calculations, the details of which are discussed in Section 3.3.5. The process includes comparing calculated bed shear stress at proposed locations (within a typical pool, riffle, inside or outside bank) to the critical shear stress required to entrain specific particles sizes.

Other proposed analyses for Meadow Reaches may include LWD and ELJ stability, and sizing of rock armor over impervious liners, the details of which are discussed in subsequent sections.

3.3.6.2 Forced Step Pool Reaches

Forced step pool reaches within the SGP site will be designed as alluvial or threshold streams with moderate to steep gradient (3 to 8%) and relatively low sinuosity (1.2 to 1.4). Step pool habitat is typically comprised of coarse-grained substrate providing both grade control during high flows and instream habitat during low flows. The arrangement of rocks and boulders within a step pool reach is expected to vary considerably and would not look like a series of boulder weirs. Pockets of immobile boulders would force hydraulic drops low enough to allow upstream fish passage while providing for deep self-sustaining pools and riffles that would promote gravel sorting. Step pool Reaches will be designed using the primary steps as detailed in USBR, 2007:

- Step 1 – Estimate step pool height (no greater than 1.5 feet);
- Step 2 – Estimate step pool spacing;
- Step 3 – Size step pool boulders and streambed material;
- Step 4 – Estimate scour potential.

Various methods for calculating step height found in the literature are presented in Table 3-11.

Table 3-11. Summary of methods for computing step pool height (from USBR, 2007).

Method	Reference
Relative drop height $H/y_c \leq 1$ Where: H=Weir Drop Height Y_c =critical depth	Thomas et al. 2000
Step Steepness $H/L = 1.5 * S$ (H/LS) values between 1 and 2 Provide maximum flow resistance Where: H=Weir Drop Height L=Weir Spacing or Step Length S=Channel Slope	Abrahams et al. 1995
H=Depends on fish species	Local agency fish passage criteria

Several methods for determining the step pool frequency are published, however each has limitations. Using the available methods, analyzing and averaging the results provides a step length that accounts for the variations of the different methods. From previous studies, step pool geometry should be designed within a range of $1 \leq H/L/S \leq 2$ (Height/Length/Slope) to provide maximum flow resistance with a mean of 1.5. From published research, results of the ratio ranged from $0.5 \leq H/L/S \leq 2.1$ with a mean of 1.4 (Chin, et al. 2009). Various methods for calculating step pool frequency found in the literature are presented in Table 3-12.

Table 3-12. Summary of methods for computing step pool frequency (from USBR, 2007).

Method	Reference
$L = 0.31 * S^{1.19}$ Where: L=step-pool spacing (m) S=channel slope	Whitaker 1987
Step-Pool spacing = 2-3 channel widths	Knighton 1998
$L = f(H, ACW, S_o, q_{design})$ Where: H=Weir Drop Height ACW=Active Channel Width S _o =Channel Slope q _{design} =Design unit discharge	Thomas et al. 2000
Step-pool spacing = 0.43-2.4 channel widths	Chin 1989
Select L such that $\Delta h_{wse} \leq 0.2m$	DVWK 2002
$H/L = 1.5 * S$	Abrahams et al. 1995
$P_s = 8.2513 S_o^{-0.9/99}$ Where: P _s = pool spacing/bankfull width	Rosgen 2001

Streambed material for alluvial Step Pool Reaches will be sized similarly to Meadow Reaches using incipient motion techniques while streambed material for threshold Step Pool Reaches will be sized similarly to Cascade Reaches discussed in Section 3.3.6.3 Cascade Reaches. To determine the size of boulders for construction of man-made step pool structures (Thomas et al., 2000) suggest using the USACE, 1991 steep slope riprap design method for sizing the step rocks supplemented with anchor boulders. An appropriate safety factor should be considered to provide ample burial depth. The USACE steep slope riprap equation is presented.

Equation 3-7

$$D_{30} = \frac{1.95 * S^{0.555} * q^{2/3}}{g^{1/3}}$$

Where:

- S slope of the rock ramp
- q is the design unit discharge, USACE 1991 recommends a 1.25 flow concentration factor such that $q = 1.25(Q/W)$
- g is the acceleration due to gravity
- D₃₀ is the characteristic stone size 30 percent quantile

The USACE relationship for steep slope results in a D30 that must be translated to a D50 for comparison with other methods using the following equation.

Equation 3-8

$$D_{50} = D_{30} * [D_{85}/D_{16}]^{1/3}$$

Where:

D_{30}	is the characteristic stone size 30 percent quantile
D_{85}	is the characteristic stone size 85 percent quantile
D_{16}	is the characteristic stone size 16 percent quantile
D_{50}	is the characteristic stone size 50 percent quantile

As with step frequency, several methods for determining the step pool scour are available, each with varying limitations. Using the available methods, analyzing and averaging the results provides a scour depth that accounts for variations of the different methods. This process is expected to be repeated for each calculated step height from the previous step. Proposed scour equations, as described in the USBR, 2007, used for evaluating Step Pool Reaches are summarized below.

Schoklitsch (1932): Equation 3-9

$$d_s = 4.75 * \frac{H^{0.2} * q^{0.5}}{D_{90}^{0.32}}$$

Where:

d_s	total depth from the downstream water surface to the deepest point in the scour hole, meters
H	difference between the upstream energy grade line and the downstream water surface, meters
q	water discharge per unit width, meters squared per second
D_{90}	particle diameter for which 90 percent of the material is finer; millimeters

Eggenberger (1943): Equation 3-10

$$h_s = d_s + h_d = C * \frac{H^{0.5} * q^{0.6}}{D_{90}^{0.4}}$$

Where:

h_s	total depth from the downstream water surface to the deepest point in the scour hole, meters
d_s	total depth from the downstream bed to the deepest point in the scour hole, meters
h_d	water depth in the downstream reach, meters
C	coefficient based on flow split, equal to 22.88 for spill over
H	difference between the upstream energy grade line and the downstream water surface, meters
q	water discharge per unit width, meters squared per second
D_{90}	particle diameter for which 90 percent of the material is finer; millimeters

Jaeger (1939): Equation 3-11

$$h_s = d_s + h_d = 6H^{0.25} * q^{0.5} * \left(\frac{h_d}{D_{90}}\right)^{1/3}$$

Where:

h_s	total depth from the downstream water surface to the deepest point in the scour hole, meters
d_s	total depth from the downstream bed to the deepest point in the scour hole, meters
h_d	water depth in the downstream reach, meters
H	difference between the upstream energy grade line and the downstream water surface, meters

q	water discharge per unit width, meters squared per second
D ₉₀	particle diameter for which 90 percent of the material is finer; millimeters

USBR (1984): Equation 3-12

$$d_s = K * H^{0.225} * q^{0.54} - d_m$$

Where:

d _s	local scour depth (below unscoured bed level) immediately downstream of vertical drop, meters
K	1.9
H	difference between the upstream energy grade line and the downstream water surface, meters
q	water discharge per unit width, meters squared per second
d _m	tailwater depth immediately downstream of scour hole, meters

D'agostino and Ferro (2004): Equation 3-13

$$\frac{s}{z} = 0.975 * \left(\frac{h_o}{z}\right)^{0.863}$$

Where:

s	total depth from the downstream bed to the deepest point in the scour hole, meters
z	difference in height between the crest of the grade control structure and the bottom of the downstream undisturbed bed level, meters
h _o	water depth at the crest, meters

3.3.6.3 Cascade Reaches

Cascade Reaches within the SGP site are characterized as threshold channels with very steep gradients (8 to 15%) and low sinuosity (near 1.0). These reaches include Blowout Creek (BC2) and Midnight Creek (MNC1). Channel design for Cascade Reaches will be completed using the primary iterative steps as detailed by the Bureau of Reclamation (USBR, 2007):

- Step 1 – Estimate channel roughness;
- Step 2 – Estimate interstitial flow velocity and discharge;
- Step 3 – Size channel (using roughness and design discharge) and determine hydraulic performance (flow velocity, depth, and basal shear stress);
- Step 4 – Size channel bed and side slope material.

Channel roughness represents the energy dissipation occurring in the channel because of the loss of mechanical and kinetic energy. In very steep channels, channel roughness is dominated by form resistance and skin friction. Form resistance results from bed material grains and other obstructions such as streambanks. Energy is also dissipated through shear forces created by the difference in flow velocities from zero at the channel bed to maximum velocity at the water surface. There are multiple empirically-derived methods for estimating roughness coefficient. Many of these methods assume that flow depth is much greater than the size of the channel bed grains, and consequently flow velocity follows a logarithmic profile from the channel bed to the water surface. However, channel bed grain size is commonly similar to flow depth in steep channels. For this reason, a flow resistance method for shallow flows is proposed to estimate channel roughness. Katul et al., 2002 found that the mean velocity between the bed grains is small relative to the mean velocity above the bed grains. This velocity differential creates shear instabilities that create an inflectional velocity profile rather than a power law profile. This

difference increases channel roughness at shallow flow depths. Therefore, channel roughness for cascade reaches will be determined using Katul et al., 2002, using the following relation (Figure 3-8):

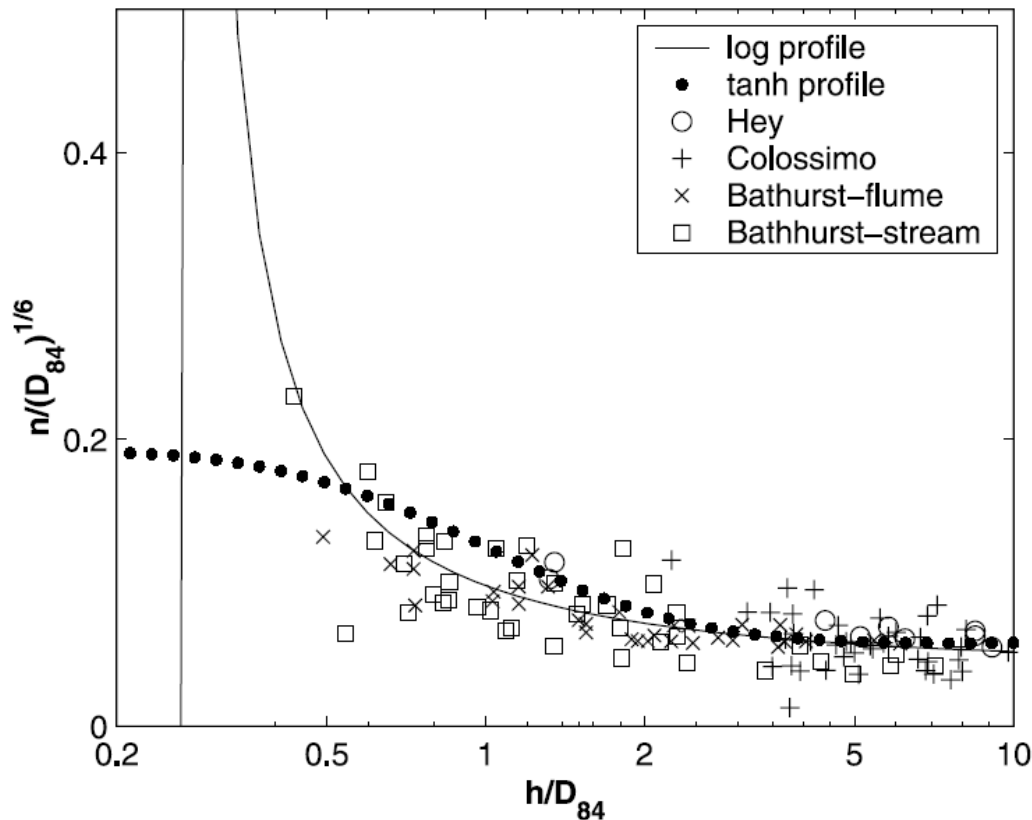


Figure 3-8. Predicted and measured $n/(D_{84})^{1/6}$ as a function of h/D_{84} for several data sets (from Katul, et al. 2002).

Where h = flow depth; “ n ” = Manning’s roughness coefficient; and D_{84} = the bed material size of which 84 percent of the bed material is finer. Selection of channel roughness for the other proposed reach types (pool riffle and step pool) will be made following the method described in Section 3.3.4.1.

The bed material of the roughened channel within cascade reaches would consist of large grain size material. Because the channel would not be sealed, some water would flow between the grains. The Stephenson equation (as cited in USBR, 2007) computes flow through a riprap layer using interstitial velocity, v_i .

Stephenson equation (USBR, 2007): Equation 3-14

$$v_i = n_p * \left(S_0 * g * \frac{D_{50}}{K'} \right)^{1/2}$$

Where:

- v_i quantity of flow passing through the riprap layer, cubic meters per second
- n_p porosity of riprap layer
- S_0 slope of rock ramp
- g acceleration due to gravity (9.81 m/s²)
- D_{50} is the characteristic stone size 50 percent quantile
- K' friction coefficient

Interstitial flow will be reduced by ensuring a wider distribution of grain sizes available to fill interstices between larger grain elements to prevent excessive subsurface flow (i.e. dry channel). The ratio of D_{84} to D_{16} is a measure of the “width” of the grain size distribution and is expected to exhibit a good representation of multiple grain sizes.

Channel dimensions of cascade reaches will be determined using Manning’s equation for mean velocity using Manning’s roughness as a function of stage and multiplying velocity by cross-sectional flow area to obtain volumetric flow rate. The Manning equation for mean velocity at a cross-section is:

Equation 3-15

$$v = \frac{1.49}{n} * R^{\frac{2}{3}} * S^{\frac{1}{2}}$$

Where:

n	Manning’s roughness value
R	hydraulic radius, feet
S	slope, feet/feet
v	mean velocity, feet per second

Streambed material for Cascade and threshold Step Pool Reaches will be sized using methods recommended by the Bureau of Reclamation (USBR, 2007). Six different rock sizing methodologies are proposed for design with the selected design median rock size (D_{50}) typically being the average of all methods excluding the highest and lowest values. However, each method has its own range of applicability, so it is important to understand the limitation of each method. Furthermore, the selected rock size for design will consider habitat goals and therefore in some cases the high, low, mean, average selected methods, or a single method may be selected for design.

Six equations used for sizing streambed material and three equations used for sizing streambank material for Cascade and Step Pool Reaches are summarized in USBR, 2007.

3.3.6.4 Rock Chutes

The design streambed material gradation may be further developed based on target rock size ratios or coefficients of uniformity as described in USBR, 2007. And, in some cases it may be necessary to evaluate the need for a streambed material filter layer to prevent piping of the underlying base material. Guidance for performing such an analysis is also described in USBR, 2007 Rock Chute Reaches.

Rock Chute Reaches within the SGP site are characterized with very steep gradients (greater than 15%) and low sinuosity (near 1.0). Currently, the conceptual design specifies rock chutes at Meadow Creek (MC3), Fiddle Creek (FC2), Hennessy Creek (HC2,), and West End (WE2 and WE3). Rock chutes would be unlined (excavated into bedrock and oversized to convey the design flow) or lined (containing a liner system, associated rock armor layer, and riprap layer). Lined rock chute channels would be located on top of DRSF sites.

For lined rock chute channels, the design will follow threshold channel design techniques. In threshold channels, movement of the channel boundary is minimal or nonexistent for stresses at or below the design flow condition. Therefore, the design approach for a threshold channel is to select a channel configuration where the stress applied during design conditions is below the allowable stress for the channel boundary. A requirement for a channel to be considered a

threshold channel is that the sediment transport capacity must not mobilize bed armor while transporting nearly all the inflowing sediment load so that there is no significant exchange of material between the sediment carried by the stream and the streambed. Many sources and techniques are available for designing stable threshold channels. It is proposed that either the allowable velocity approach or allowable shear stress approach be used for designing rock chutes such as the methodologies detailed in NRCS, 2007a.

3.3.6.5 Energy Dissipation Pools

Energy dissipation pools are located within Cascade and Rock Chute Reaches. These structures are strategically located as channel planform and stream profile allow to dissipate high stream energy instead of transferring it to downstream reaches in an uncontrolled fashion. The design procedure for energy dissipation pools will follow the guidelines as detailed in Hydraulic Engineering Circular No. 14, Third Edition (FHWA, 2006). Figure 3-9 shows a typical profile of an energy dissipation pool with the following features:

- The basin is pre-shaped and lined with riprap to a thickness that is at least two times that of the median grain size of the riprap;
- The riprap floor is constructed at the approximate depth of scour that would occur in a thick pad of riprap. The h_s/D_{50} of the riprap material should be greater than 2;
- The length of the energy dissipating pool (L_S) is $10 \cdot h_s$, but no less than $3 \cdot W_0$; the length of the apron (L_A) is $5 \cdot h_s$, but no less than W_0 . The overall length of the basin (L_B), is $15 \cdot h_s$, but no less than $4 \cdot W_0$;
- A riprap cutoff wall or sloping apron can be constructed if downstream channel degradation is anticipated.

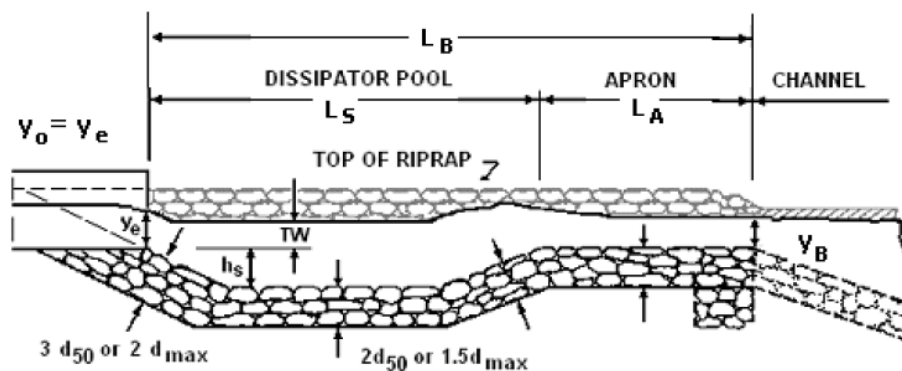


Figure 3-9. Typical profile of energy dissipation pool (from FHWA, 2006).

3.3.6.6 Small Woody Debris (SWD) and Large Woody Debris (LWD) Structures

The PNF defines LWD as pieces greater than 12 inches in diameter and 35 feet in length (USFS, 2003). The Matrix WCI criteria are defined in terms of LWD density and recruitment potential. For stream reaches not functioning appropriately and/or functioning at unacceptable risk according to the Stream Functional Assessment (HDR, 2016), installation of SWD and/or LWD

is proposed to meet target LWD densities (understanding that the Stream Functional Assessment only considers LWD). Several different types of woody structures are proposed for both restored and enhanced reaches ranging from single log to multiple log structures and each type of structure is intended to serve a specific function. Table 3-13 summarizes the type and function of LWD structures proposed for the SGP.

Table 3-13. Proposed Wood Structures for the SGP.

LWD Structure	Wood Type/ Size	Function
Log Floodplain Roughness Structure	Can be SWD or LWD	Floodplain habitat
Toe Log Structure	Can be SWD or LWD	Instream habitat; initial bank stability
Small Apex Jam Structure	Can be SWD or LWD	Instream habitat; split flow; bar formation
Tight Radius Jam Structure	Can be SWD or LWD	Instream habitat; initial bank stability
Bend Jam Structure	Can be SWD or LWD	Instream habitat; initial bank stability
Sweeper Log Structure	Can be SWD or LWD	Instream habitat; improve wood recruitment
Channel Spanning Structure	Can be SWD or LWD	Instream habitat; improve wood recruitment
Wood Habitat Structure	Can be SWD or LWD	Instream habitat; initial bank stability
Turning Log Structure	Can be SWD or LWD	Instream habitat; flow deflector

The design procedure for SWD and LWD structures will be based on USBR's Large Woody Materials Risked-Based Design Guidelines (USBR, 2014). Safety factors are ratios of resisting to driving forces. Engineers often compensate for uncertainty in design computations by modifying designs in order to increase the safety factor. The USBR (ibid) recommend safety factors for large wood structures based on risk profile and failure mode as shown below in Table 3-14. Risk is divided between the overall project and individual structures. Our evaluation of the overall project risk has been evaluated as "Low" for both public safety and property damage. Individual structure risk will be evaluated at a future date as part of a later design phase.

Table 3-14. Proposed Safety Factors used for Wood Structure Stability Design.

Public Safety Risk	Property Damage Risk	Stability Design Flow Criteria	FOS _{sliding}	FOS _{bouyancy}	FOS _{rotation} FOS _{overturning}
High	High	100-Year	1.75	2.0	1.75
High	Moderate	50-Year	1.5	1.75	1.5
High	Low	25-Year	1.5	1.75	1.5
Low	High	100-Year	1.75	2.0	1.75
Low	Moderate	20-Year	1.5	1.75	1.5
Low	Low	10-Year	1.25	1.5	1.25

Note: Table from USBR, 2014.

Design Criteria

Principal design criteria for the SGP stream design include channel slope, channel capacity, channel bed stability, pool depth, wood loading, and FPW. The development of each principal design criterion is summarized below, with additional criteria and rationale summarized in the following sections.

Channel Slope – Channel slope is a critical variable in determining channel form and associated channel type. Average reach slopes have been broken into five ranges that have been used to classify the design channel type (Table 3-15).

Table 3-15. Channel Slope and Associated Type.

Reach Slope Range (ft/ft)	Channel Type	Rosgen Classification
$0.0010 < S < 0.0050$	Equi-width Meandering Channel	E
$0.0010 < S < 0.0300$	Pool Riffle Meandering Channel	C
$0.0300 < S < 0.0800$	Step Pool Channel	B
$0.0800 < S < 0.1500$	Cascade Channel	A
$S > 0.1500$	Rock Chute Channel	Aa+

Channel Capacity – Channel capacity is the volume of water a channel can convey before it begins to overtop its banks. For channels in this region this discharge is typically considered to be the 1.5-year peak flow discharge (Castro and Jackson, 2001; USFS, 2004). All channels within Meadow, Step Pool, and Cascade Reaches have been designed to convey the 1.5-year discharge at bankfull conditions, except for Rock Chute Reaches which are sized for the 100-year peak discharge plus a freeboard allowance of 1 foot.

Channel Bed Stability – Channel bed stability determines the relative stability of the channel bed and its ability to scour and adjust vertically as well as the channel's ability to transport that bed sediment downstream. Channels will either be designed as an alluvial channel or a threshold channel. An alluvial channel bed is a channel where bed sediment can mobilize on a fairly regular basis. This is dependent upon local shear and velocities within the channel to estimate channel bed competency. Alluvial channels will be designed with a stable bed at the 1.5-year bankfull discharge. Threshold channels are armored channels that prohibit or limit movement of the channel bed and predominately transport all incoming sediment through a reach with little to no channel boundary deformation. Armored beds will be designed with a stable bed at the 100-year discharge event.

Pool Depth – Pool depth is the depth of a pool at the bankfull discharge. Pools can expend energy within a channel; create more diverse hydraulic conditions; and provide cover, resting habitat, and temperature refuge for fish. Pool scour depth is estimated based on the ratio of radius of curvature to BFW. The average ratio of radius of curvature to BFW in natural channels is approximately 2.8 (NRCS, 2007b). This correlates to an average pool scour depth of approximately 2.0 times the average depth for the proposed channels in the SGP area (*ibid*).

Wood Loading – Wood loading is the abundance or density of large woody material interacting with the channel. Long term wood loading is the abundance or density of large woody material

that has the potential to interact with the channel (within the floodplain or within fall distance of the floodplain). The PNF Plan and the National Marine Fisheries Service (NMFS) wood loading criterion is a minimum of 20 key pieces per mile (NMFS, 1996; USFS, 2003). A key piece is defined as a log with a minimum diameter of 12 inches and a minimum length of 35 feet. For an area to be considered functioning acceptably, it must meet the wood loading criteria and have an adequate source of LWD for both long and short-term recruitment (USFS, 2003). A study by Fox and Bolton 2007 evaluated wood loading in a variety of natural, unmanaged streams of various types and ecoregions in the northwest United States. Their findings recommend that the 75th percentile of the reported range of appropriate wood loading densities (or greater) be used as a temporary management density until basin-scale wood loads achieve the average (50th percentile) tendencies of natural and unmanaged wood-loading ranges. Based on a Douglas fir and ponderosa pine forest, it is estimated a minimum of 32 key pieces per mile would be required to meet the 75th percentile. Based on an alpine forest, it is estimated a minimum of 64 key pieces per mile would be required to meet the 75th percentile.

In addition to key pieces, total number of LWD pieces (total LWD) affects wood loading and associated habitat. From Fox and Bolton, 2007 LWD is defined as a log greater than 4 inches in diameter and greater than 6 feet in length. As with key member recommendations, the total LWD findings from Fox and Bolton, 2007 also recommend using the 75th percentile of the reported range of total LWD as a temporary management objective. Their recommendations include a range (based on channel width) of total LWD loading between 464 and 560 pieces per mile for Douglas fir and ponderosa pine forests, and range of 896 to 1008 pieces per mile for alpine forest. The reported range is a result of findings that suggest the greater the channel width, the greater the wood loading. It is assumed that the SGP is located somewhere in the middle of these two forest types (Douglas fir/ponderosa pine and alpine) and the average of each 75th percentile was used to estimate our minimum wood loading rates of 48 key pieces per mile and 512 to 952 total pieces of wood per mile (depending on channel width).

Floodplain Width – FPW is the average width of the area adjacent the main channel that is accessible to 100-year flood discharge events. FPWs on constructed channel segments are intended to provide sufficient room for long-term lateral migration of the channels. In constructed channels with liners, this FPW is assumed to be 1.25 times the maximum channel belt width (BW). In constructed floodplains without liners, this FPW is assumed to be 2 times the maximum channel BW.

Table 3-16 summarizes the stream design criteria for all proposed enhancement and restoration reaches within the SGP area (refer to Figure 3-1 for map of proposed stream design reaches).

Table 3-16. Stream Design Criteria by Reach.

Reach ID	Channel Capacity	Channel Type	Bed Stability	Pool Depth	Wood Loading	Floodplain Width
MC1A*	1.5-Year Peak Flood Discharge	Equi-width Meandering	Alluvial	2 x Bankfull Riffle Depth	48 Key Pieces Per Mile	1.25 x BW
MCT1B*		Equi-width Meandering	Alluvial			1.25 x BW
MCT1C*		Equi-width Meandering	Alluvial			1.25 x BW
MC1D*		Equi-width Meandering	Alluvial			1.25 x BW
MC1E*		Equi-width Meandering	Alluvial			1.25 x BW
MC2*		Equi-width Meandering	Alluvial			1.25 x BW
MC3*		Rock Chute	Threshold		0	1.25 x BW
MC4		Pool Riffle Meandering	Alluvial		48 Key Pieces Per Mile	2 x BW
MC5		Pool Riffle Meandering	Alluvial			2 x BW
MC6		Pool Riffle Meandering	Alluvial			2 x BW
BC1		Equi-width Meandering	Alluvial		0	2 x BW
BC2		Cascade	Threshold			1.25 x BW
BC3		Step Pool	Threshold		48 Key Pieces Per Mile	2 x BW
EF1		Step Pool	Alluvial			2 x BW
EF2A		Step Pool	Alluvial			2 x BW
EF2B		Step Pool	Alluvial			2 x BW
EF2C		Step Pool	Alluvial			2 x BW
EF3A*		Step Pool	Alluvial			1.25 x BW
EF3B*		Step Pool	Alluvial			1.25 x BW
EF3C*		Step Pool	Alluvial			1.25 x BW
EF4		Step Pool	Alluvial			2 x BW
FC1*		Equi-width Meandering	Alluvial			1.25 x BW
FC2*		Rock Chute	Threshold		0	1.25 x BW
MNC1		Cascade	Threshold			2 x BW
MNC2*		Step Pool	Alluvial		48	2 x BW
HC1		Rock Chute	Threshold		0	2 x BW
HC2*		Step Pool	Alluvial			2 x BW
GC1		Step Pool	Alluvial		48	2 x BW
WE1*		Equi-width Meandering	Alluvial		0	1.25 x BW
WE2*		Rock Chute	Threshold			1.25 x BW
WE3		Rock Chute	Threshold			1.25 x BW

Note: Refer to Figure 3-1 for map of proposed stream design reaches.

Wood loading refers to key pieces per mile, not including additional non-key pieces.

* Denotes reaches restored atop a stream liner.

The proposed restoration activities within the SGP are driven by a number of constraints, objectives, design criteria and general geomorphic characteristics. Constraints include proposed features such as the TSF and DRSFs, existing channel configuration, etc. Objectives were previously defined, but generally include preferential habitat for endangered species act (ESA)-listed salmonids. Geomorphic characteristics include the proper form and function of the channel and associated floodplain to allow the proposed designs to persist in a natural manner at the valley gradient present or expected. These four primary drivers shaped the development of suitable design rationale for each reach as discussed in the following sections.

3.3.7 Valley Shape

Valley Slope

Valley slope is controlled by multiple variables including:

- Natural valley configuration where no major mine operations are occurring;
- Natural settlement and consolidation slopes associated with the TSF;
- Constructed slopes along the face of the constructed DRSF;
- Constructed slopes along the top of the constructed DRSF.

Floodplain Width (FPW)

FPWs have been designed to accommodate future lateral migration of the channel allowing for the establishment of a robust floodplain riparian corridor, long term channel stability, and future large wood recruitment. Design criteria and rationale are summarized above.

3.3.8 Channel Shape

Stream channels are predominately formed from what is commonly called the channel forming flow, often referred to as the bankfull discharge. The channel forming flow for most streams has been reported to typically fall between a 1-year and 3-year recurrence interval for peak flood flows (Segura and Pitlick, 2010). For streams within the Pacific Northwest this has been narrowed down to correlate more with the 1.5-year to 2-year recurrence interval peak flow (Castro and Jackson, 2001). For this study it has been assumed that the channel forming discharge is the peak flow having an annual recurrence interval of 1.5-years.

Channel Slope

Channel slope is a function of the valley slope and proposed sinuosity. Channel slope was estimated based on valley slope, fish intrinsic potential, reference reach sinuosity and professional judgment. Channels were categorized into four different channel types based on proposed slopes as defined below:

- Slopes less than 3% are designed as pool riffle/forced pool channels;
- Slopes between 3% and 8% are designed as forced step pool channels;
- Slopes between 8% and 15% are designed as cascade channels;
- Slopes greater than 15% are designed as rock chute channels.

Channel Width

Channel width was estimated from 16 total equations including 15 regression equations developed from observations of natural, gravel-bed streams in the US, Canada, and the UK

(NRCS, 2007b) and a site-specific regression equation developed from observations at selected SGP reference sites. The 15 previously established regression equations follow a similar format of the power curve in Figure 3-10 except that bankfull discharge (rather than drainage area) is raised to an exponent and multiplied by a coefficient. These coefficients tend to range from 2 to 8 while the exponent typically ranges from 0.4 to 0.8 (NRCS, 2007b). The site-specific regression equation was developed by fitting a power curve to a series of points representing the BFW and associated drainage basin area from observed reference sites as seen in Figure 3-10.

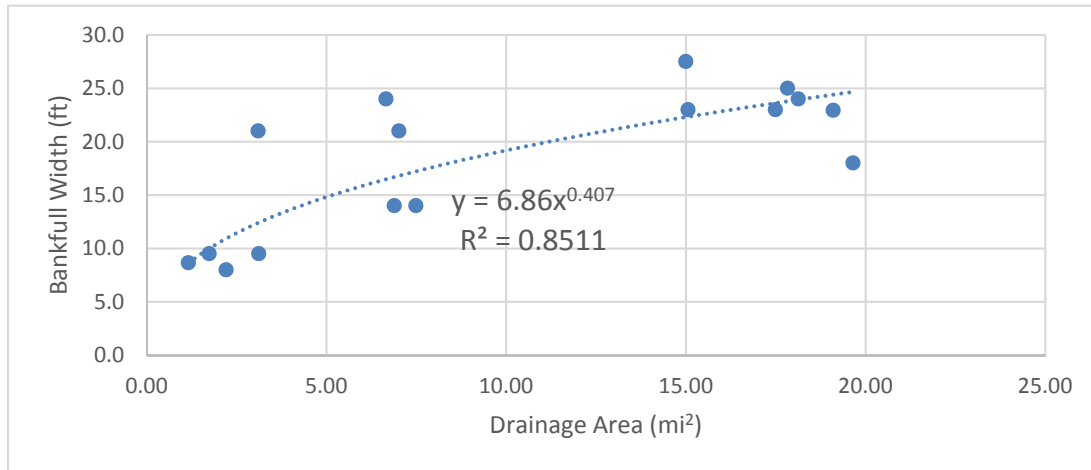


Figure 3-10. Localized Bankfull Width Regression Equation Based on Drainage Area.

Width to Depth Ratio

An initial width to depth ratio was estimated utilizing a manipulated regression equation that estimated depth based on channel sinuosity and channel width. This equation is shown as Equation 3-11. Upon completing at-a-station hydraulic calculations (described above), the width to depth ratio was slightly refined to accommodate desired sediment competency.

$$WD_{ratio} = \frac{W_{bf}}{0.09W_{bf}^{0.59}S^{1.46}} \quad \text{Equation 3-11}$$

Where:

- WD_{ratio} is the width to depth ratio
- W_{bf} is the bankfull full width of the channel (m)
- S is the channel sinuosity

Radius of Curvature

A range of estimated and allowable radius of curvature for each reach was based on physical observances both from local reference reach locations and nationwide data. The nationwide data obtained from NRCS indicated that 90% of all radius of curvature to width ratios were less than or equal to 6 while 10% of radius of curvature to width ratios were equal to or greater than 1.5 as seen in Figure 3-11 (NRCS, 2007c). It was assumed that these would equal the minimum and maximum envelope of allowable radii for the restored channel segments. Larger radii of curvature are typically more stable and perhaps more hydraulically homogeneous while smaller radii of curvatures are potentially more dynamic and provide greater hydraulic heterogeneity which increases potential aquatic habitat. The proposed design utilized the following equation (Equation 3-12) from the NRCS, 2007c to approximate the average radius of curvature for

channel design (Figure 3-11) around which a range of recommended values has been provided based on reference site comparisons and professional judgement.

$$R_c = 2.3593W_{bf}^{1.0306} \quad \text{Equation 3-12}$$

Where:

R_c is the average radius of curvature (ft)

W_{bf} is the bankfull full width of the channel (ft)

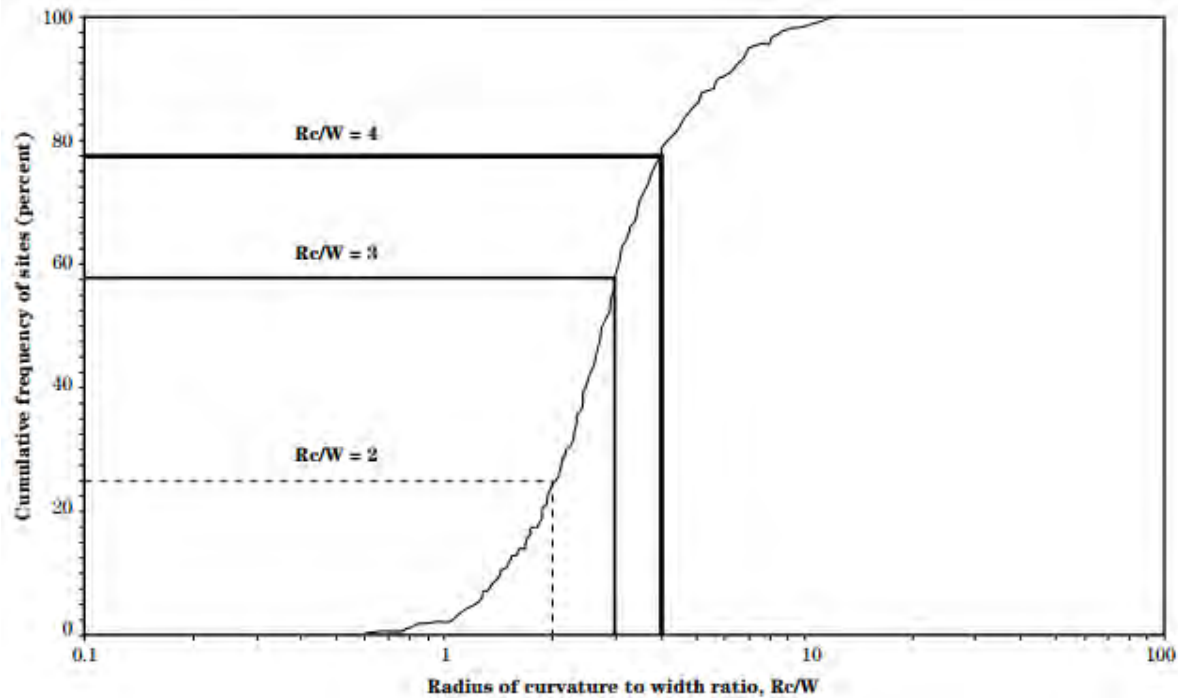


Figure 3-11. Cumulative Distribution of Radius of Curvature-to-width Ratio Derived from a Composite Data Set of 263 Sites (NRCS, 2007c).

The regression equation and envelope ratios described above were compared to observed and measured radii of curvature to width ratios from reference reach sites. Reference reach data matched up well with the envelope values as seen on Figure 3-12. The average radius of curvature equation results in a slightly tighter radius of curvature than the average trendline from the reference sites, but given the good fit of enveloped data, and the much larger data set used to create it, the regression equation for average radius of curvature was used for design purposes.

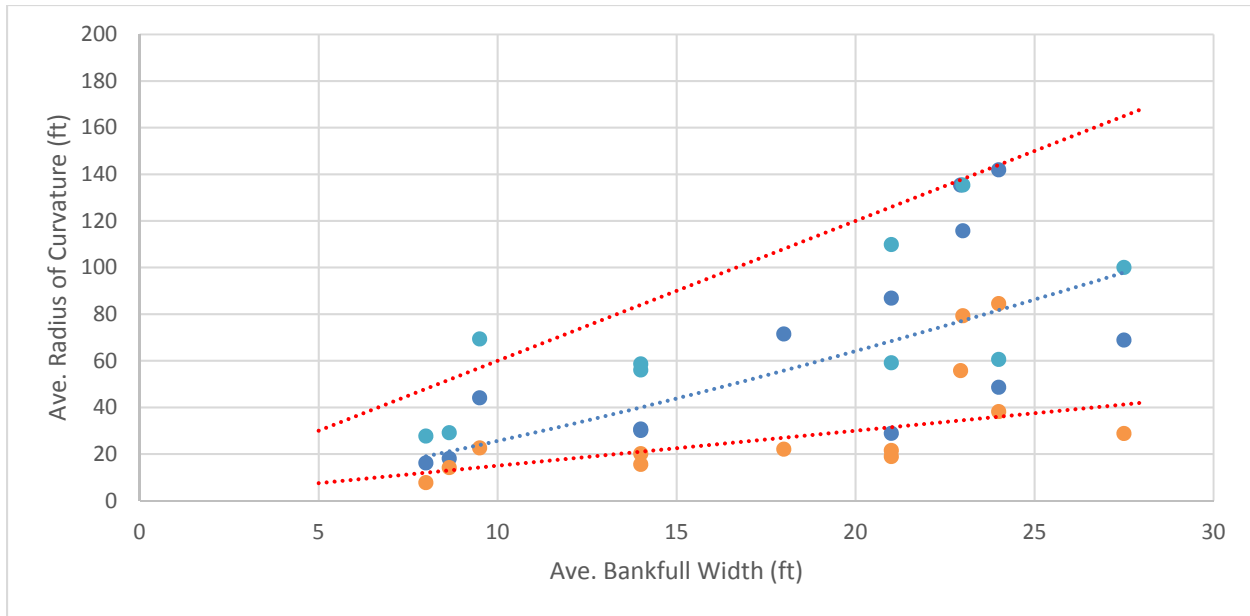


Figure 3-12. Minimum, Average and Maximum Measured Radii of Curvature.

Note: Gold = Minimum, Dark Blue = Average, Light Blue = Maximum measured bend radius from reference sites. The Red dashed lines represent the 10% and 90% cumulative frequency distribution data, and the blue dashed line is the average of those data (NRCS, 2007c) illustrating a close correlation between SGP-specific reference site data and national NRCS data.

Depth

Average channel depth was calculated from the BFW and estimated width to depth ratio (BFW divided by the width to depth ratio). Average depth is assumed to be the approximate depth occurring in a riffle section and does not account for pool depths. Residual pool depths will be based on potential channel scour and fish use preferences.

3.3.9 Fish Passage and Habitat

Fish passage design criteria and specific species and life stage habitat design criteria were identified by BioAnalysts Inc. These design criteria were used on a per reach basis, based on the primary fish use objective for that given reach. This includes substrate, large wood structure density, jump height, and pool depths. See Appendix A and Appendix D for details.

Fish Passage

Fish passage variables include flow depth, flow velocity, and jump height. These hydraulic variables are assessed at fish passage design flows. Fish passage design flows are approximated as the 5% and 95% average daily exceedance flows for the species and life stage of interest. The design of proposed channels will consider fish passage for target species and life stages as summarized in Table 3-17. Time frames were previously discussed in the Periodicity and Fish Use section (Section 2.2.2) and Appendix A.

Table 3-17. Summary of Fish Passage Criteria for Proposed Reaches.

Stream	Reach ID	Action Type	Fish Passage (Y/N)	Target Species: Chinook salmon (CH) steelhead (ST) bull trout (BT) Westslope cutthroat trout (CT)	Target Life Stages
Meadow Creek	MC1a	Restoration	Y	BT, CT	Adult, Juvenile
	MC1b	Restoration	Y	BT, CT	Adult, Juvenile
	MC1c	Restoration	Y	BT, CT	Adult, Juvenile
	MC1d	Restoration	Y	BT, CT	Adult, Juvenile
	MC1e	Restoration	Y	BT, CT	Adult, Juvenile
	MC2	Restoration	Y	BT, CT	Adult, Juvenile
	MC3	Restoration	N		
	MC4	Restoration	Y	CH, ST, BT, CT	Adult, Juvenile
Blowout Creek	MC5	Enhancement	Y	CH, ST, BT, CT	Adult, Juvenile
	BC1	Enhancement	Y	CT	Adult, Juvenile
	BC2	Restoration	N		
EFSFSR	BC3	Restoration	Y	CH, ST, BT, CT	Adult, Juvenile
	EF1	Enhancement	Y	CH, ST, BT, CT	Adult, Juvenile
	EF2	Enhancement	Y	CH, ST, BT, CT	Adult, Juvenile
	EF3	Restoration	Y	CH, ST, BT, CT	Adult, Juvenile
Fiddle Creek	EF4	Enhancement	Y	CH, ST, BT, CT	Adult, Juvenile
	FC1	Restoration	Y	CT	Adult, Juvenile
Midnight Creek	FC2	Restoration	N		
	MNC1	Restoration	N		
Hennessy Creek	MNC2	Restoration	Y	CH, ST, BT, CT	Adult, Juvenile
	HC1	Restoration	N		
Garnet Creek	HC2	Restoration	Y	CH, ST, BT, CT	Adult, Juvenile
	GC1	Restoration	Y	CH, ST, BT, CT	Adult, Juvenile
West End Creek	WE1	Restoration	N		
	WE2	Restoration	N		
	WE3	Restoration	N		

Fish Habitat

Fish habitat includes preferences for depth, velocity, cover (large wood, boulders, etc.), and distance to cover. These criteria are summarized above (Section 2.2) and discussed in more detail in Appendix A. Large wood structures would be installed at a frequency and location suitable for fish usage and to meet minimum WCI criteria (Section 3.4).

3.4 Risk to Property and Safety

The risk, in the context of the likelihood of failure of any one component, combination of components, or all components of the design and the consequences of the failure to property and safety, is assumed to be Low based on the remoteness of the SGP, relatively small size of streams, distance to nearest community, and lack of infrastructure within the floodplain. Natural streams are dynamic and can be dangerous. The goal of the stream design is to emulate natural

stream conditions in most of the restored reaches, therefore neither raising nor lowering the inherent risk to property and safety compared with other natural streams in the region.

3.5 Sustainability and Uncertainty

Channel geometry fluctuates around an average condition balancing competing tendencies toward minimizing total work and uniform distribution of work (Langbein and Leopold, 1964). This so called “Quasi-Equilibrium” represents the natural maintenance of channel dimension, pattern, and profile around an idealized average over time. Conditions fluctuate regularly in response to changing discharge, disturbance, and many complex relationships between internal and external drivers, but as an average the channel tends to hover around the most probable state. The SGP stream design has been developed to approximate a geomorphically appropriate quasi-equilibrium state, while enabling each stream reach to evolve naturally over time in response to changing environmental drivers and potential future disturbances (i.e. fire, climate change, etc.).

Built into the SGP stream design are a diversity of treatments and channel prescriptions allowing a certain amount of variability and associated uncertainty in the channel response over time. For example, by using appropriate streambed, bank, and floodplain materials; allowing channels to migrate across appropriately sized floodplains; incorporating horizontal and vertical control at strategic locations; and incorporating bioengineered bank stabilization treatments and revegetation, the design mimics the stability and diversity observed in natural reference streams. This approach provides some amount of resilience to disturbances and sets the project up for long-term sustainability. However, the stream design has limitations that are difficult to quantify and, therefore, do not account for all uncertainties and unforeseen events. Rio ASE makes no warranty, expressed or implied, to our services, the stream design, and this report. Please refer to Appendix I for a full disclosure of report limitations and guidelines for use.

SECTION 4: CONSTRUCTION

4.1 Schedule

Outlined below is a summary of the proposed construction schedule for stream design implementation as it relates to key benchmarks in the mine sequence. The beginning of mining operations is identified as Year 1. Elements occurring prior to mining operations are shown in sequential negative years (there is no Year 0), while elements occurring after the initiation of mining operations are shown in sequential positive years. Many elements can be implemented across a range of time; therefore, for simplicity, the earliest possible timing has been assumed for all elements. Elements occurring within a given year are said to have been completed by the end of the year. For that reason, each year demarcation is identified as “End of Year” (EOY). Reference the SGP Site Wide Water Balance Proposed Action Report (Brown and Caldwell, 2018) for a detailed summary with accompanying maps of the water management sequencing. Sequencing modifications to align with the Proposed Action SPLNT model (Brown and Caldwell, 2019) were incorporated.

Permitting = 2 years

- EOY -5
- EOY -4

Pre-Production and Construction = 3 years

- EOY -3
 - No significant stream alterations
- EOY -2
 - Begin construction of EFSFSR fish tunnel around Yellow Pine pit (2 years to build)
 - Divert Meadow Creek and tributaries around both sides of TSF and Hangar Flats DRSF
- EOY -1
 - EFSFSR fish tunnel completed
 - EFSFSR, Midnight Creek, and Hennessy Creek diverted into EFSFSR tunnel
 - Yellow Pine pit lake dewatered
 - Divert West End Creek around DRSF and West End pit
 - Sediment control and rock drain constructed on East Fork Meadow Creek (Blowout Creek)
 - Enhancement in EFSFSR (excluding Yellow Pine Pit)
 - Divert Meadow Creek into a restored channel around Hangar Flats pit footprint and enhance the channel downstream to the confluence with EFSFSR

Mining Operations = 12 years

- EOY 1
 - East Fork Meadow Creek (Blowout Creek) restored upper meadow
- EOY 2
 - Divert Fiddle Creek around footprint of Fiddle DRSF
- EOY 3 – EOY 6
 - No significant stream alterations

- EOY 7
 - Complete Fiddle DRSF
 - Complete West End DRSF
 - West End DRSF surface prep for stream liner and placement of floodplain material and growth media
 - West End Creek stream restoration atop DRSF (earliest possible timing)
- EOY 8
 - Fiddle Creek DRSF surface prep for stream liner and placement of floodplain material and growth media
 - Fiddle Creek stream restoration (earliest possible timing); flow not yet directed into restored channel
- EOY 9
 - Divert portion of Fiddle Creek into restored channel to allow riparian vegetation development
- EOY 10
 - Restore all flows into the restored Fiddle Creek channel
 - Yellow Pine Pit DRSF filled to river level
- EOY 11
 - Yellow Pine DRSF surface prep for stream liner and placement of floodplain material and growth media
 - Yellow Pine DRSF stream restoration (earliest possible timing) including EFSFSR and Hennessy Creek, flow not yet directed into restored channels
 - Hangar Flats Lake begins to fill
- EOY 12
 - Yellow Pine backfill complete
 - Yellow Pine DRSF stream restoration (earliest possible timing) including Midnight Creek
 - A portion of flow directed into the restored EFSFSR, Hennessy Creek, and Midnight Creek over the Yellow Pine DRSF to allow riparian vegetation development
 - Hangar Flats Lake continues to fill
 - Final tailings deposited into TSF; TSF allowed to consolidate before placing stream liner and growth media

Closure = 5+ years

- EOY 13
 - Restore all flows into EFSFSR, Hennessy Creek, and Midnight Creek over the Yellow Pine DRSF
 - EFSFSR diversion tunnel deactivated, but available as needed for adaptive management of EFSFSR restoration
 - Construct rock chute down face of West End DRSF into West End pit
 - West End Lake begins to fill
 - Construct spillway on West End Lake
 - Hangar Flats Lake continues to fill
 - Entrance and exit channels connecting Meadow Creek and East Fork Meadow Creek (Blowout Creek) to Hangar Flats Lake constructed

- East Fork Meadow Creek (Blowout Creek) restored from upper meadow downstream to the confluence with Meadow Creek
 - Groundwater table restored in upper East Fork Meadow Creek meadow
- EOY 14
 - EFSFSR diversion tunnel inactive, but available if needed for adaptive management of EFSFSR restoration
 - Hangar Flats Lake filled
- EOY 15
 - EFSFSR diversion tunnel decommissioned
 - Meadow Creek and East Fork Meadow Creek (Blowout Creek) permanently routed into Hangar Flats Lake
 - Plant site and ancillary facilities reclaimed
 - Garnet Creek enhancement/restoration
 - West End Lake continues to fill
- EOY 16
 - No significant stream alterations
- EOY 17
 - Meadow Creek surface prep for stream liner and placement of floodplain material and growth media atop TSF and Hangar DRSF
 - Meadow Creek stream restoration (earliest possible timing); flow not yet directed into restored channel
 - Divert portion of Meadow Creek into restored channel to allow riparian vegetation development
 - West End Lake continues to fill
- EOY 18
 - Restore all of Meadow Creek flow into new channel
 - West End Lake continues to fill and begins to spill at EOY 22

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SECTION 5: REFERENCES

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SECTION 6: ACRONYMS

BFW	Bankfull Width
BMPs	Best Management Practices
BPA	Bonneville Power Administration
Design Report	Stream Design Report
DRSF	Development Rock Storage Facility
EFSFSR	East Fork of the South Fork of the Salmon River
EOY	End of Year
ESA-listed	Endangered Species Act-listed
FA	Functioning Appropriately
FHWA	Federal Highway Administration
FPW	Floodplain Width
FR	Functioning at Risk
GIS	Geographic Information System
HIP III	Habitat Improvement Program
LWD	Large Woody Debris
Midas Gold	Midas Gold Idaho, Inc.
msl	Mean Sea Level
PNF	Payette National Forest
NMFS	National Marine Fisheries Service
SFSR	South Fork Salmon River
SGP	Stibnite Gold Project
SODA	Spent Ore Disposal Area
SWD	Small Woody Debris
TSF	Tailings Storage Facility
UR	Functioning at Unacceptable Risk
USACE	United States Army Corps of Engineers
USBR	United States Bureau of Reclamation
USGS	United States Geological Survey
USFWS	U.S. Fish and Wildlife Service
WCI	Watershed Condition Indicators

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APPENDIX A: FISH BIOLOGY

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Fish Biology Report

Stibnite Gold Project

Midas Gold Idaho, Inc.



A pair of bull trout spawning in Profile Creek September 2017

Prepared by:



BioAnalysts, Inc.™

**4725 N. Cloverdale Rd. Ste. 102
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SECTION 1: INTRODUCTION

1.1 Purpose

The purpose of this report is to summarize information related to key fish species in support of stream restoration designs for Midas Gold's Stibnite Gold Project. The Plan of Restoration and Operations (PRO, Midas Gold 2016) outlines the proposed mitigation plan and identified spring/summer Chinook salmon (*Oncorhynchus tshawytscha*), steelhead (*O. mykiss*), bull trout (*Salvelinus confluentus*), and Westslope cutthroat trout (*O. clarki lewisi*) as species of concern in the project area. As stated in the PRO, the objective of the restoration work is to establish a sustainable fishery with enhanced habitat to support natural populations of salmon, steelhead, and bull trout; improve water quality; establish a productive and sustainable vegetative community; and enhance wildlife habitat, all contributing to a self-sustaining and productive ecosystem (Midas Gold 2016).

Current status of key fish species is provided in the following:

- Snake River Basin spring/summer Chinook salmon were listed as a threatened species in 1992 (57 FR 14653; April 22, 1992).
- Snake River Basin steelhead were listed as a threatened species in 1997 (62 FR 43937; August 18, 1997).
- Columbia River bull trout were listed as a threatened species in 1998 (63 FR 31647; June 10, 1998).
- Westslope cutthroat trout are considered a species of conservation concern (SOCC) with the United States Forest Service (USFS) Region 4 (USFS 2016) and are assigned a state rank of S4 in Idaho indicating that the species is not rare and apparently secure, but with cause for long-term concern (IDFG 2018).

1.2 Organization of Report

Information in this report is organized on the following topics:

- Section 1, the introduction, explains the purpose of this report and provides the status of key fish species of interest.
- Section 2 contains an overview of fish distribution for spring/summer Chinook salmon, steelhead, bull trout, and Westslope cutthroat trout in the project area and nearby streams.
- Section 3 provides information on periodicity and fish use for key fish species.
- Section 5 covers habitat requirements and physical habitat criteria for key fish species.
- Section 6 assigns reach level biological objectives intended to guide stream restoration and enhancement in the project area.
- Section 7 provides references used throughout this report.

SECTION 2: FISH DISTRIBUTION

Multiple sources of information were reviewed to describe the presence of spring/summer Chinook salmon, steelhead, bull trout and Westslope cutthroat trout in the project area and nearby streams (IDEQ 2018; IFWIS 2018; Kuzis 1997; MWH 2017, StreamNet 2018; Thurow 1987, Zurstadt and Nelson 2010). The presence of fish within the project area was compiled by stream and enumerated by the reference source (Table 2-1). MWH (2017) provided baseline fish sampling to document the presence of key fish species within the project area. The Idaho Department of Environmental Quality (IDEQ) maintains a database of fish sampled during their beneficial use reconnaissance program (BURP) (IDEQ 2018; data accessed March 7, 2018). Likewise, Idaho Department of Fish and Game (IDFG) maintains the Idaho Fish and Wildlife Information System (IFWIS 2018; data accessed March 8, 2018) that provides numerous data types (i.e., redd location, fish presence, fish stocking records, trap counts, etc.). StreamNet GIS fish distributions were also reviewed to document the presence of fish within the project area.

Table 2-1. Presence of spring/summer Chinook salmon, steelhead, bull trout and Westslope cutthroat trout in project area and nearby streams. Numbers in the table refer to the source of information footnoted below. Dashes indicate no information for the presence of that species within that stream. Passage barriers have been indicated on EFSFSR, West End Creek, Midnight Creek, Fiddle Creek and Hennessy Creek (MWH 2017). An asterisk indicates streams where the presence of that species was detected from eDNA.

Stream	Steelhead (<i>O. mykiss</i>)	Chinook Salmon	Bull Trout	Westslope Cutthroat Trout	Brook Trout
No Mans Creek	---	---	---	2	---
Profile Creek	2,3,4	2	2,3,4	2,3,4	---
Missouri Creek	---	---	2	2	---
Bishop Creek	---	---	---	2	---
Tamarack Creek	1,2,3,4	1,2,3,4	1,2,3,4	1,2,3,4	---
Salt Creek	2	2	---	2,5	---
Pepper Creek	---	---	---	2	---
Sugar Creek	1,2,4	2,4,5	1,2,4,5	1,2,4	---
West End Creek (barrier)	---	---	---	---	---
EFSFSR below Yellow Pine pit	1,2,3,4,5	2,3,4,6	2,3,4	1,2,3,4	---
EFSFSR above Yellow Pine pit (barrier)	7	1,2,6	1	1,2	---
Unnamed tributary to Upper EFSFSR	---	---	1*	---	---
Fiddle Creek (barrier)	7	---	1*	1	---
Midnight Creek (barrier)	---	---	---	---	---
Hennessy Creek (barrier)	---	---	---	---	---
Garnet Creek (barrier)	---	---	---	1	---
Meadow Creek	7	1,2,6	1,2	1,2,4,5	---
Unnamed tributary to Meadow Creek	---	---	1*	1*	---
Fern Creek	---	---	1*	5	---
EF Meadow Creek (Blowout Ck.) (barrier)	1*	1	---	1	---

Reference: 1. MWH. 2017; 2. StreamNet Fish Distribution; 3.Thurow 1987; 4. Kuzis 1997; 5. IDEQ 2018; 6. IFWIS 2018; 7. Zurstadt and Nelson 2010.

2.1 Spring/summer Chinook Salmon

Adult spring/summer Chinook salmon have been transplanted upstream from the barrier at Yellow Pine pit and successful reproduction has produced juveniles observed in the project area (IFWIS 2018; MWH 2017). Transplanted adult Chinook salmon have constructed redds in the EFSFSR upstream and downstream of Meadow Creek and within Meadow Creek (IFWIS 2018). Juvenile Chinook salmon have been observed in the EFSFSR upstream and downstream of the Meadow Creek confluence and within Meadow Creek (MWH 2017). They have also been observed in the lowermost section on the East Fork Meadow Creek (Blowout Creek) (MWH 2017). Juvenile Chinook salmon observed in lower East Fork Meadow Creek are likely the result of juvenile emigration from Meadow Creek. Chinook salmon occur naturally downstream from the Yellow Pine pit in the EFSFSR, and in the EFSFSR tributaries of Sugar Creek, Tamarack Creek and Profile Creek (Table 2-1).

2.2 Steelhead

Summer steelhead are known to occur downstream from the Yellow Pine pit in the EFSFSR, Sugar Creek, Tamarack Creek, Profile Creek and Salt Creek (Table 2-1). Summer steelhead were not detected in aquatic baseline surveys of the upper EFSFSR upstream from the Yellow Pine pit (MWH 2017). However, environmental deoxyribonucleic acid (eDNA) samples collected upstream from the Yellow Pine pit revealed some *O. mykiss* markers in the upper Meadow Creek basin (in Meadow Creek Lake) and in East Fork Meadow Creek (MWH 2017). Detection of *O. mykiss* in the lake is likely Golden trout that are known to have been planted in Meadow Creek Lake (IFWIS 2018; Kuzis 1997). Zurstadt and Nelson (2010) show *O. mykiss* in Fiddle Creek, Meadow Creek and EFSFSR above and below the Meadow Creek confluence. However, the presence of steelhead/redband in these locations was not confirmed by other source information (MWH 2017; IDEQ 2018). The lack of widespread detection of native *O. mykiss* upstream from Yellow Pine pit suggests that their distribution is limited to areas downstream from the Yellow Pine pit passage barrier.

2.3 Bull Trout

Bull trout are known to occur downstream of the Yellow Pine pit in the EFSFSR, Sugar Creek, Tamarack Creek, Profile Creek and Missouri Creek (Table 2-1). Bull trout have been observed upstream from the Yellow Pine pit in Meadow Creek and EFSFSR. Bull trout were not observed nor did eDNA samples reveal their presence in East Fork Meadow Creek, Midnight Creek and Garnet Creek (MWH 2017). Samples of eDNA in lower Fiddle Creek were positive for bull trout near the confluence with the EFSFSR. However, the presence of bull trout upstream of the barrier on Fiddle Creek was not confirmed during visual surveys or eDNA collections (MWH 2017). Positive detection of bull trout eDNA also occurred in Fern Creek and an unnamed tributary of upper Meadow Creek.

2.4 Westslope Cutthroat Trout

Cutthroat trout are widespread occurring upstream and downstream from the Yellow Pine pit (Table 2-1). Upstream from the Yellow Pine pit, they have been observed in the EFSFSR, Meadow Creek, East Fork Meadow Creek and Fiddle Creek (MWH 2017). Westslope cutthroat

trout were not observed nor did eDNA samples detect their presence in Midnight Creek, upper Garnet Creek or upper Fiddle Creek.

2.5 Brook Trout

Brook trout were not observed in streams upstream from the Yellow Pine pit and eDNA samples did not indicate the presence of brook trout in the upper EFSFSR watershed (MWH 2017). Brook trout have been observed in the Johnson Creek (Thurow 1987).

SECTION 3: PERIODICITY

The following information was assembled to provide guidance on periodicity and potential fish use for spring/summer Chinook salmon, summer steelhead, bull trout, and Westslope cutthroat trout. Potential fish use and periodicity is key to understanding the life history of native species and their potential reintroduction/colonization through elimination of passage barriers and stream restoration. When possible, the information presented has been drawn from reference data within the South Fork Salmon River subbasin. Indeed, recolonization of the currently inaccessible habitats would likely occur from local fish populations and hatchery sources. Detailed life history information is lacking on resident forms of bull trout and Westslope cutthroat trout. Moreover, specific life history information on spring spawning species (i.e., steelhead and Westslope cutthroat trout) is scarce.

PIT tag data from a station (ESS) on the EFSFSR (RM 13.0) was used to describe adult migrations of Chinook salmon and steelhead to the EFSFSR watershed but falls short of describing arrival distribution to the project area. Currently, there are no active¹ PIT tag stations near the confluence of Sugar Creek and EFSFSR that would describe the arrival distribution for Chinook salmon and steelhead to the project area. Thus, it is important to acknowledge that periodicity is from a much larger geographic scale than the current project area. Periodicity for different life stages has been displayed in two week intervals reflecting the general level of detail that is noted in the literature and stream surveys.

3.1 Spring/summer Chinook Salmon

Chinook salmon entering the South Fork Salmon River are a spring/summer-run salmon. Juveniles of spring/summer Chinook salmon in the South Fork Salmon River exhibit a stream-type life history. That is, juveniles spend a full year in freshwater before they migrate to the ocean. Table 3-1 and the following sections present information on potential fish use and periodicity expected for spring/summer Chinook salmon near the project area.

Table 3-1. Periodicity and fish use for different life stages of spring/summer Chinook salmon.

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Spring/ Summer Chinook Salmon	Adult Migration												
	Adult Spawning												
	Incubation/Emergence												
	Juvenile Rearing												
	Juvenile Emigration												

Adult Migration-In the Columbia River, the South Fork Salmon River adult migration to Bonneville (50th percentile) for summer Chinook salmon was June 1 based on PIT tagged adult salmon (Crozier 2016). PIT tag data from the EFSFSR near Parks Creek showed that the 50th percentile for spring/summer Chinook salmon was about July 8 over the period 2009-2017

¹ . A PIT tag array has been installed downstream from the YPP Lake and will be operated in 2018.

(Table 3-1). However, in Johnson Creek, a tributary to the EFSFSR, Rabe et al. (2017) noted that adult run timing assessed at the adult weir was bimodal for adult spring/summer Chinook salmon with peaks occurring in both late June and again in mid-August. Adult run time typically initiated in June and is complete by mid-September (Rabe et al. 2017). PIT tag data suggest that adult Chinook salmon enter the EFSFSR sporadically in May with peak occurrence in early July with migration ending mid-September.

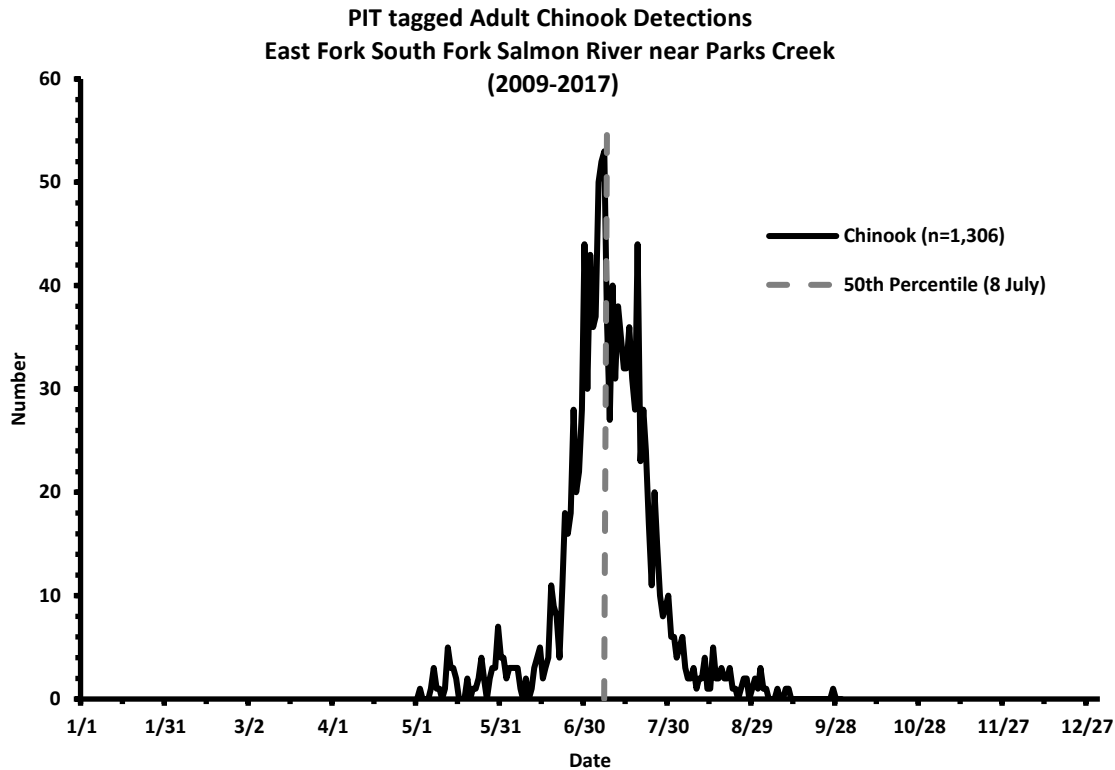


Figure 3-1. Arrival distribution of PIT tagged Chinook salmon at the PIT tag array located on the EFSFSR (RM 13) near Parks Creek.

Adult Spawning-Rabe et al. (2006) have observed that spawning in Johnson Creek typically starts in early August and peaks during the third week of August. Spawning is typically complete by mid-September. By comparison, in the South Fork Salmon River, spawning typically occurred from mid-August to mid-September with some spawning noted in late September (Young and Blenden 2011). Peak spawning for spring/summer Chinook salmon in the South Fork Salmon River occurred within the first two weeks of September. Redd surveys conducted in Sugar Creek (2008-2016) show that spawning begins in August and ends mid-September (Nez Perce Tribe data, Jan. 2018). The earliest known spawning occurred on 13 August 2010 and the latest occurred on 10 September 2009. It should be noted that spawning surveys in Sugar Creek may have occurred as much as 14 days apart, which could bias counts of new redds toward later spawning dates. Regardless, there is considerable agreement among the spawning areas (i.e., SF Salmon, Johnson Creek and Sugar Creek) which indicates that spawning is likely to occur from August through mid-September in the project area (Table 3-1).

Incubation/Emergence-For spring/summer Chinook salmon, the incubation/emergence period extends from the time of spawning to emergence from the streambed. The term alevin describes yolk sac fry after hatching. Emergence is the time at which the alevin has absorbed the yolk sac and emerges from the substrate, and is termed a fry. For Chinook salmon, the incubation/emergence period extends from early August (spawning) to end of April (emergence) the following year (Rabe et al. 2006; Nez Perce Tribe data, Jan. 2018; Miller et al. 2014, USBWP 2005) (Table 3-1).

Juvenile Rearing-Juvenile Chinook salmon fry emerge from the streambed in the spring and spend a full year rearing in freshwater until they emigrate as parr and smolts. After emergence, fry may be displaced downstream by stream flow seeking refuge in low velocity habitats with abundant cover (i.e., wood, undercut banks, vegetative overhang, etc.) along the stream margins. As fry grow and stream temperatures increase, they transition into parr selecting habitats suitable for their needs. For Chinook salmon parr, this is typically expressed as pool habitat in the summer that provides adequate food and cover (Bjornn and Reiser 1991). As stream temperatures decline parr seek suitable habitats for winter refuge. These habitats provide resting and hiding areas (i.e., wood, undercut banks, streambed interstitial spaces). Juvenile Chinook salmon rearing would occur year-round within the project area (Table 3-1).

Juvenile Emigration-In Johnson Creek, the juvenile emigration period occurs from March into November (Rabe et al. 2006). Rabe et al. (2006) noted that smolts in Johnson Creek typically emigrated during the early spring months of March-May, while parr emigrated throughout the summer, and presmolts emigrated in the fall. Juvenile Chinook salmon emigration would occur throughout most of the year with peaks likely observed in the spring, summer and fall. Juvenile emigration during winter months would be minimal in project area (Table 3-1).

3.2 Summer Steelhead

South Fork Salmon River steelhead are summer-run fish which appear to be predominately B-run steelhead that pass Bonneville Dam after August 25 (Thurow 1987). A portion of the steelhead destined for the SFSR ascend the Salmon River in fall, overwintering in the mainstem Salmon River or South Fork Salmon River, while the remainder overwinter in the Snake River (Mallet 1970). Steelhead stage in these areas before migrating to SFSR spawning areas in the spring. Table 3-2 and the following sections present information on periodicity and potential fish use for steelhead.

Table 3-2. Periodicity and fish use for different life stages of summer steelhead.

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Steelhead	Adult Migration												
	Adult Spawning												
	Incubation/Emergence												
	Juvenile Rearing												
	Juvenile Emigration												

Adult Migration-Information suggests that South Fork Salmon River steelhead ascend the Columbia River in late summer and overwinter in the Snake and Salmon rivers before entering

the South Fork Salmon River (SFSR) in spring (Mallet 1970; Thurow 1987). In the Columbia River, the South Fork Salmon River adult steelhead migration to Bonneville (50th percentile) for wild steelhead (n=312; 2001-2016) was September 16 based on PIT tagged adult steelhead (PTAGIS September 19, 2017; query Bonneville Dam detections of SFSR steelhead). Thurow (1987) noted that wild steelhead are in the vicinity of the SFSR around mid-September with steelhead staging at the mouth of the SFSR in the fall and spring. Adult steelhead then ascend the SFSR in the spring and proceed to spawning streams (Thurow 1987). Spawning ground surveys on the SFSR indicate that steelhead arrived at Poverty Flat (RM 56) by April 16. PIT tag data from the EFSFSR near Parks Creek showed an adult migration period from late March to end of May with the 50th percentile occurring on 23 April for the period 2009-2017.

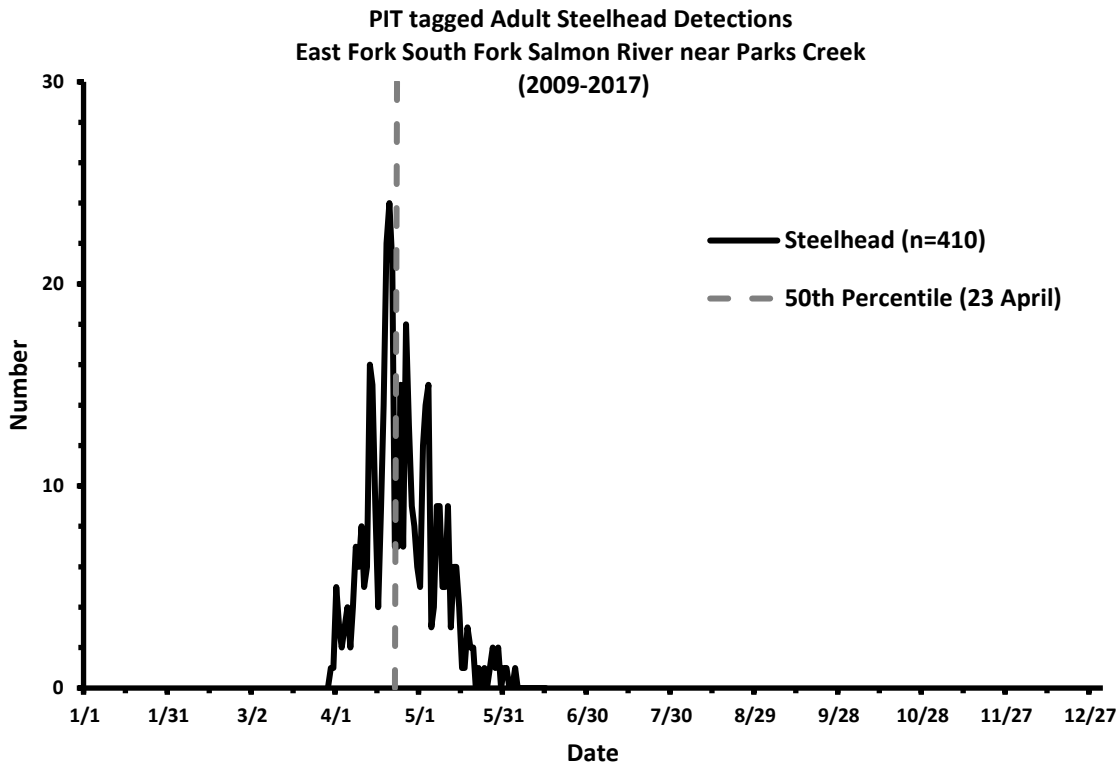


Figure 3-2. Arrival distribution of PIT tagged steelhead at the PIT tag array located on the EFSFSR (RM 13) near Parks Creek.

Adult Spawning-Holubetz (1995) speculated that spawn time may be related to elevation. In high elevation tributaries, steelhead typically spawned in a narrow time frame from April 15 to May 15 (Thurow 1983; Orcutt et al. 1968). In the mainstem South Fork Salmon River, Thurow (1987) observed steelhead spawning from mid-April to end of May. Tributary spawning areas included sections of Burntlog, Johnson, and Lick creeks, and East Fork of the South Fork Salmon and Secesh rivers. Steelhead began spawning in tributaries about one week later than steelhead in mainstem areas. In the project area, spawning is likely to occur from late April to end of May (Table 3-2).

Incubation/Emergence-For steelhead the incubation/emergence period extends from the time of spawning to emergence from the streambed. Thurow (1987) noted that variability in environmental conditions can be seen in steelhead emergence in the South Fork Salmon River. In 1984, 98 percent of the steelhead fry emerged by August 10 and in 1985, 98 percent emergence occurred by July 17. Thurow (1987) pointed out that lower stream discharge and warmer water temperatures accelerated emergence in 1985 as compared to 1984. Given the observed variability in time of emergence, the incubation/emergence period is likely to extend from mid-April to mid-August (Table 3-2).

Juvenile Rearing-Juvenile steelhead emerge from the streambed in the late spring and summer and may spend several years rearing in streams before migrating to the ocean. Thurow (1987) observed multiple age classes of juvenile steelhead within tributaries of the South Fork Salmon River basin. Juvenile steelhead rearing would occur year-round (Table 3-2).

Juvenile Emigration-Juvenile emigration for steelhead can occur throughout the year (USBWP 2005). Smolt trapping on the lower SFSR from March through November indicates that juvenile steelhead emigrate throughout the season with definite peaks in July and August (Albee and Orme 2011). Juvenile emigration within the project area would likely occur year-round with peak emigration occurring in summer months (Table 3-2).

3.3 Bull Trout

In the SFSR, Thurow (1986) documented the presence of both resident and fluvial stocks in all reaches and 18 tributaries that were surveyed. Watry and Scarnecchia (2008) also noted adfluvial life histories in the Secesh watershed. MWH (2017) observed different size classes of bull trout in project area streams which suggest year-round residence and production from area streams. Table 3-3 and the following sections present information on periodicity and potential fish use expected for bull trout.

Table 3-3. Periodicity and fish use for different life stages of bull trout.

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bull Trout	Adult Migration												
	Adult Spawning												
	Incubation/Emergence												
	Juvenile Rearing												
	Juvenile Emigration												

Adult Migrations-Life history strategies and migratory patterns of bull trout were studied in the Secesh River and EFSFSR watersheds (Hogen and Scarnecchia 2006; Watry and Scarnecchia 2008). In the Secesh River watershed, Watry and Scarnecchia (2008) found that upstream migrations occurred during late June and early July with migrations into two spawning tributaries during late July and early August. Primary over-wintering areas were Loon Lake, the lower Secesh River, and the lower SFSR. For the EFSFSR, Hogen and Scarnecchia (2006) found that bull trout overwintered in the large rivers downstream from the EFSFSR (SFSR and the Salmon River further downstream). Upon return, bull trout migrated upstream to the EFSFSR in June and July and further upriver into small tributaries to spawn in August and September

(Hogen and Scarnecchia 2006). In both studies, upstream migrations occurred in late June and early July with migrations for some bull trout into spawning tributaries during late July and August. Movements of resident bull trout related to spawning are not well documented, but given their resident life history likely fall within the range noted for fluvial bull trout in the EFSFSR. The information suggests that adult bull trout return to the EFSFSR in late June through early July with some adults staging near spawning tributaries in August (Table 3-3).

Adult Spawning-Adult spawning periods reported for the SFSR subbasin occur from late August to mid-October (Burns et al. 2005). However, biotelemetry studies on bull trout in both the Secesh and EFSFSR watersheds indicate spawning likely occurs from late August through mid-September (Hogen and Scarnecchia 2006; Watry and Scarnecchia 2008). In both studies, bull trout typically left spawning tributaries by end of September. In the EFSFSR, spawning areas included Tamarack, Profile and Sugar creeks and some tributaries to those streams (Burns et al. 2005). As reported by Hogen (2002) cited in (Burns et al. 2005) spawning occurred over a short, definite time period, from September 1 –15 with all spawning completed by September 20. Bull trout redd surveys conducted in Sugar Creek (2009-2014, 2016) show that spawning begins in late August and ends near mid-September (Nez Perce Tribe data, Jan. 2018). The earliest redd reported in Sugar Creek was observed on 28 August and the last redds were observed on 16 September. Recent observations by Midas Gold contractors of bull trout redds and spawning activity in Sugar (Sep 13, 2017) and Profile (Sep 14, 2017) creeks comport well with the end of the spawning period noted in the EFSFSR radio tag study (Hogen and Scarnecchia 2006). The information presented in the EFSFSR telemetry study and redd surveys in Sugar Creek suggest that the spawning period for bull trout likely occurs from mid-August to mid-September (Table 3-3).

Incubation/Emergence-As cited by Batt (1996), the incubation period for bull trout is about 100 to 145 days, with hatching occurring in late January requiring an additional 65 to 90 days for yolk sac absorption (Heimer 1965, McPhail and Murray 1979, Allan 1980, Weaver and White 1984; Shepard et al. 1984). Fry normally emerge from early April through May depending upon water temperatures and increasing stream flows (Pratt 1992; Ratliff and Howell 1992). The incubation/emergence period for bull trout would extend from mid-August through end of May the following year (Table 3-3).

Juvenile Rearing-MWH (2017) observed different size classes of bull trout in a baseline study of streams in the aquatic resource study area. This suggests multiple age classes and extended rearing in tributary streams. Thurow (1987) noted that bull trout displayed increased growth rates after age three which reflects movements of fluvial stocks from tributaries to mainstem areas. Mainstem areas likely serve primarily as overwintering, adult migration and rearing habitat for bull trout while tributaries are principally for juvenile rearing and adult spawning. Juvenile rearing would occur year-round in streams of the project area (Table 3-3).

Juvenile Emigration-Juvenile bull trout emigration is not well documented in the SFSR subbasin. However, emigrant behavior might be approximated from other sources. Downs et al. (2006) observed that juvenile bull trout emigrated in pulses with one occurring in the spring and another in fall. Following the large pulse of age one and older juveniles emigrating in spring, they observed a second peak in downstream movement in fall (Downs et al. 2006). Lower emigration rates were noted in late July and August. Bellerud et al. (1997) also identified two emigration peaks of juvenile bull trout separated by a period of low movement in July in Oregon's Grand Ronde River system. Juvenile emigration in the project area would probably

follow similar patterns as noted. Therefore, juvenile emigration is likely to occur from April to end of November with little emigration occurring during winter months (Table 3-3).

3.4 Westslope Cutthroat Trout

MWH (2017) observed different size classes of Westslope cutthroat trout in aquatic resource study area streams which suggest year-round residence and production from area streams. IDFG (2013) reported that densities of Westslope cutthroat trout in the South Fork Salmon River subbasin were highest in the EFSFSR watershed. Table 3-4 and the following sections present information on periodicity and potential fish use expected for westslope cutthroat trout.

Table 3-4. Periodicity and fish use for different life stages of Westslope cutthroat trout.

Species	Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Westslope Cutthroat Trout	Adult Migration												
	Adult Spawning												
	Incubation/Emergence												
	Juvenile Rearing												
	Juvenile Emigration												

Adult Migrations-Adult migrations of fluvial Westslope cutthroat trout are not well documented in the SFSR. However, adult migration might be approximated from other studies of Westslope cutthroat trout. In the Upper Salmon River basin, Schoby and Curet (2007) noted that Westslope cutthroat trout entered spawning tributaries between mid-April and early June. Schmetterling (2003) found that cutthroat tagged in April-June sometimes migrated extensive distances (62 miles) to ascend tributaries of the Clark Fork River to spawn. In the Coeur d’Alene River basin, Dupont (2008) found that movement patterns were generally the most extensive in the months of April-June with less movement occurring during summer and winter. In the Middle Fork Salmon River, Zurstadt and Stephan (2004) observed that upstream movements started in late March with peak movement in May. In that study, they found that extensive downstream movements occurred from May through July (Zurstadt and Stephan 2004). The pattern of movement observed in these studies is probably related to both spawning and cold water refuge and suggests that adult migrations within the project area are likely to occur from late March through June (Table 3-4).

Adult Spawning-USBWP (2005) indicated a spawning period for cutthroat trout that extends from May to the end of the first week of July for most tributaries of the Upper Salmon River basin. The information comports well with the movement studies previously noted for adult migrations (Schoby and Curet 2007; Zurstadt and Stephan 2004). The information suggests that the spawning period for Westslope cutthroat trout likely extends from mid-April through mid-July (Table 3-4).

Incubation/Emergence-As noted by Miller et al. (2014), the incubation/emergence period for salmonids is quite variable and dependent on stream temperature. The incubation/emergence period for Westslope cutthroat trout likely extends from mid-April through July with the possibility that resident cutthroat in smaller streams at higher elevations may emerge as late as August. Observations by Midas Gold contractors of very small (<25mm) trout in mid-

September (Sep 14, 2017) in Fiddle Creek suggest that an emergence period ending in August would encompass fish in small streams (Table 3-4).

Juvenile Rearing-Westslope cutthroat trout inhabit streams that are cold and nutrient-poor (IDFG 2013). In the Management Plan for the Conservation of Westslope Cutthroat Trout in Idaho, IDFG (2013) note that the distribution and abundance of larger WCT is strongly associated with pool habitat and suggest that stream reaches with numerous pools support the highest densities of fish. Moreover, habitats that provide some form of cover also seem to be preferred. MWH (2017) observed several different sizes classes of Westslope cutthroat trout in the upper EFSFSR suggesting that juvenile rearing occurs year-round (Table 3-4).

Juvenile Emigration-Juvenile Westslope cutthroat trout emigration from tributary streams is not well documented and complicates our understanding of their early life history. As noted in IDFG (2013) Westslope cutthroat trout may spend 1-4 years in tributary streams depending on their life history. As resident cutthroat trout, they can remain in tributary streams completing their entire life cycle. Like bull trout, age one and older Westslope cutthroat trout likely make up the majority of spring emigrants while summer and fall periods may show an increase in young-of-the-year migrants. Therefore, juvenile emigration is likely to occur from April through the end of November in aquatic area resource streams with little emigration occurring during winter months (Table 3-4).

SECTION 4: SALMONID HABITAT REQUIREMENTS

Physical habitat criteria are often used to help describe complex salmonid habitat requirements that support different species and life stages. In this section, habitat requirements are outlined for spawning, incubation and rearing of key fish species. References are provided in the tables.

4.1 Spring/summer Chinook Salmon

Chinook salmon in the South Fork Salmon River basin exhibit a stream-type life history rearing a full year in freshwater before they migrate downstream to the ocean. Therefore, it is important to identify the aquatic habitats used by juvenile spring/summer Chinook salmon in their first year of life. In freshwater, juvenile rearing requirements begin early as fry seek low velocity shallow water habitats along the stream margins. Along these stream margins, overhanging vegetation and woody debris provide important cover (Table 5-1). As they grow and become larger (parr), juvenile Chinook salmon move into deeper water preferring pool and run type habitats over fast water habitat types such as riffles. Juvenile Chinook salmon would make good use of cover seeking woody debris, undercut banks, depth and large substrate as cover. As stream temperatures decline in winter, juvenile Chinook salmon hide in coarse substrate emerging at night and resting in low velocity areas. In spring, with increasing stream temperature and discharge juvenile Chinook salmon begin their downstream migration to the ocean.

Upon return, adults mostly 3 to 5 years old migrate upstream and spawn during late summer. Adult spring/summer Chinook salmon typically rest in large deep pools before spawning. Adequate stream temperatures (42-57°F) allow adult to rest and mature before they spawn. Adult Chinook salmon select low gradient riffle type habitat with water depths greater than 11.8 inches for spawning. Chinook salmon generally spawn in stream channels that are less than 4 percent with the highest potential noted between 0.0 and 1.5 percent. Redds are typically constructed in substrate that varies from large gravel to moderate sized cobble. They prefer to have pools with cover in close proximity to spawning. Redd size varies from about 55-101 ft² with a recommended area of about 216 ft² per spawning pair. Females bury their eggs in substrate that is about 7.9-11.8 inches deep. Recommended temperatures during spawning vary from 42.1-57.0 °F. During incubation stream temperature between 41.0-57.9 °F displayed the highest survival. Low stream temperatures (<39.9 °F) may be experienced during the incubation period as long as initial development occurs within a suitable range for normal egg development.

Table 5-1. Habitat requirements and physical habitat criteria for different life stages of Chinook salmon.

Life Stage	Parameter	Criteria	Reference
Spawning	Substrate (in)	0.51-3.58; D50 Range (0.43-2.70)	Bjornn and Reiser 1991 (summer Chinook); Kondolf and Wolman 1993 (D50 Range Idaho Chinook)
	Water Velocity (ft/s)	1.05-3.58	Bjornn and Reiser 1991 (summer Chinook)
	Water Depth (in)	≥11.8	Bjornn and Reiser 1991 (summer Chinook)
	Stream Temperature (°F)	42.1-57.0	Bjornn and Reiser 1991 (summer Chinook); Kuzis 1997
	Redd Size (ft ²)	54.9-101.2	Bjornn and Reiser 1991 (summer Chinook)

Life Stage	Parameter	Criteria	Reference
	Channel Type	1. Forced pool-riffle 2. Pool-riffle 3. Plane bed	Roni, Pess, Beechie and Hillman Presentation 2012 (Chinook and Steelhead Habitat Requirements)
	Gradients (%) with Bankfull widths (12.1-164 ft.)	0.0-0.5% medium to high spawning potential	Cooney and Holzer 2006
		0.5-1.5% low to high spawning potential	
		1-4% low to medium spawning potential	
		4-7% low potential	
		>7%-No potential	
	Spawning area/spawning pair (ft ²)	216.4	Bjornn and Reiser 1991 (summer Chinook salmon)
Migration Barrier	20% gradient 656+feet	Cooney and Holzer 2006	
Cover	Large woody debris, deep water (pools & runs), turbulence, and undercut banks in close proximity to spawning.	Bjornn and Reiser 1991	
Incubation	Egg Pocket Depth (in)	7.9-11.8 (mean)	DeVries 1997; Bjornn Reiser 1991 (Columbia R.)
	Intragravel DO (ppm)	8.0	Bjornn and Reiser 1991 (Steelhead & Coho)
	Temperature (°F)	35.6-57.9; 41.0-57.9; 42.8-53.6	Velsen 1987; Bjornn and Reiser 1991; Kuzis 1997; Myrick and Cech 2001 (42.8-53.6°F best range)
	Fines (<0.25 in)	<30%	Kuzis 1997
	Stream Icing & Scouring	Anchor and frazil ice as well as scouring can reduce intragravel survival.	Bjornn and Reiser 1991
Rearing	Post-emergent	Post-emergent Chinook salmon cluster at stream margins in slow (0-0.33 ft/s) and shallow water (<1.97 ft). Chinook salmon fry typically station over fine substrates with abundant vegetation cover (brush, grasses, and woody debris). Chinook salmon select shallow, quiet (<0.03 ft/s) water at night.	Roni, Pess, Beechie and Hillman Presentation 2012 (Chinook salmon and Steelhead Habitat Requirements)
	Summer	As Chinook salmon grow, they use faster (0.07-1.44 ft/s) and deeper (0.82-9.84 ft) water, and select brush, woody debris, or cobble/boulder cover. Chinook salmon select shallow, quiet (<0.03 ft/s) water at night.	Roni, Pess, Beechie and Hillman Presentation 2012 (Chinook salmon and Steelhead Habitat Requirements)
	Winter	Select slow water habitat types in winter with coarse substrates for concealment. At temperatures are less than 50°F, Chinook salmon remain concealed in cover (woody debris or coarse substrate). Chinook salmon emerge at night and reside near the stream bed over sand, bedrock, or boulders in depths that range from 1.64-6.56 ft. Juvenile Chinook salmon use velocities less than 0.07 ft/s at night.	Roni, Pess, Beechie and Hillman Presentation 2012 (Chinook salmon and Steelhead Habitat Requirements)
	Channel Type	Chinook salmon preferred channel types that contained pool and run habitat types over pocket water and riffles.	Bjornn and Reiser 1991
	Gradient	>4%-Limited	Cooney and Holzer 2006

4.2 Summer Steelhead

South Fork Salmon River steelhead are summer-run fish which appear to be predominately B-run steelhead that pass Bonneville Dam after August 25 (Thurow 1987). Post-emergent steelhead seek shallow, low velocity habitats along the stream margins (Table 5-2). As steelhead grow and become larger, juvenile fish move into deeper, faster water and can be found in a variety of habitat types. Juvenile steelhead prefer pocket water but can also be found in pools, runs and riffles. As stream temperatures decline in winter, most juvenile steelhead hide in coarse substrate emerging at night and resting in low velocity areas. In spring, with increasing stream temperature and discharge some juvenile steelhead may begin their downstream migration to the ocean or remain for another year.

South Fork Salmon River steelhead have a diverse life history, spending 1-5 years in freshwater and 1-3 years in the ocean with adults returning predominantly as 5 year old fish (Copeland et al. 2017). Adult steelhead ascend the SFSR in the spring and proceed to spawning streams by mid-April (Thurow 1987). Adult steelhead spawn in riffle habitat at water depths greater than 9.45 inches. In general, steelhead spawn in stream channels of less than 4 percent gradient with the highest potential noted between 0.5-4.0 percent. Redds are typically built in streambed material that varies from large gravel to moderate sized cobble. Redd size varies from about 47.4-58.1 ft² with egg pocket depths between 5.9 and 11.8 inches. Recommended temperatures during spawning vary from 39.0-48.9°F with temperatures between 41-50 °F during incubation displaying the highest survival.

Table 5-2. Habitat requirements and physical habitat criteria for different life stages of steelhead.

Life Stage	Parameter	Criteria	Reference
Spawning	Substrate (in)	0.24-4.02; D50 Range (0.41-1.81)	Bjornn and Reiser 1991 (Steelhead); Kondolf and Wolman 1993 (D50 Range all steelhead)
	Water Velocity (ft/s)	1.31-2.99	Bjornn and Reiser 1991 (Steelhead)
	Water Depth (in)	≥9.45	Bjornn and Reiser 1991 (Steelhead)
	Stream Temperature (°F)	39.0-48.9	Bjornn 1991 (Steelhead)
	Redd Size (ft ²)	47.4-58.1	Bjornn and Reiser 1991 (Steelhead)
	Spawning area/spawning pair (ft ²)	No data	
	Channel Type	1. Forced pool-riffle 2. Pool-riffle 3. Plane bed	Roni, Pess, Beechie and Hillman 2012
	Bankfull Width (ft) Intrinsic Potential	<12.5 - None	Cooney and Holzer 2006
		12.5-164 - Low to High	
		>164 - Low	
	Gradient (%)	0.0-0.5% low spawning potential	Cooney and Holzer 2006
		0.5-4.0% low to High spawning potential	
		4-7% Low spawning potential	
>7%-No spawning potential			
Migration Barrier	20% gradient 656+feet	Cooney and Holzer 2006	
Cover	Large woody debris, deep water (pools & runs), turbulence, and undercut banks in close proximity to spawning.	Bjornn and Reiser 1991	

Life Stage	Parameter	Criteria	Reference
Incubation	Egg Pocket Depth (in)	5.9-11.8 (mean)	DeVries 1997
	Intragravel DO (ppm)	8.0	Bjornn and Reiser 1991 (Steelhead & Coho)
	Temperature (°F)	>35.6; 41-50	Velsen 1987; Myrick and Cech 2001 (41-50 °F best survival)
	Fines (<0.25 in)	<25%	Kuzis 1997
	Stream Icing & Scouring	Anchor and frazil ice as well as scouring can reduce intragravel survival.	Bjornn and Reiser 1991
Rearing	Post-emergent	Post-emergent steelhead cluster at stream margins in slow (0-0.33 ft/s) and shallow water (<23.6 in). Steelhead fry typically station over cobble and small boulder substrates. Steelhead select shallow, quiet (<0.03 ft/s) water at night.	Roni, Pess, Beechie and Hillman 2012
	Summer	As steelhead grow, they use faster (0.06-1.12 ft/s) and deeper (7.5-74.8 in) water use cobble and boulders as cover. Steelhead select shallow, quiet (<0.03 ft/s) water at night. They use areas with fine sediments, bedrock, or coarse substrate at night. At night, larger fish use deeper (15.8-35.4 in) water than smaller fish (5.9-23.6 inches)	Roni, Pess, Beechie and Hillman 2012
	Winter	During periods when temperatures are less than 50°F, steelhead remain concealed in cover (woody debris or coarse substrate). Steelhead emerge from cover at night and reside near the stream bed over sand, bedrock, or boulders in depths that range from 19.7-78.7 in. Steelhead use low velocity (0.06 ft/s) areas at night.	Roni, Pess, Beechie and Hillman 2012
	Channel Type	Steelhead densities (fish/area) were highest in pocket water but were also found in decreasing order in pools, runs and riffles.	Bjornn and Reiser 1991
	Gradient	>10%-Limited	Cooney and Holzer 2006

4.3 Bull Trout

Life history characteristics of bull trout are quite diverse with resident, fluvial and adfluvial forms often occurring within the same basin. Newly emerged fry are secretive and hide in the gravel along stream margins and in side channels (Table 5-3). Early rearing habitat is characterized by low velocity, shallow water with substrate that provides adequate interstitial spaces as cover. As they grow and become larger they can be found mostly in pool habitat and maintain focal areas near the stream bottom. Bull trout occur most often in A (entrenched, step-pool, 4-10 percent gradient) and C (meandering, riffle-pool, <2 percent gradient) channel types. In winter, bull trout use concealment cover of large woody debris and boulder substrate crevices in deep pools during the day. At night, fish emerge from cover and select low velocity habitat as they maintain their position near the stream bottom.

Bull trout may live in tributary streams their entire lives as resident forms and some may emigrate from their natal streams at about age 3 and become migratory which is reflected in their increased growth as they get older (Thurow 1987). Bull trout can reach maturity in 4-7 years and individuals have been known to live as long as 20+ years (USFSW 2015). Bull trout typically spawn in low gradient riffle habitat with water depths greater than 9.4 inches. They have been noted to spawn in higher gradient channels where hydraulic controls allow accumulations of spawning gravels. Redds are typically constructed in gravel sized substrate that varies from 0.3-2.5 inches. Resident forms of bull trout build smaller (2.6-16.2 ft²) redds than migratory forms (1.4-26.9 ft²) with egg pocket depths occurring between 3.9 and 7.9 inches. Recommended temperatures during spawning vary from 39.2-48.2 °F.

Table 5-3. Habitat requirements and physical habitat criteria for different life stages of bull trout.

Life Stage	Parameter	Criteria	References
Spawning	Substrate (in)	87% of the dominant substrate sizes measured at bull trout redd sites were in the pebble (0.26-1.00) and small gravel (1.00-2.00) categories. Pea gravel (0.08 to < 0.31) and gravel (0.31-2.52) were dominant substrates (> 60%) in redds.	Anglin et al. 2008; Guzevich and Thurow 2017
	Water Velocity (ft/s)	0.66-1.97 (0.82 mean); 0.06-2.13 (0.70 mean)	Anglin et al. 2008; Anglin et al. 2008; Guzevich and Thurow. 2017
	Water Depth (in)	7.9-23.6 Range (10.6 mean); 1.9-20.9 range (7.8-mean)	Anglin et al. 2008; Guzevich and Thurow. 2017
	Stream Temperature (°F)	Spawning areas are often associated with cold-water springs, groundwater infiltration, and the coldest streams in a given watershed. Watershed conditions indicators (WCI) 7-Day Average Maximum Temperature for bull trout spawning period 39.2-48.2 °F.	USFWS 2015; Baxter and Hauer 2000; USFS 2003 Appendix B
	Redd Size (ft ²)	Resident (range 2.58-16.2); Fluvial (range 4.3-26.9); Fluvial (range 1.40-25.6, mean 7.3)	Anglin et al. 2008; Guzevich and Thurow. 2017
	Channel Type	Sites where bull trout spawn are characterized by relatively low gradients, a predominance of small gravel, low velocities and proximity to cover (cutbanks, log jams, pools, overhanging bush, etc.). In larger streams redds are often sited downstream of aggrading areas and are associated with ground water sources; whereas, in smaller streams redds are associated with pockets of suitable gravel. Redds occur in patches of sorted gravels along the margins of runs, in high gradient riffles, and downstream from boulders or large woody debris. In higher gradient channels, redds have been observed either downstream from boulders or upstream from natural hydraulic controls where gravels accumulate. Hydraulic controls often result from accumulations of large woody debris and sediment. Pool-riffle and forced pool-riffle channel types would fit this habitat description and comport with redds observed in Sugar and Profile creeks in 2017.	McPhail and Baxter 1996; Guzevich and Thurow. 2017; Miller personal communication 2017
	Gradient (%)	<3%	Fraley and Shepard 1989

Life Stage	Parameter	Criteria	References
	Migration Barrier	Bull trout have been observed in presence absence surveys in gradients up to 23%. This is very close to the 20% defined for anadromous steelhead and Chinook salmon	Watson and Hillman 1997
	Cover	Large woody debris, deep water (pools & runs), boulders, and turbulence.	Wissmar and Craig 2004
Incubation	Egg Pocket Depth (in)	3.94-7.87	DeVries 1997
	Intragravel DO (ppm)	8.0	Bjornn and Reiser 1991 (Steelhead & Coho)
	Temperature (°F)	success increases with temperatures <50°F, optimum 35.6 to 39.2 °F	Kuzis 1997 (Bull Trout)
	Fines (<0.03 in)	<12% fines (0.03 inches) in gravel; Surface fines (≤0.24 in) ≤20%	Same as WCI, USFS 2003 Appendix B
	Stream Icing & Scouring	Anchor and frazil ice as well as scouring can reduce intragravel survival.	Bjornn and Reiser 1991
Rearing	Post-emergent	Newly emerged fry are secretive and hide in the gravel along stream edges and in side channels. Early rearing habitat is characterized as low velocity, shallow habitat along stream margins with adequate interstitial spaces in the substrate to provide cover.	McPhail and Baxter 1996
	Summer	As juveniles grow, they select deeper habitats found mainly in pools, but also in riffles and runs. They maintain focal sites near the bottom and are strongly associated with instream cover, especially overhead cover.	McPhail and Baxter 1996
	Winter	Bull trout used concealment cover of large woody debris and boulder substrate crevices in deep pools during the day. At night, fish emerged from cover and habitat use shifted to shallow water with low cover. Microhabitat partitioning among species (bull trout and cutthroat) and size classes occurred at night, cutthroat trout moving into shallower, faster water that was farther from cover compared to bull trout. Smaller fish of both species occupied focal positions in slower, shallower water closer to the substrate than larger fish.	Jakober et al. 2000
	Channel Type	Bull trout occurred more often in A (entrenched, step-pool, 4-10% gradient) and C (meandering, riffle-pool, <2% gradient) channel types. Bull trout most often occupied slow-water habitats (scour and dam pools) within alluvial lowlands and valleys. The dominant riparian vegetation in these sites consisted of trees and shrubs.	Watson and Hillman 1997
	Bankfull Width (ft)	0.98-86.0	Watson and Hillman 1997
	Gradient	>23%-None A (entrenched, step-pool, 4-10% gradient) and C (meandering, riffle-pool, <2% gradient)	Watson and Hillman 1997

4.4 Westslope Cutthroat Trout

As noted previously, Westslope cutthroat trout have a widespread distribution and may exhibit resident or migratory life histories. Resident forms remain in their natal streams while migratory forms move downstream occupying habitats in larger streams. The status review for Westslope cutthroat trout characterized spawning habitat as low-gradient stream reaches that have gravel substrate ranging from 0.09-2.95 inches in diameter. Several researchers confirm that Westslope cutthroat trout spawn in low gradient stream reaches between 0.5-4.4 percent. Spawning occurs in riffle habitat in water less than 9 inches deep with velocities ranging between 0.8-2.6 ft/s. Females construct redds that vary in size from 0.97-9.69 ft² and bury their eggs in substrate about 3.9-7.9 inches deep.

Temperature during the incubation period may range from 43-63 °F but 50 °F is optimal. Fry typically emerge from the gravel 45 to 75 days after egg fertilization depending on water temperature (Calhoun 1944; Lea 1968; Scott and Crossman 1973). Post-emergent fry seek low velocity lateral habitats with cover and larger growth increments occurring after age 3 suggest that emigration occurs at this age to more productive downstream habitats (Thurow 1987). Idaho Department of Fish and Game (2013) note that the distribution and abundance of larger cutthroat trout is strongly associated with pool habitat and suggest that stream reaches with numerous pools support the highest densities of fish.

Table 5-4. Habitat requirements and physical habitat criteria for different life stages of Westslope cutthroat trout.

Life Stage	Parameter	Criteria	Reference
Spawning	Substrate (in)	0.03-1.4; 0.12-3.15 average; 0.08-2.95	Kuzis 1997; Hickman and Raleigh 1982; (average size); USFWS 1999
	Water Velocity (ft/s)	0.98-1.97; Average 1.84 (0.82-2.56)	Hickman and Raleigh 1982; Schmetterling 2000
	Water Depth (in)	1.7-9.0; average 5.1	Schmetterling 2000
	Stream Temperature (°F)	43.0 to 63.0	Kuzis 1997
	Redd Size (ft ²)	0.97-9.69	Kuzis 1997
	Channel Type	Cutthroat trout prefer channel types that contain pools, pool tailouts, and riffles.	Hickman and Raleigh 1982
	Gradient (%)	0.5- 4.4	Magee et al. 1996; Zurstadt and Stephan 2004; Schmetterling 2000; Marotz and Fraley 1986
	Migration Barrier	>17	Peterson et al. 2014-excluded as potentially unsuitable habitat for Westslope cutthroat trout
Incubation	Egg Pocket Depth (in)	3.9-7.9	DeVries 1997
	Intragravel DO (ppm)	7-8	Hickman and Raleigh 1982; Bjornn and Reiser 1991 (Steelhead & Coho)
	Temperature (°F)	43-63 range; 50 optimal	Hickman and Raleigh 1982
	Fines (<0.25 in)	Decreased survival >10% fines	Kuzis 1997
	Stream Icing & Scouring	Anchor and frazil ice as well as scouring can reduce intragravel survival.	Bjornn and Reiser 1991
Rearing	Post-emergent	Fry selected lateral habitats with low velocities (<0.07 ft/sec). Lateral habitats were along the stream margin, backwaters and side channels.	Moore and Gregory 1988;

Life Stage	Parameter	Criteria	Reference
	Summer	As cutthroat grow (>2.2 in) they can select deeper and faster velocities away from the stream margin (>0.16 ft/sec). Juvenile cutthroat are most often found in stream pools and runs and a diversity of cover. Adult cutthroat trout are strongly associated with pools and cover.	Moore and Gregory 1988; USFWS 1999; IDFG 2013
	Winter	Cutthroat trout used concealment cover of large woody debris and boulder substrate crevices in deep pools during the day. At night, fish emerged from cover and habitat use shifted to shallow water with low cover. Microhabitat partitioning among species (bull trout and cutthroat) and size classes occurred at night, cutthroat trout moving into shallower, faster water that was farther from cover compared to bull trout. Smaller fish of both species occupied focal positions in slower, shallower water closer to the substrate than larger fish.	Jakober et al. 2000
	Channel Type	Variable-mostly pools and runs	Kuzis 1997; Moore and Gregory 1988; USFWS 1999
	Gradient	>17	Peterson et al. 2014-excluded as potentially unsuitable habitat for Westslope cutthroat trout

SECTION 5: BIOLOGICAL OBJECTIVES

Biological objectives were assessed for reaches of the EFSFSR (EF1-EF4) and Meadow Creek (MC4-MC6) based on intrinsic potential for Chinook salmon and steelhead (Cooney and Holzer 2006). For others reaches the current distributions and barriers were used to determine appropriate biological objectives. This is an initial coarse scale assessment that will be refined and replaced when intrinsic potential is applied globally using GIS techniques to all accessible (< 20 percent gradient) stream reaches in the upper EFSFSR. Developing intrinsic potential for all stream reaches will help identify net benefits associated with the Stibnite Gold Project Conceptual Mitigation Plan.

5.1 Anadromous Salmonids

Cooney and Holzer (2006) used channel slope (gradient), bankfull width (BFW) and the ratio of valley width to bankfull width to assess intrinsic potential for anadromous spring/summer Chinook salmon and steelhead (see Table 6-1 and Table 6-2).

Table 6-1. Intrinsic potential for Interior Columbia basin Spring/Summer Chinook salmon spawning and initial rearing.

Chinook salmon relative potential for spawning and initial rearing				
Stream width / Gradient Categories		Valley Width Ratio (ratio of valley width to bankfull stream width)		
Bankfull Width (ft)	Gradient (%)	Confined (≤4 x BFW)	Moderately Confined (4 to 20 x BFW)	Unconfined (> 20 x BFW)
BFW <12.1	≥ 0.0	None	None	None
BFW 12.1 to 82	0.0 - 0.5	Medium	High	High
	0.5 - 1.5	Low	Medium	High
	1.5 - 4.0	Low	Low	Medium
	4.0 - 7.0	Negligible	Low	Low
	>7.0	None	None	None
BFW 82-164	0.0 - 0.5	None	Medium	Medium
	0.5 -10.0	None	None	None
	≥ 10.0	None	None	None
BFW > 164	≥ 0.0	None	None	None

Note: Intrinsic potential categories (i.e., none - high) were assessed for potential anadromous reaches in Meadow Creek and EFSFSR. Intrinsic potential categories were based on proposed bankfull width (BFW), gradient (%), and the ratio of floodplain width (FPW) to bankfull width (FPW/BFW). For example, streams with a BFW from 12.1 to 82 feet, a gradient from 0.0%-0.5% and confinement ratio greater than 20 (i.e., unconfined) were considered to have a high intrinsic potential for Chinook salmon (Cooney and Holzer 2006).

Table 6-2. Intrinsic potential for interior Columbia basin summer steelhead spawning and initial rearing.

Steelhead relative potential for spawning and initial rearing				
Stream width / Gradient Categories		Valley Width Ratio (ratio of valley width to bankfull stream width)		
Bankfull Width (ft)	Gradient (%)	Confined (≤4 x BFW)	Moderately Confined (4 to 20 x BFW)	Unconfined (> 20 x BFW)
BFW <12.5	≥ 0.0	None	None	None
BFW 12.5 - 82	0.0 - 0.5	None	Medium	Medium
	0.5 - 4.0	Low	High	High
	4.0 - 7.0	None	Low	Low
	> 7.0	None	None	None
BFW 82 - 164	0.0 - 4.0	Low	Medium	Medium
	>4.0	None	None	None
BFW > 164	≥ 0.0	None	Low	Low

Note: Intrinsic potential categories (i.e., none - high) were assessed for potential anadromous reaches. Intrinsic potential categories were based on bankfull width (BFW), gradient (%), and the ratio of floodplain width (FPW) to bankfull width (FPW/BFW). For example, streams with a BFW from 12.5 to 82 feet, a gradient from 0.0%-0.5% and confinement ratio greater than 20 (i.e., unconfined) were considered to have a medium intrinsic potential for steelhead (Cooney and Holzer 2006).

Intrinsic potential helped identify potential biological objectives for restoration and enhancement reaches of the EFSFSR and Meadow Creek (Table 6-3 and Table 6-4). Intrinsic potential for spring/summer Chinook salmon in the EFSFSR is considered low largely because of stream gradient. However, for steelhead intrinsic potential varied from low to high in different reaches of the EFSFSR. In Meadow Creek, intrinsic potential for spring/summer Chinook salmon varied from low to high but remained high for steelhead. This suggests that multiple biological objectives could be achieved with stream restoration/enhancement and elimination of the passage barrier at the Yellow Pine pit. Successful reproduction for spring/summer Chinook salmon has been demonstrated by observations of juvenile Chinook salmon following translocation of adult spawners the year before (MWH 2017). This assessment also suggests that successful steelhead production is probable given the high intrinsic potential noted. However, the rate of recolonization would be influenced by habitat quality and size of the nearby steelhead population.

Table 6-3. Coarse scale assessment of intrinsic potential for spring/summer Chinook salmon and steelhead in reach EF1 to EF4 of the EFSFSR.

Stream	Reach Designation	Valley & Channel Characteristics						Intrinsic Potential ²	
		Channel Slope	Bankfull Width (ft)	FP/BF ratio (min)	FP/BF ratio (max)	Floodplain Width ft (min)	Floodplain Width ft (max)	Chinook salmon	Steelhead
East Fork South Fork Salmon River (EFSFSR)	EF1	6.48	15	4.8	9.7	72	145	Low	Low
	EF2a	3.07	25	5.4	10.8	135	269	Low	High
	EF2b	2.85	25	5.4	10.8	135	269	Low	High
	EF2c	6.61	25	5.4	10.8	135	269	Low	Low
	EF3a	3.76	25	3.8	7.6	96	191	Low	Low & High
	EF3b	3.76	22	5.4	10.7	118	236	Low	High

Stream	Reach Designation	Valley & Channel Characteristics						Intrinsic Potential ²	
		Channel Slope	Bankfull Width (ft)	FP/BF ratio (min)	FP/BF ratio (max)	Floodplain Width ft (min)	Floodplain Width ft (max)	Chinook salmon	Steelhead
	EF3c	3.76	26	4.5	9.0	117	234	Low	High
	EF3d	3.76	22	5.7	11.5	126	252	Low	High
	EF3e	3.76	26	5.2	10.5	136	272	Low	High
	EF4	2.62	26	3.2	6.2	84	161	Low	Low & High

2. In EF3a and EF4 the variation in floodplain width produced FP/BF ratios where intrinsic potential would vary from low to high for steelhead.

Table 6-4. Coarse scale assessment of intrinsic potential for spring/summer Chinook salmon and steelhead in reaches MC4 to MC6 of Meadow Creek.

Stream	Designation	Valley & Channel Characteristics						Intrinsic Potential ³	
		Channel Slope	Bankfull Width (ft)	FP/BF ratio (min)	FP/BF ratio (max)	Floodplain Width ft (min)	Floodplain Width ft (max)	Chinook Salmon	Steelhead
Meadow Creek	MC4	0.98	16	11.5	23.0	184	368	Med-High	High
	MC5	1.39	17	10.9	21.9	186	372	Med-High	High
	MC6	2.29	17	6.1	12.1	103	206	Low	High

3. In MC4 and MC5 the variation in floodplain width produced FP/BF ratios where intrinsic potential would vary from medium to high for spring/summer Chinook salmon.

These reaches of Meadow Creek and the EFSFSR would also provide potential spawning, rearing and migratory corridors for bull trout and westslope cutthroat trout. Some overlap in spawning distributions of bull trout and spring/summer Chinook salmon observed in Sugar Creek is encouraging and suggests that multiple biological objectives could be achieved (Figure 6-1, Figure 6-2, Figure). In addition, the lowermost sections of some tributaries streams (i.e., East Fork Meadow Creek, Garnet Creek, and Midnight Creek) may provide some limited juvenile rearing habitat for steelhead and spring/summer Chinook salmon. However, for other streams like Fiddle Creek and West End Creek the steep gradient at the confluence preclude that potential.

5.2 Migratory or resident salmonids

With stream connectivity restored across the current Yellow Pine pit, migratory forms of westslope cutthroat trout and bull trout are likely to migrate to the upper EFSFSR. The biological objective for Fiddle Creek and East Fork Meadow Creek is westslope cutthroat trout based on current distribution (Figure 3-1). Stream restoration atop the tailing storage facility in upper Meadow Creek would encourage continued occupancy for both westslope cutthroat trout and bull trout. West End Creek would remain non-fish bearing. The majority of Garnet Creek, Midnight Creek, and Hennessy Creek would also be non-fish bearing except near their confluence with the EFSFSR.

With stream restoration and enhancement focused on developing high quality habitat, multiple biological objectives may be addressed for spring/summer Chinook salmon, steelhead, bull trout, and westslope cutthroat trout within the Stibnite Gold Project.

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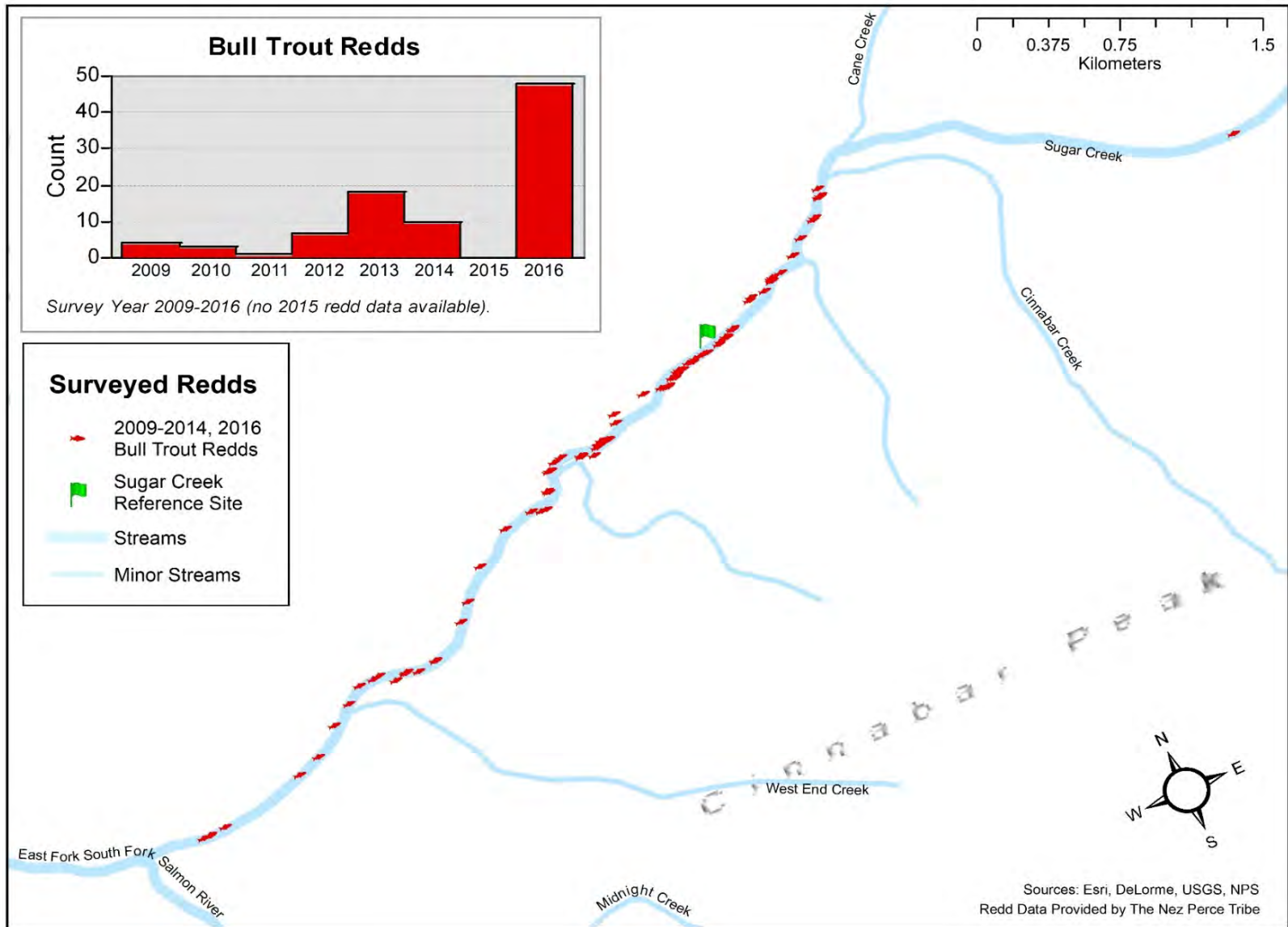


Figure 5-1. Bull trout redds observed in Sugar Creek (2009-2014, 2016). Information provided by the Nez Perce Tribe (2018).

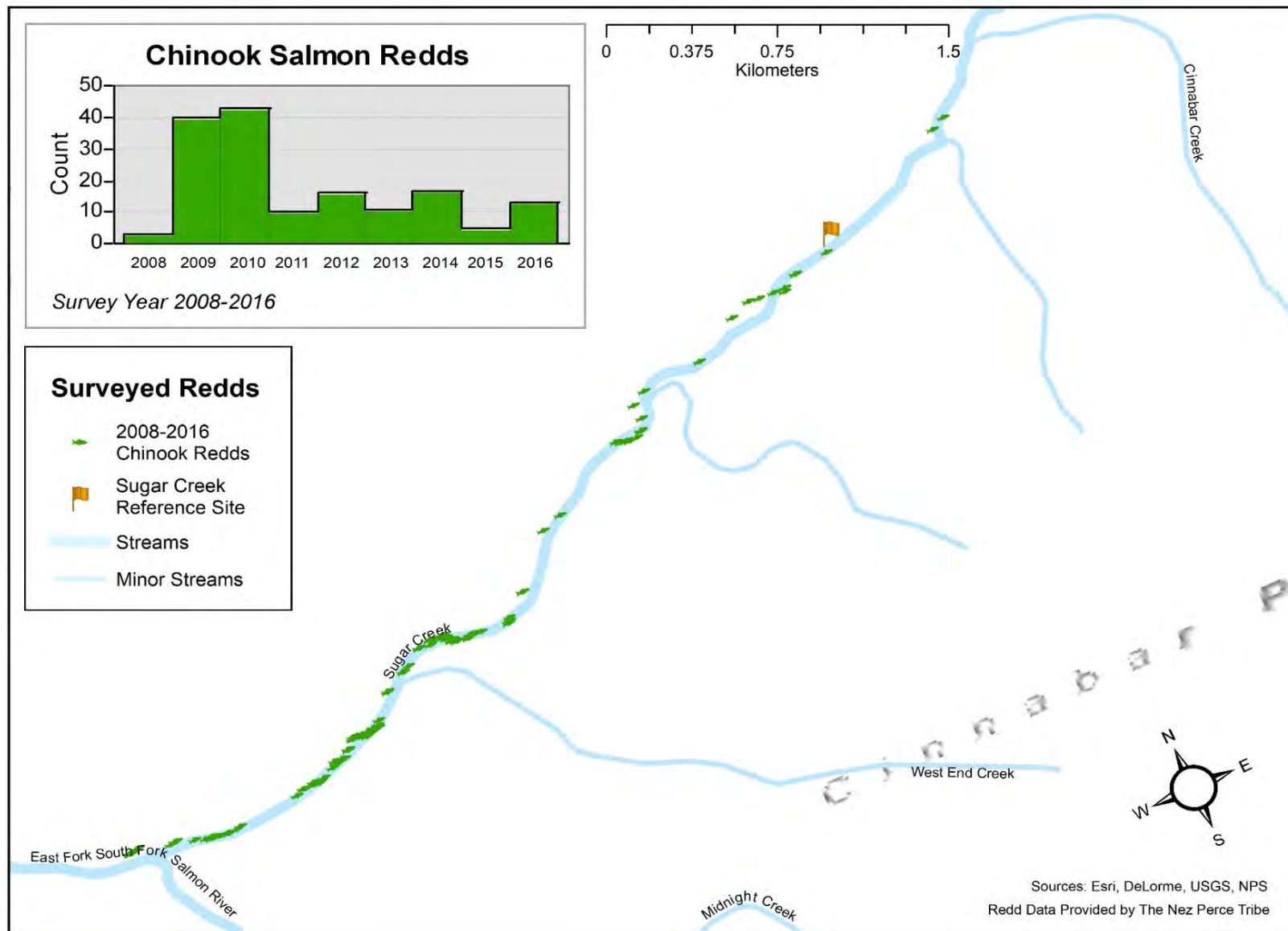


Figure 5-2. Chinook Salmon Redds observed in Sugar Creek (2008 – 2016). Information provided by the Nez Perce Tribe (2018).

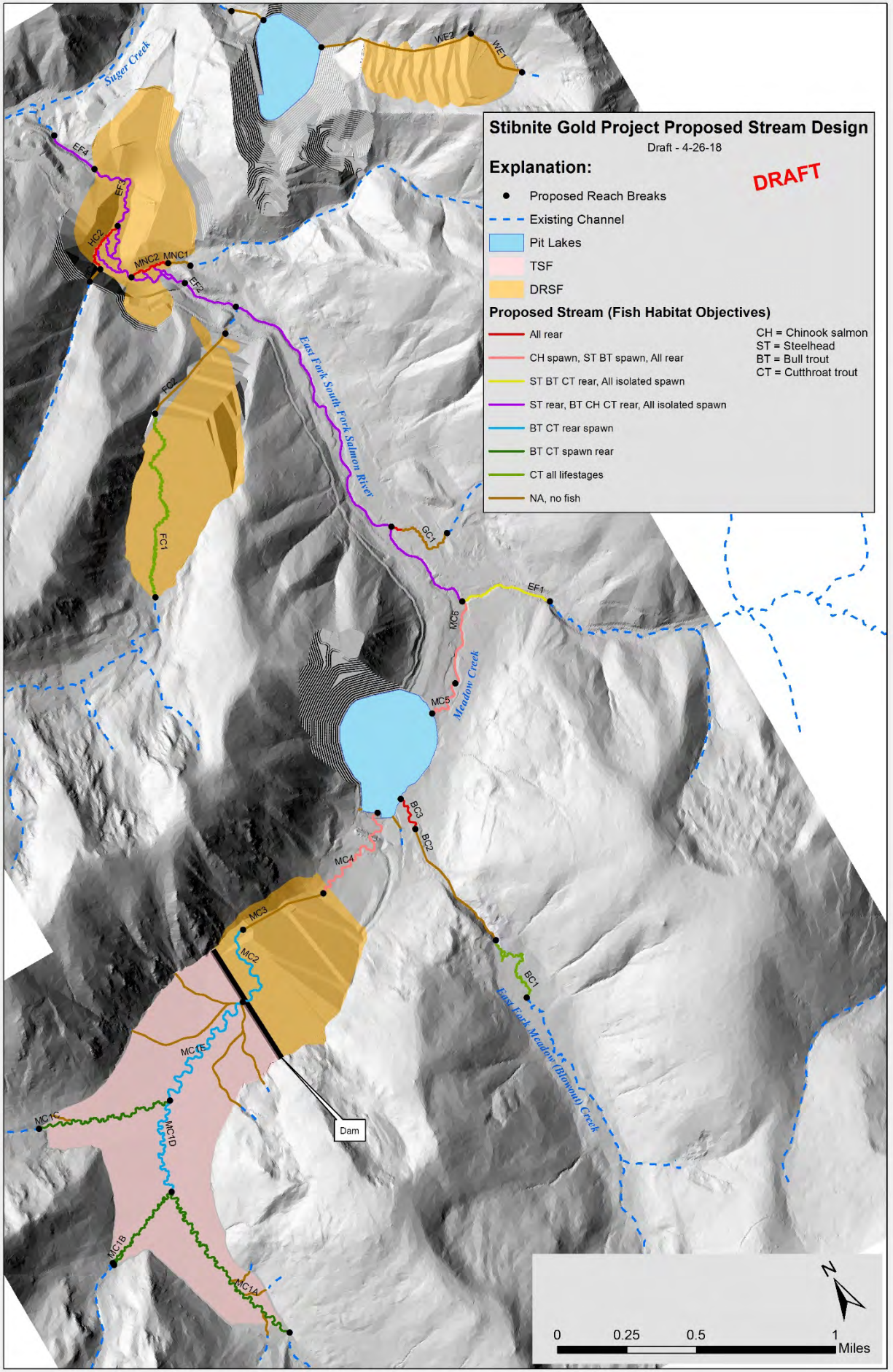


Figure 5-3. Proposed biological objectives for streams of the upper EFSFR.

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Appendix B
Reference Sites

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APPENDIX B - REFERENCE SITES

Reference sites represent areas in or near the project area that exhibit characteristics (in part or whole) that are useful for understanding stream function, habitat, and ultimately stream restoration and enhancement design. The stream designs seek to emulate certain reference conditions considered positive while seeking to avoid other reference conditions considered negative or detrimental.

Candidate reference sites were identified based on applicability relative to proposed restoration reaches, intrinsic geomorphic character, habitat quality, and accessibility. The restoration and enhancement design reaches span a broad range of geomorphic conditions. Similarly, candidate sites were identified that would provide reference for a broad range of conditions based on channel gradient, confinement, stream size (order), lithology (granitic or not), elevation, fire history, and ease of access.

- Gradient (channel and/or valley slope as calculated or measured from available 10m and 10ft [LiDAR] digital elevation models).
- Confinement (relative valley width compared to stream channel width as interpreted from aerial photos and available topography).
- Relative Stream Order (the relative size of the stream based on the number and size of tributaries entering the channel upstream from the selected site).
- Lithology (granitic or non-granitic bedrock in the contributing watershed, recognizing that granitic bedrock often weathers to and produces relatively high volumes of sand-sized sediment).
- The existing Stream Functional Assessment (HDR, 2016) identifies four reference streams including Goat, Fourmile, Profile, and Tamarack Creeks. These four streams have relatively large, existing datasets associated with past work. Reference sites were identified on these streams as a priority for that reason.

Twenty (20) candidate reference sites were identified using GIS analysis. GIS-measured conditions used to select candidate reference sites are listed in Table B-1 along with three additional sites (21-23) added subsequently.

Table B-1. Candidate Reference Sites with GIS-Measured Characteristics

ID	Stream Name	Gradient from GIS (%)	Confinement	Relative Stream Order ¹	Lithology	Elev (ft)	Lat	Long
①	Goat Creek	6.67	Confined	3	Granitic	4884	44.755651	-115.679964
2	Goat Creek	14.50	Confined	2	Granitic	5398	44.764783	-115.663781
3	Goat Creek	4.44	Unconfined	2	Granitic	6651	44.773251	-115.637982
4	Fourmile Creek	8.99	Confined	3	Granitic	4347	44.862663	-115.685974
⑤	Profile Creek	2.66	Unconfined	3	Other	5340	44.966229	-115.423487
⑥	Profile Creek	7.00	Confined	3	Other	5471	44.974628	-115.420313
7	Profile Creek	3.55	Confined	3	Other	5939	44.999498	-115.403506
8	Profile Creek	6.21	Confined	2	Other	6122	45.008887	-115.394073
9	Tamarack Creek	1.96	Unconfined	3	Other	5522	44.963529	-115.384891
⑩	Cinnabar Creek	5.00	Unconfined	2	Granitic	6396	44.951265	-115.288873
⑪	Sugar Creek	1.76	Unconfined	3	Granitic	6227	44.946963	-115.302364
⑫	EFSFSR	2.10	Unconfined	3	Granitic	6895	44.891102	-115.303198
⑬	EFSFSR	2.43	Unconfined	2	Granitic	7183	44.884848	-115.286474
14	Riordan Creek	0.12	Unconfined	4	Granitic	6076	44.887935	-115.460585
15	Riordan Creek	2.94	Unconfined	4	Granitic	6220	44.873363	-115.450357
16	Riordan Creek	0.67	Unconfined	3	Granitic	6551	44.848694	-115.426506
17	Riordan Creek	1.50	Unconfined	3	Granitic	6597	44.84605	-115.415734
18	South Fork Salmon	0.31	Unconfined	3	Granitic	6264	44.510054	-115.707897
⑰	Fiddle Creek	14.52	Confined	2	Granitic	6620	44.915427	-115.34031
20	Fiddle Creek	1.22	Unconfined	2	Granitic	7253	44.908913	-115.355147
⑳	Meadow Creek	1.00	Unconfined	2	Granitic	6611	44.889488	-115.356419
㉑	Meadow Creek	0.40	Unconfined	3	Granitic	6544	44.896169	-115.336511
㉒	EFSFSR	2.90	Confined	4	Granitic	6383	44.907573	-115.329647

Note: ¹Relative stream order determined using detailed stream layer refined from National Hydrography Dataset

X – demarks non-visited candidate reference site for which no detailed data were collected

O – demarks selected final reference site from which more detailed data were collected

Sixteen of the twenty candidate reference sites were visited in the field to take observations, photos, and channel measurements (gradient, sinuosity, bankfull width, average depth, max depth, grain sizes, max drop height, and riffle-pool spacing). Sites #3 (Upper Goat Creek), #18 (South Fork Salmon River), #7, and #8 (Upper Profile Creek) were not visited due to fire closures, difficult access and/or the presence of similar conditions as other sites. Channel sections and water surface heights were strategically measured within reference sites to evaluate local hydrologic and hydraulic conditions to verify suitability as “reference” for proposed reach(es). Site-specific measurements derived from a combination of field measurements and GIS are provided for the observed candidate reference sites in Figures B-2 through B-32.

Final reference sites were identified based on a combination of the initial GIS evaluation, field observations, and professional judgement. Eight of the initial candidate sites were selected for more specific field data collection along with three additional sites (11 total) located within the project area. All 11 total sites are circled in Table B-1 (above). The three additional sites included:

- Upper Meadow Creek (Site #21) – The meadow located on top of existing Bradley tailings immediately upstream of the SODA.

- Lower Meadow Creek (Site #22) – The restored section of Meadow Creek between the confluence with Blowout Creek and the East Fork South Fork Salmon River (EFSFSR).
- Mainstem EFSFSR (Site #23) – Between the confluence with Meadow Creek and the existing Yellow Pine pit.

Detailed field measurements and observations were collected from each of the 11 final reference sites including detailed channel geometry (cross sections and profile), identification of specific in-stream and off-channel habitat features, velocity measurements associated with habitat features, riparian vegetation identification, Wolman pebble counts, and geomorphic observations regarding sediment scour, deposition, large woody debris, channel roughness, and channel form. Five riparian vegetation zones (ecology zones) were identified at select sites:

- Zone 1: Channel and banks below the ordinary high-water mark
- Zone 2: Banks above the ordinary high-water mark
- Zone 3: Floodplain
- Zone 4: Upland
- Zone 5: Floodplain/off-channel wetland

All reference sites are identified on Figure B-1. Summaries of initial and refined (final) reference data are provided below in figures B-2 through B-24 plus pebble count data from the delta forming at the EFSFSR inlet to Yellow Pine pit (B-25).

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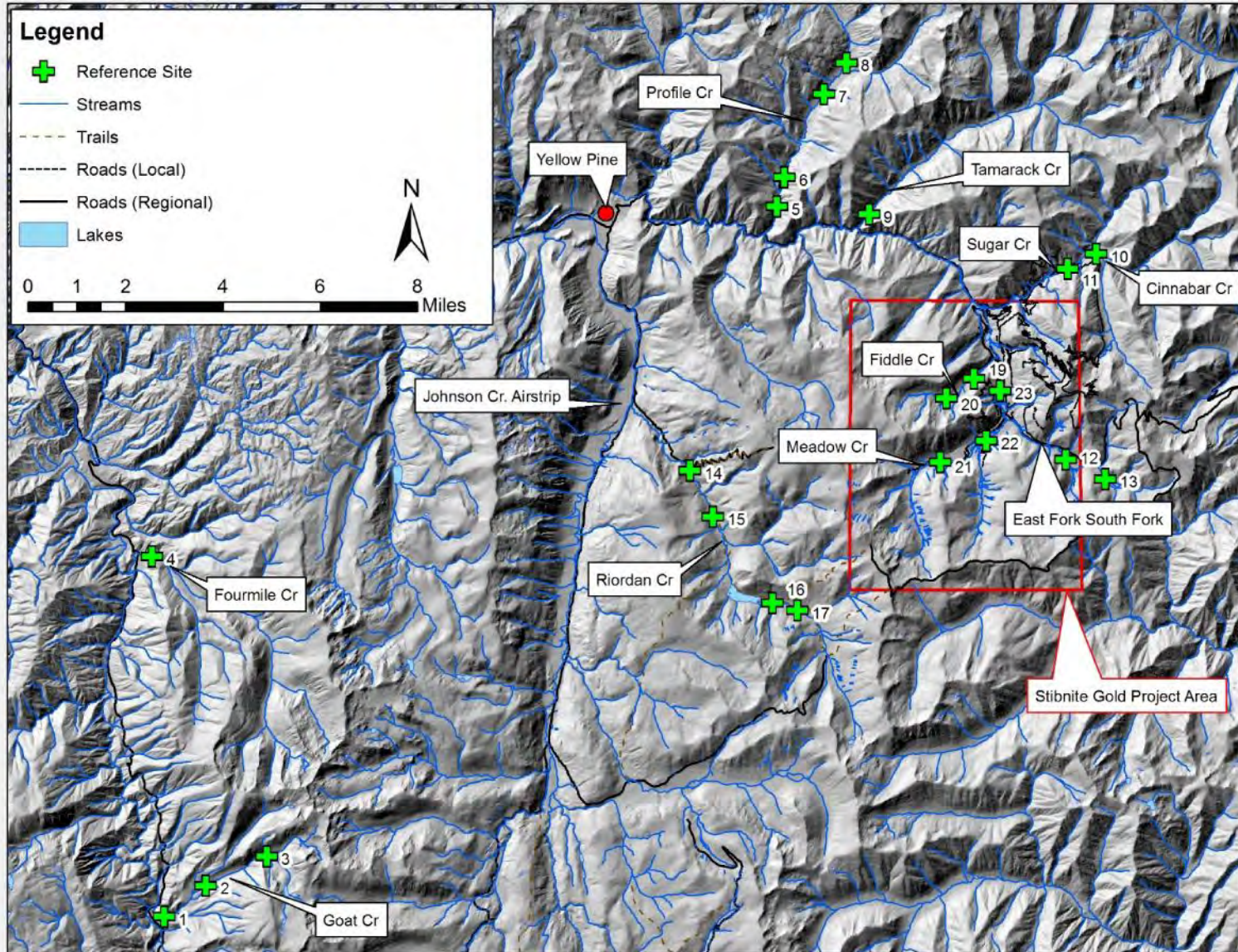


Figure B-1. Reference Sites

Note: The South Fork Salmon River (Site # 18 – not visited / no data) is not shown on this map.

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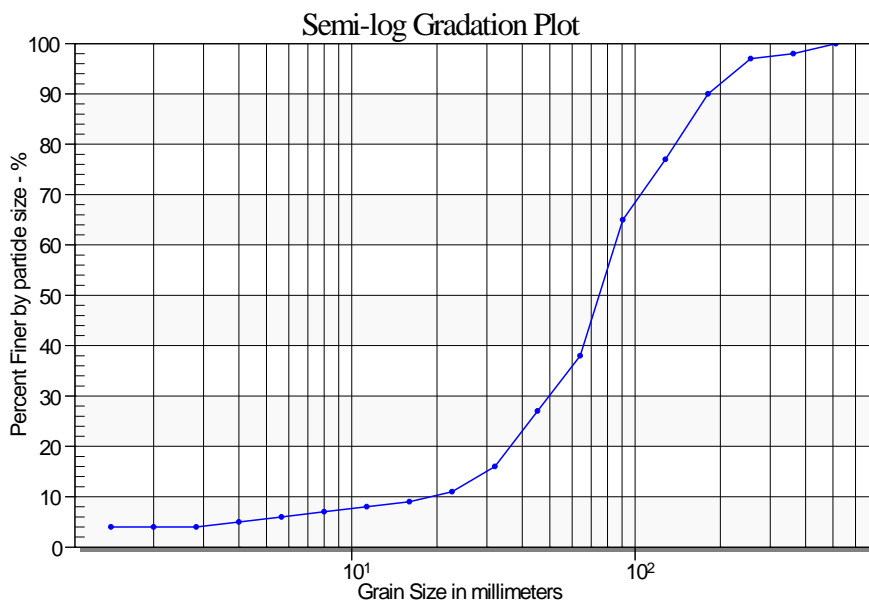
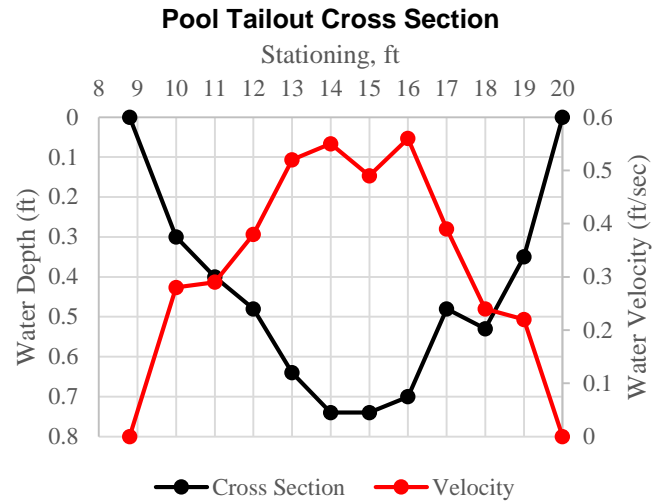
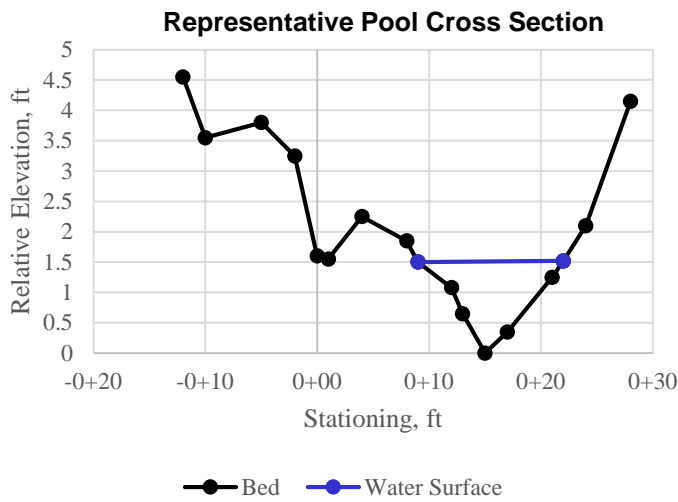
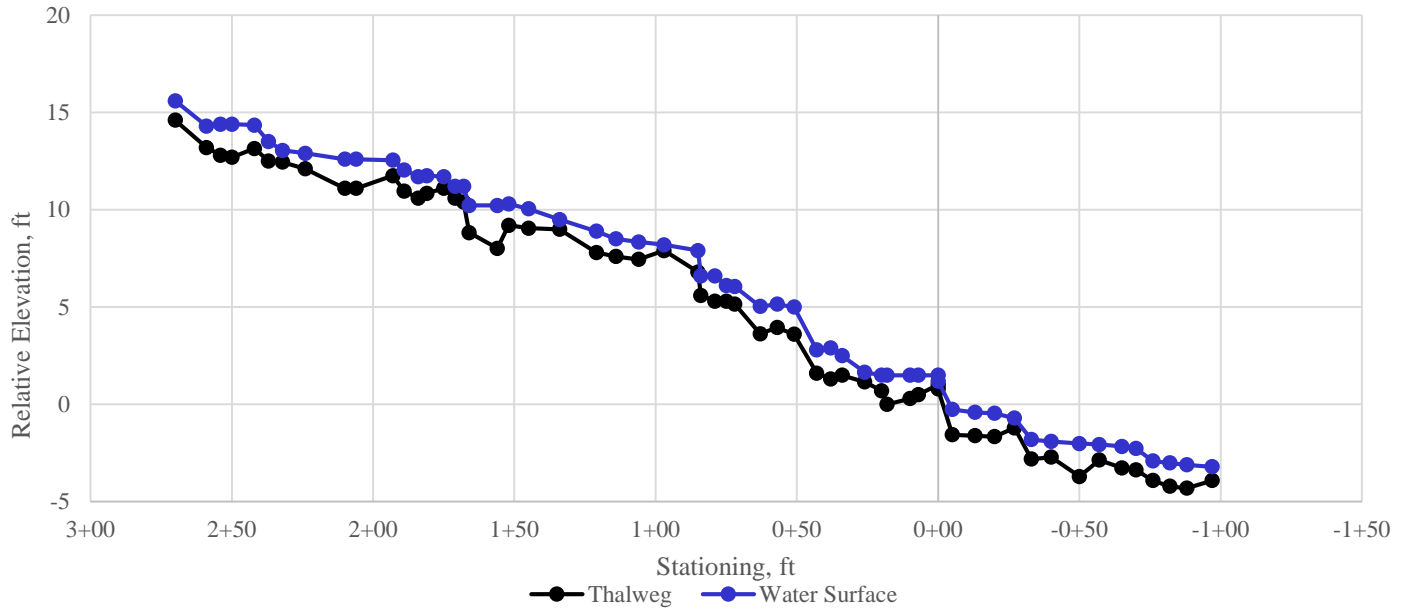


Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Step-Pool	--	Observation
Rosgen	n/a	--	B4c	--	Observation
Basin Area	sqmi	--	6.66	--	StreamStats
Precip	in	--	42.3	--	StreamStats
Valley Grade	ft/ft	--	0.067	--	10m DEM
Chan Grade	ft/ft	--	0.067	--	Field Measured
Sinuosity	ft/ft	--	1.2	--	Aerial Photo
Valley W	ft	56.8	47.3	38.7	Aerial Photo
BF W	ft	25	24	23	Field Measured
Entrenchment	ft/ft	--	2.1	--	Calculated
BF D	ft	--	2	--	Field Measured
Max D (BF)	ft	--	3.4	--	Field Measured
BF W:D	ft/ft	--	12.0	--	Calculated
Wavelength	ft	178.6	98.9	48.2	Aerial Photo
Radius	ft	60.5	48.6	38.2	Aerial Photo
Beltwidth	ft	98.3	65.5	46.8	Aerial Photo
Drop	ft	--	1	--	Field Measured
Riffle Spacing	ft	72	48	24	Field Measured
Relative Bank Stability	n/a	Very Stable			Field Observation
Riparian Condition	n/a	Dense, post-fire veg			Field Observation
Wetland Interaction	n/a	Narrow floodplain			Field Observation

**Site #1 – Goat Creek
(Lower)**

Reference Site Summary

Figure B-2.1

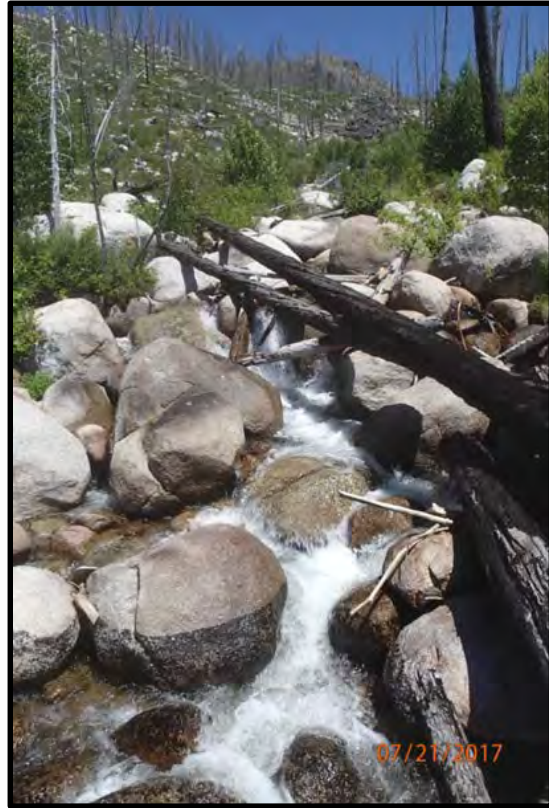


Discharge Summary

Date: 9/15/17
 Time: 2:30pm
 Wetted Cross Section Area = 5.4 ft²
 Average Velocity = 0.4 ft/sec
 Discharge = 2.2 ft³/sec
 Note: Discharge was taken in the tailout of a pool to obtain adequate depth.

Pebble Count Summary

D15 = 30 mm
 D50 = 76 mm
 D85 = 161 mm
 D100 = 512 mm



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Cascade	--	Observation
Rosgen	n/a	--	A2a+	--	Observation
Basin Area	sqmi	--	3.1	--	StreamStats
Precip	in	--	44.5	--	StreamStats
Valley Grade	ft/ft	--	19.2%	--	10m DEM
Chan Grade	ft/ft	--	13.5%	--	Field Measured
Sinuosity	ft/ft	--	1.1	--	Aerial Photo
Valley W	ft	77.4	57.2	46.2	Aerial Photo
BF W	ft	--	21	--	Field Measured
Entrenchment	ft/ft	--	2.7	--	Calculated
BF D	ft	--	2.5	--	Field Measured
Max D (BF)	ft	--	4.3	--	Field Measured
BF W:D	ft/ft	--	8.4	--	Calculated
Wavelength	ft	164.9	142.0	126.3	Aerial Photo
Radius	ft	109.8	86.8	21.5	Aerial Photo
Beltwidth	ft	99.2	64.7	51.3	Aerial Photo
Drop	ft	3	1	--	Field Measured
Riffle Spacing	ft	15	10	5	Field Measured
Relative Bank Stability	n/a	Very Stable			Field Observation
Riparian Condition	n/a	Alder, willow			Field Observation
Wetland Interaction	n/a	Floodplain wetland			Field Observation

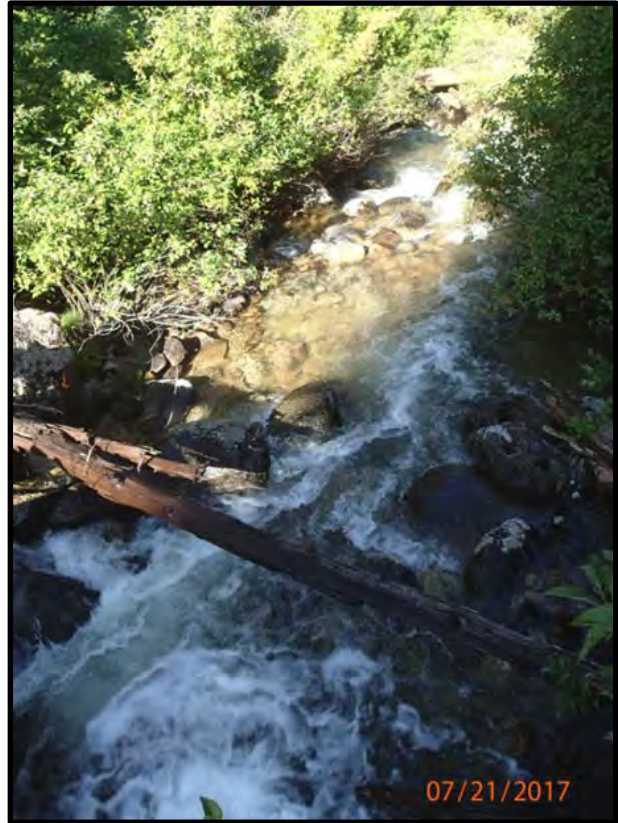
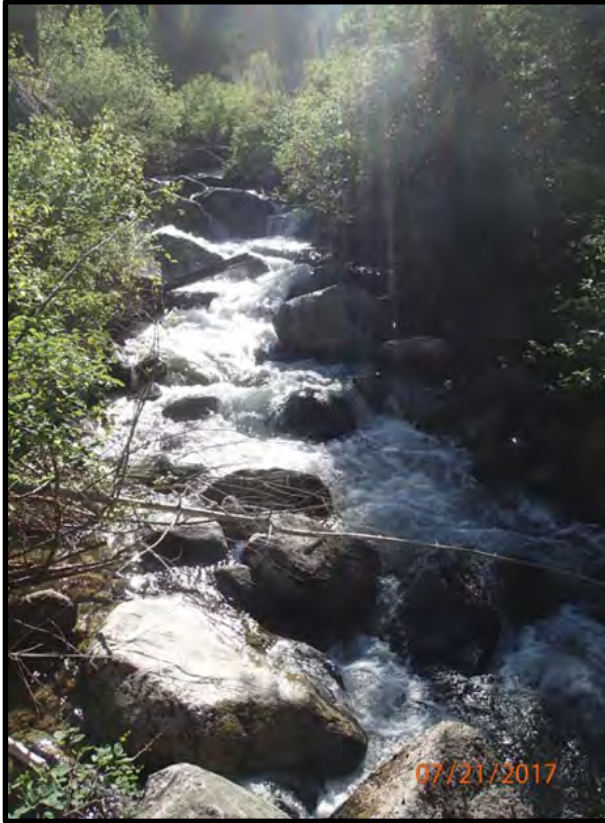
**Site #2 – Goat Creek
(Middle)**

Reference Site Summary

Figure B-3.1

Candidate Reference Site
No detailed profile or cross section data collected

No Data Collected – Site Omitted



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Cascade	--	Observation
Rosgen	n/a	--	A2a+	--	Observation
Basin Area	sqmi	--	15.06	--	StreamStats
Precip	in	--	38.2	--	StreamStats
Valley Grade	ft/ft	--	14.5%	--	Calculated
Chan Grade	ft/ft	--	14.5%	--	Field Measured
Sinuosity	ft/ft	--	1.0	--	Aerial Photo
Valley W	ft	53.5	38.1	31.3	Aerial Photo
BF W	ft	--	23	--	Field Measured
Entrenchment	ft/ft	--	1.7	--	Calculated
BF D	ft	--	3.2	--	Field Measured
Max D	ft	--	5.2	--	Field Measured
BF W:D	ft/ft	--	7.2	--	Calculated
Wavelength	ft	--	--	--	N/A
Radius	ft	--	--	--	N/A
Beltwidth	ft	--	--	--	N/A
Drop	ft	--	2	--	Field Measured
Riffle Spacing	ft	--	9	--	Field Measured
Relative Bank Stability	n/a	Very Stable			Field Observed
Riparian Condition	n/a	Alder, dogwood			Field Observed
Wetland Interaction	n/a	None			Field Observed

**Site #4 – Fourmile
Creek**

Reference Site Summary

Figure B-5.1

Candidate Reference Site
No detailed profile or cross section data collected

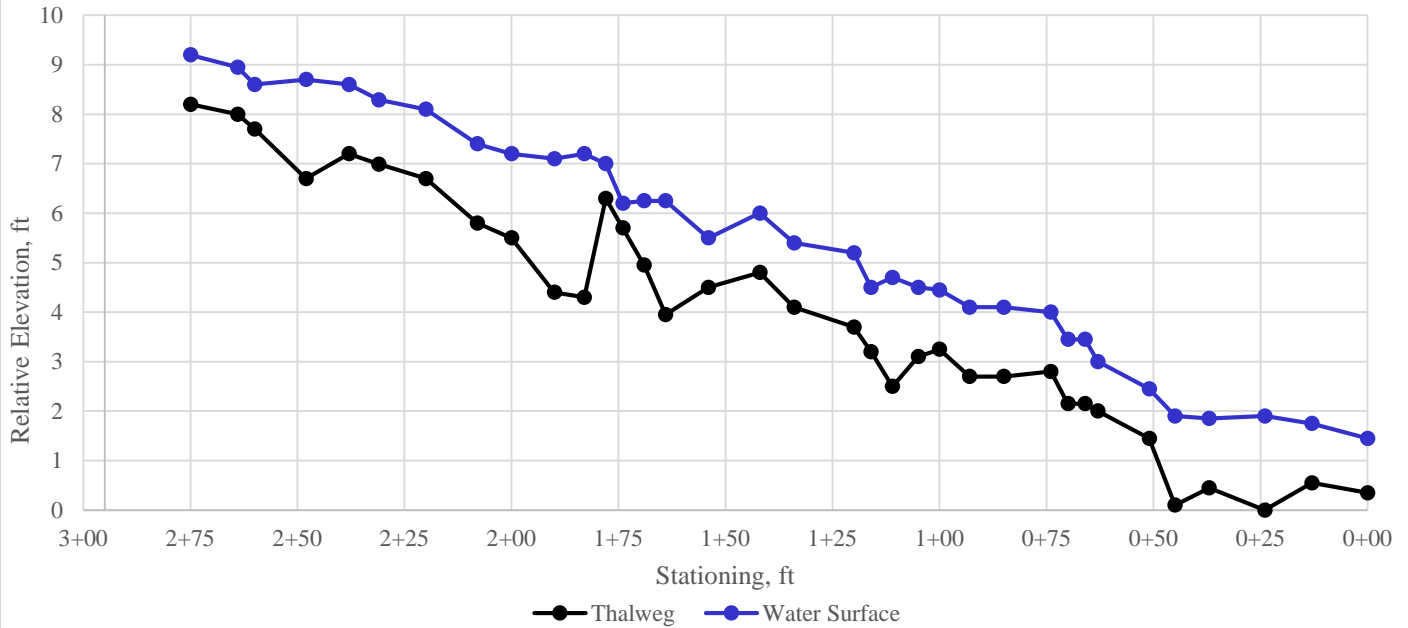


Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a		Forced pool-riffle		Observation
Rosgen	n/a	--	B3a	--	Observation
Basin Area	sqmi	--	19.1	--	StreamStats
Precip	in	--	29.6	--	StreamStats
Valley Grade	ft/ft	--	3.3%	--	LiDAR
Chan Grade	ft/ft	--	2.9%	--	LiDAR
Sinuosity	ft/ft	--	1.1	--	Calculated
Valley W	ft	171.4	140.2	109.5	LiDAR
BF W	ft	30.0	22.9	16.2	LiDAR
Entrenchment	ft/ft	6.75	6.20	5.72	Calculated
BF D	ft	--	--	--	N/A
Max D	ft	--	--	--	N/A
BF W:D	ft/ft	--	--	--	N/A
Wavelength	ft	687.0	557.4	484.7	LiDAR
Radius	ft	235.4	135.3	55.7	LiDAR
Beltwidth	ft	225.3	183.4	144.0	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Moderate			Field Observation
Riparian Condition	n/a	Mixed			Field Observation
Wetland Interaction	n/a	Broad floodplain			Field Observation

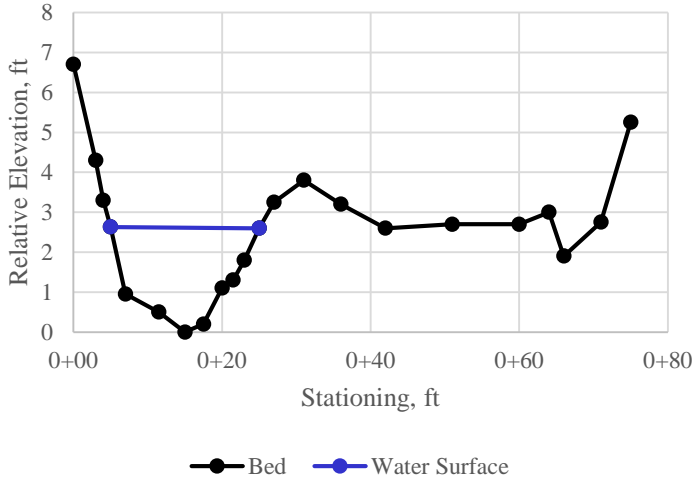
**Site #5 – Profile
Creek (Lower)**

Reference Site Summary

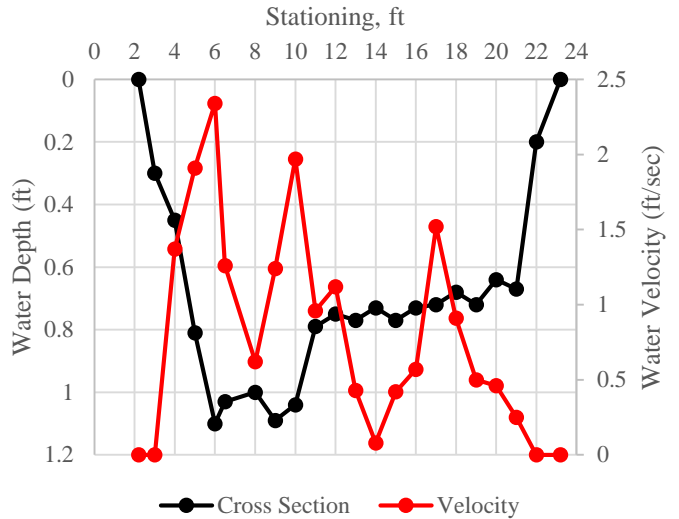
Figure B-6.1



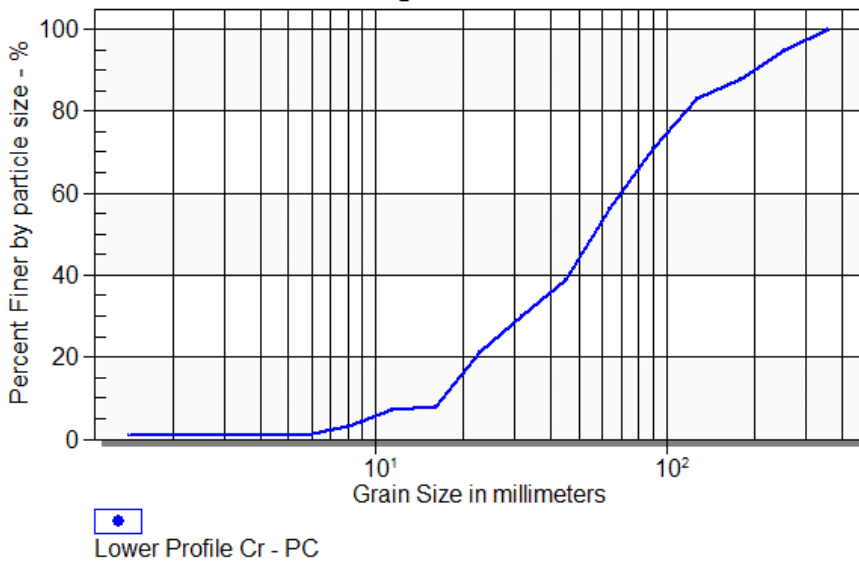
Representative Pool Cross Section



Glide Cross Section



Semi-log Gradation Plot



Discharge Summary

Date: 9/14/17
 Time: 9:00 am
 Wetted Cross Sectional Area = 15.0 ft²
 Average Velocity = 1.0 ft/sec
 Discharge = 14.6 ft³/sec
 Note: Discharge was measured in a glide to obtain adequate flow depth.

Pebble Count Summary

D15 = 20 mm
 D50 = 57 mm
 D85 = 149 mm
 D100 = 362 mm

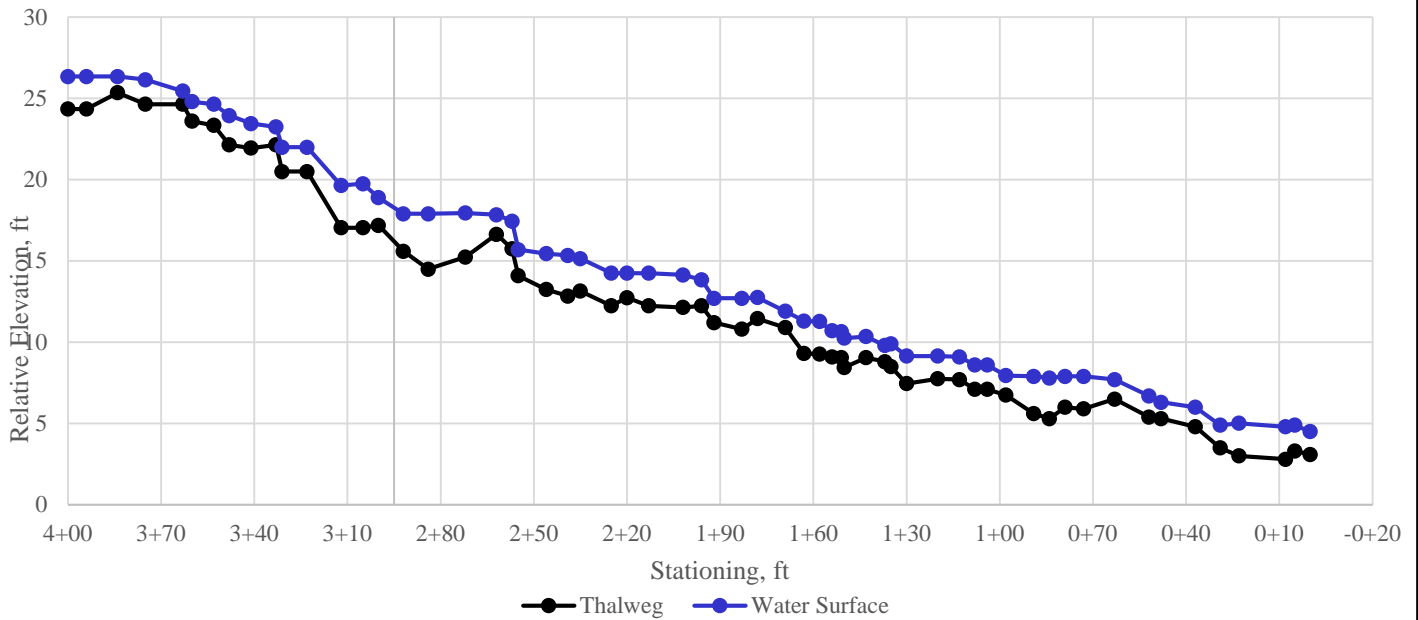


Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Step-Pool	--	Observation
Rosgen	n/a	--	A2a+	--	Observation
Basin Area	sqmi	--	17.83	--	StreamStats
Precip	in	--	29.9	--	StreamStats
Valley Grade	ft/ft	--	5.6%	--	Field Measured
Chan Grade	ft/ft	--	5.6%	--	Field Measured
Sinuosity	ft/ft	--	1.0	--	LiDAR
Valley W	ft	--	25.1	--	LiDAR
BF W	ft	--	25	--	Field Measured
Entrenchment	ft/ft	--	1.0	--	Calculated
BF D	ft	--	4	--	Field Measured
Max D	ft	--	6.2	--	Field Measured
BF W:D	ft/ft	--	4.0	--	Calculated
Wavelength	ft	--	--	--	N/A
Radius	ft	--	--	--	N/A
Beltwidth	ft	--	--	--	N/A
Drop	ft	2	1.5	1	Field Measured
Riffle Spacing	ft	50	46	42	Field Measured
Relative Bank Stability	n/a	Very Stable			Field Observation
Riparian Condition	n/a	Discontinuous			Field Observation
Wetland Interaction	n/a	None			Field Observation

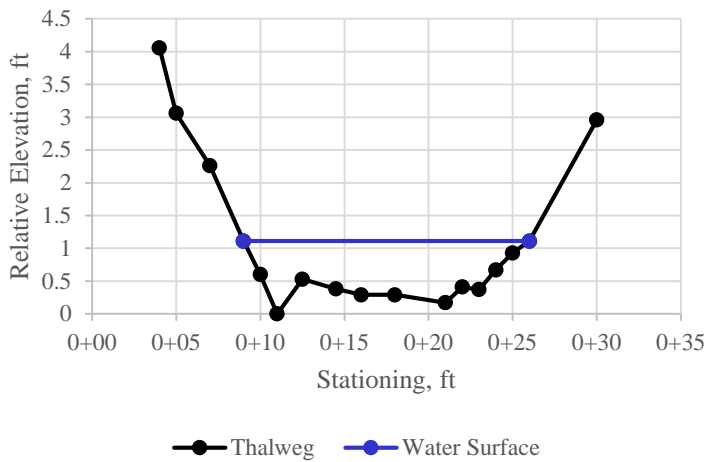
**Site #6 – Profile
Creek (Middle)**

Reference Site Summary

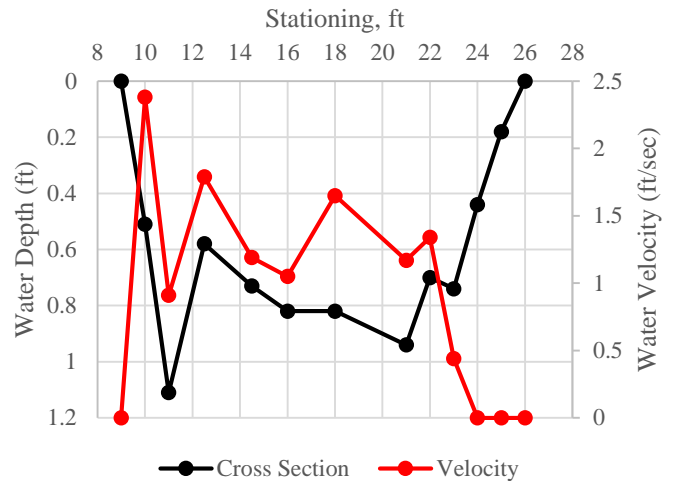
Figure B-7.1



Representative Pool Cross Section



Pool Tailout Cross Section



Discharge Summary

Date: 9/14/17

Time: 10:30 am

Wetted Cross Sectional Area = 11.6 ft²

Average Velocity = 1.2 ft/sec

Discharge = 14.3 ft³/sec

Note: Discharge was measured in a pool tailout to obtain less air entrainment and adequate depth.

No pebble count data were collected due to the size of the substrate forming the step pool system.

No Data Collected – Site Omitted

Note: Site omitted due to fire restriction.
Limited access was later provided enabling photo collection only.
See following pages.



**Site #7 – Profile
Creek (Upper A)**

Reference Site Summary

Figure B-8.2



**Site #7 – Profile
Creek (Upper B)**

Reference Site Summary

Figure B-8.3

Site omitted – No data collected

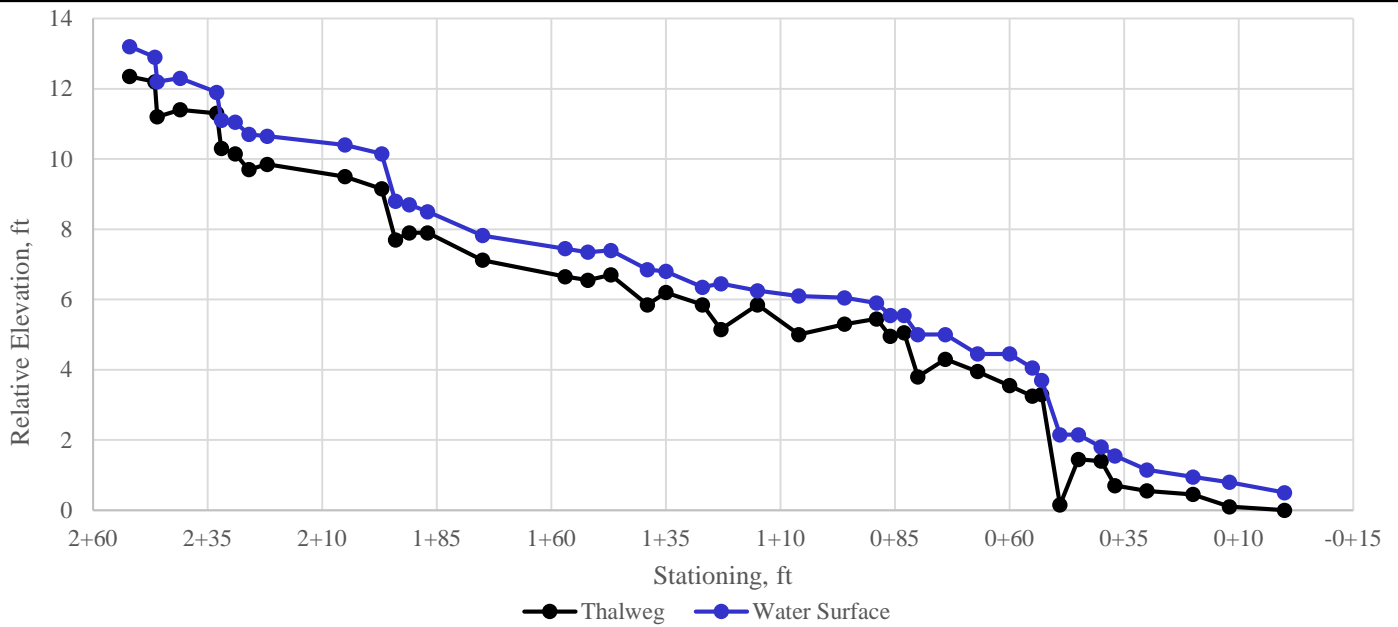


Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Plane bed	--	Observation
Rosgen	n/a	--	C4b	--	Observation
Basin Area	sqmi	--	18.13	--	StreamStats
Precip	in	--	30.2	--	StreamStats
Valley Grade	ft/ft	--	2.6%	--	LiDAR
Chan Grade	ft/ft	--	2.5%	--	LiDAR
Sinuosity	ft/ft	--	1.0	--	LiDAR
Valley W	ft	263.8	231.4	197.3	LiDAR
BF W	ft	--	24	--	Field Measured
Entrenchment	ft/ft	--	9.640594	--	Calculated
BF D	ft	--	3	--	Field Measured
Max D	ft	--	4.6	--	Field Measured
BF W:D	ft/ft	--	8	--	Calculated
Wavelength	ft	362.5	313.9	195.1	LiDAR
Radius	ft	265.4	141.8	84.5	LiDAR
Beltwidth	ft	197.9	185.1	161.9	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Moderately Stable			Field Observation
Riparian Condition	n/a	Mixed			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation

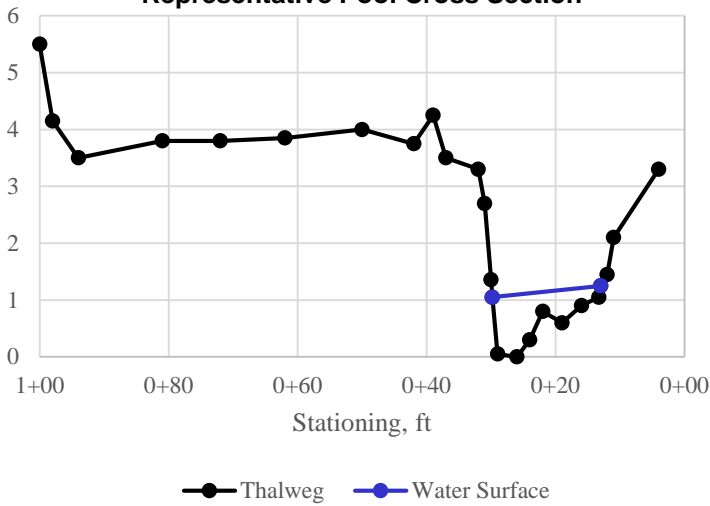
Candidate Reference Site
No detailed profile or cross section data collected



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Forced step-pool	--	Observation
Rosgen	n/a	--	G4	--	Observation
Basin Area	sqmi	--	3.12	--	StreamStats
Precip	in	--	29.1	--	StreamStats
Valley Grade	ft/ft	--	6.3%	--	LiDAR
Chan Grade	ft/ft	--	4.9%	--	LiDAR
Sinuosity	ft/ft	--	1.3	--	LiDAR
Valley W	ft	119.6	87.2	47.0	LiDAR
BF W	ft	17.5	9.5	--	Field Measured
Entrenchment	ft/ft	6.8	9.2	4.9	Calculated
BF D	ft	--	2.0	--	Field Measured
Max D	ft	--	3.5	--	Field Measured
BF W:D	ft/ft	--	4.8	--	Calculated
Wavelength	ft	245.4	154.5	90.7	LiDAR
Radius	ft	69.3	44.1	22.5	LiDAR
Beltwidth	ft	111.4	85.0	61.8	LiDAR
Drop	ft	3	2	1	Field Measured
Riffle Spacing	ft	20	17.5	15	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation

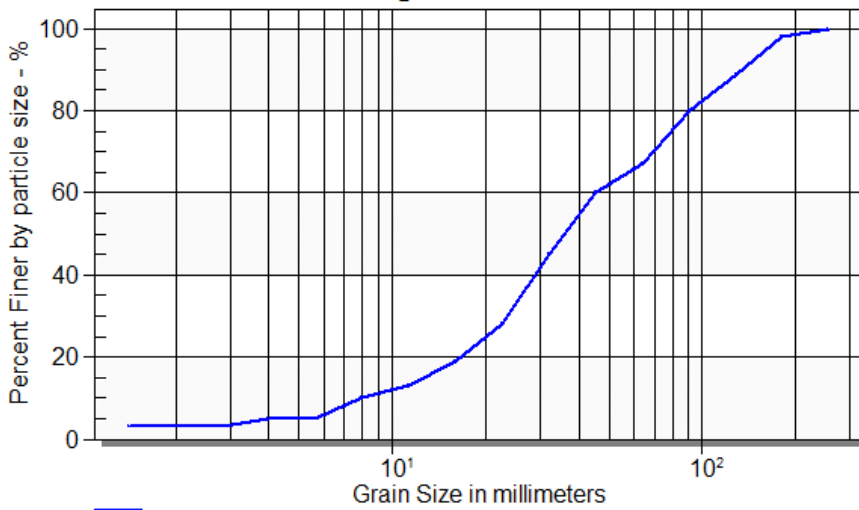


Representative Pool Cross Section



No discharge data were collected due to shallow water depths.

Semi-log Gradation Plot



Pebble Count Summary

- D15 = 13 mm
- D50 = 36 mm
- D85 = 111 mm
- D100 = 256 mm

● Cinnabar Cr

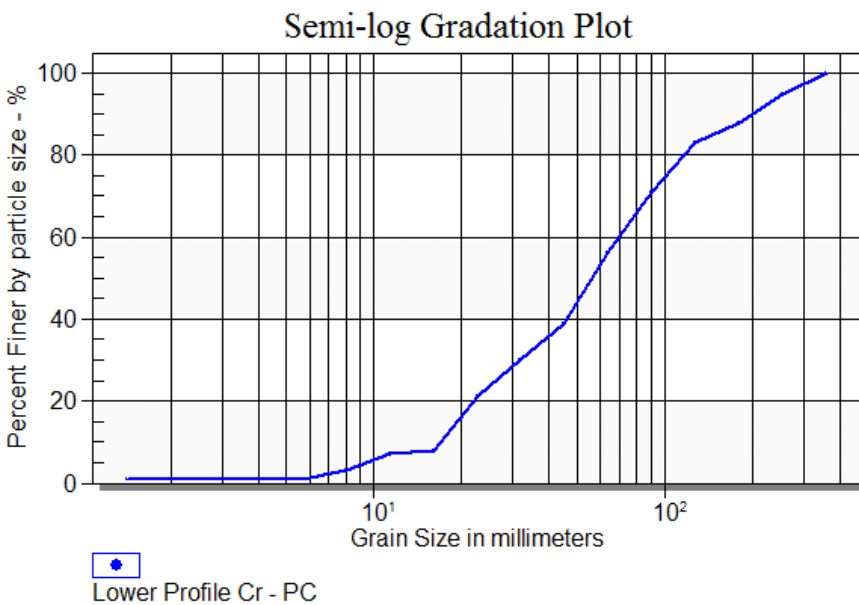
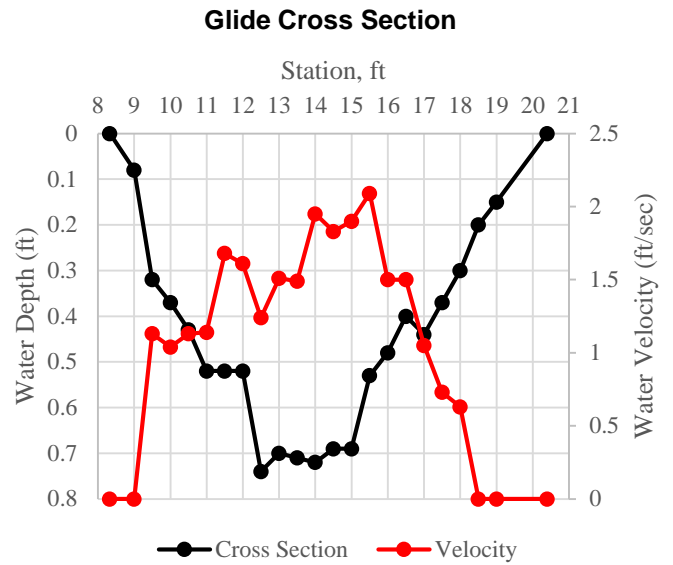
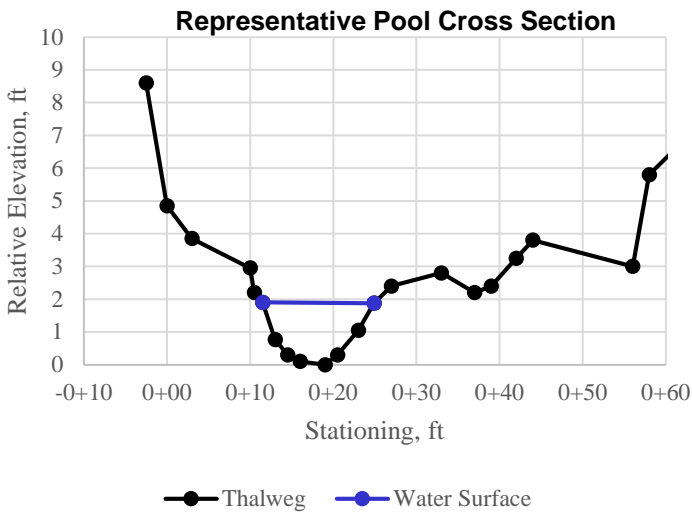
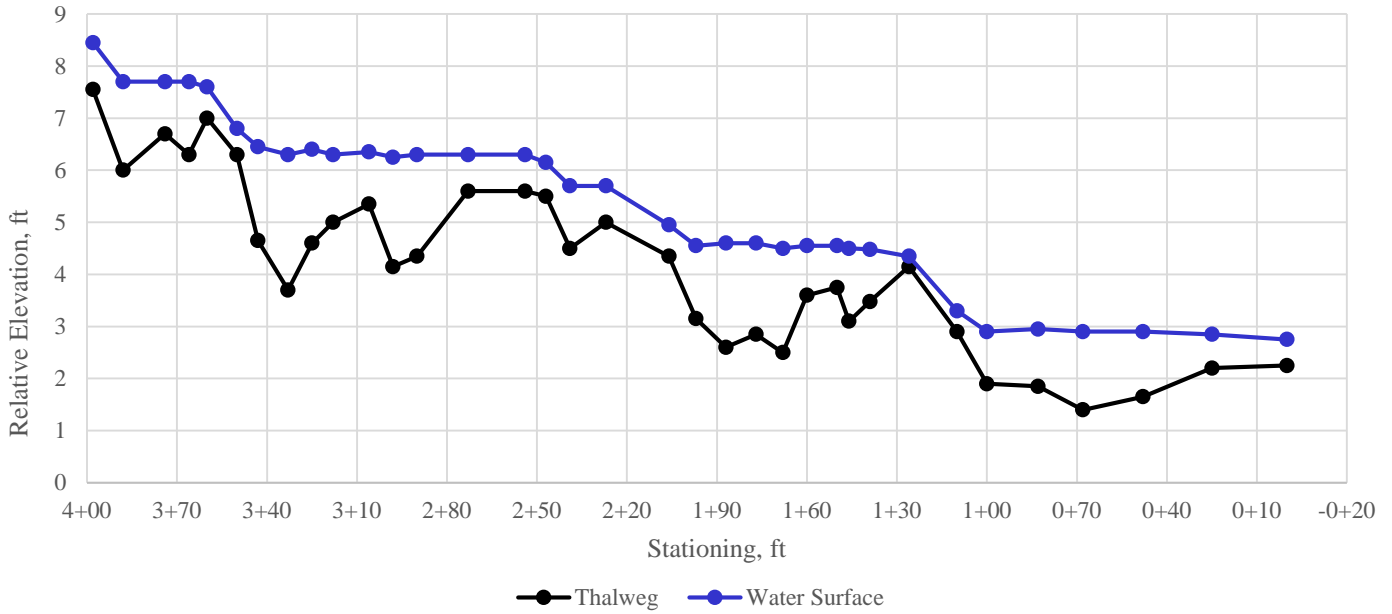


Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool-Riffle	--	Observation
Rosgen	n/a	--	C4	--	Observation
Basin Area	sqmi	--	15	--	StreamStats
Precip	in	--	28.5	--	StreamStats
Valley Grade	ft/ft	--	2.0%	--	LiDAR
Chan Grade	ft/ft	--	1.8%	--	LiDAR
Sinuosity	ft/ft	--	1.1	--	LiDAR
Valley W	ft	320	287	252	LiDAR
BF W	ft	42	27.5	13	Field Measured
Entrenchment	ft/ft	7.6	10.4	19.4	Calculated
BF D	ft	--	2.5	--	Field Measured
Max D	ft	--	4.4	--	Field Measured
BF W:D	ft/ft	--	11	--	Calculated
Wavelength	ft	447.2	349.8	211.8	LiDAR
Radius	ft	100.0	68.9	28.7	LiDAR
Beltwidth	ft	251.9	201.8	149.4	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	128	128	--	N/A
Relative Bank Stability	n/a	Relatively Unstable			Field Observation
Riparian Condition	n/a	Mixed			Field Observation
Wetland Interaction	n/a	Limited / Floodplain			Field Observation

Site #11 - Sugar Creek

Reference Site Summary

Figure B-12.1

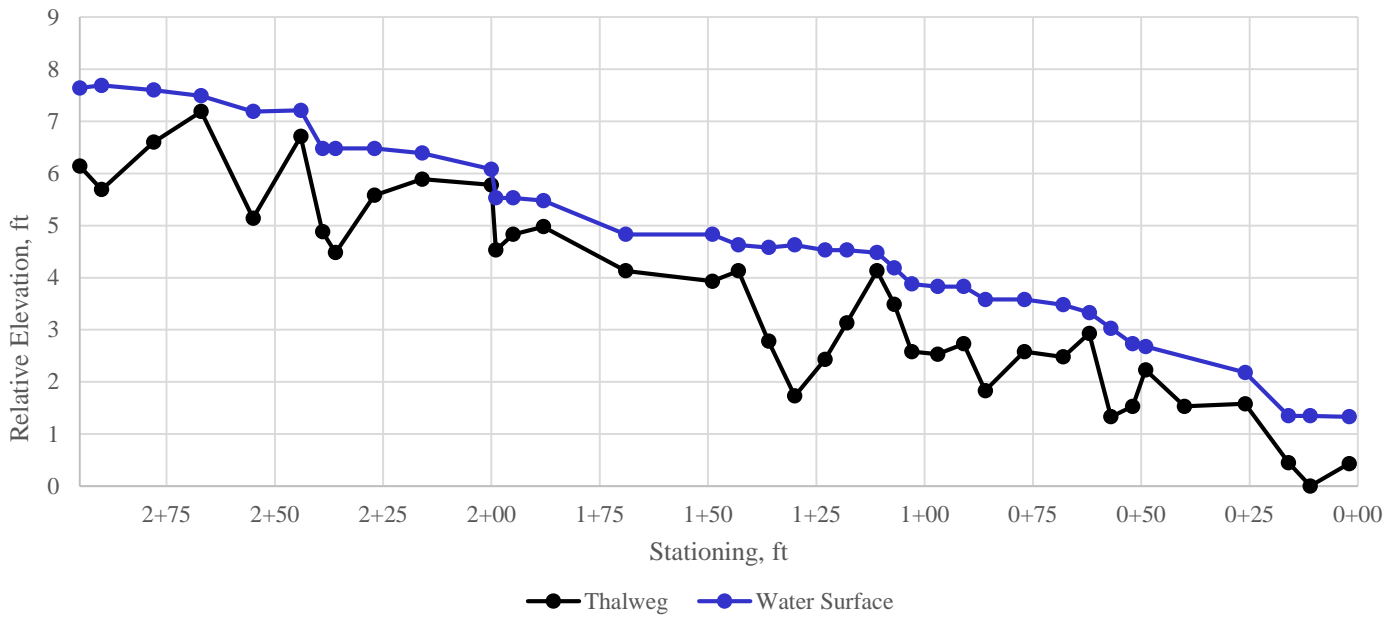


Discharge Summary
 Date: 9/13/17
 Time: 9:30 am
 Wetted Cross Sectional Area = 5.0 ft²
 Average Velocity = 1.4 ft/sec
 Discharge = 6.9 ft³/sec
 Note: Discharge was measured in a glide to obtain adequate flow depth.

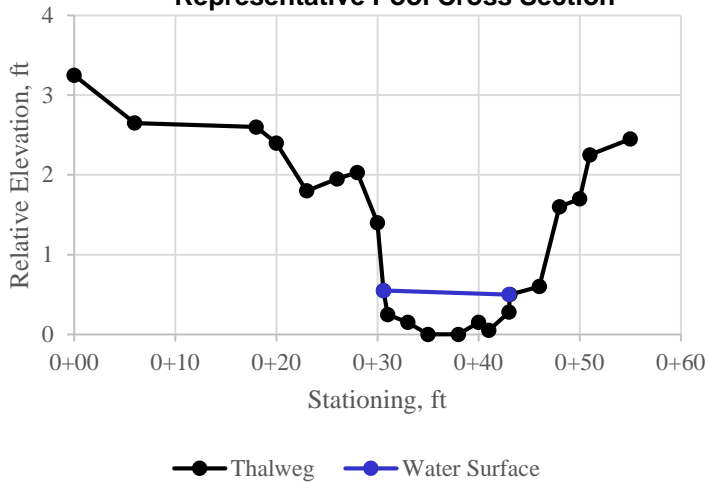
Pebble Count Summary
 D15 = 20 mm
 D50 = 57 mm
 D85 = 149 mm
 D100 = 362 mm



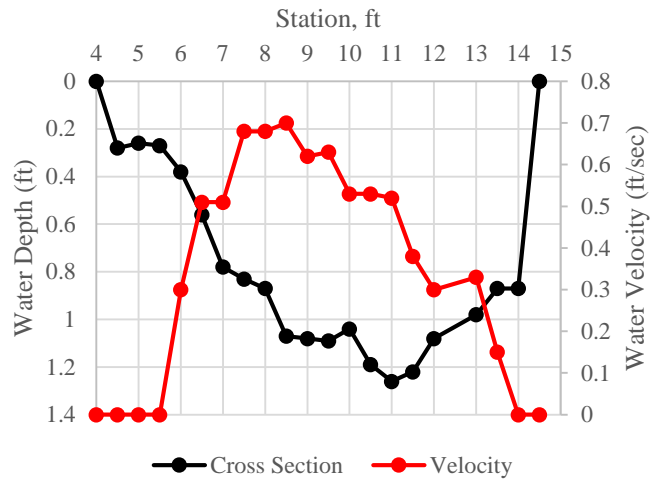
Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool-Riffle	--	Observation
Rosgen	n/a	--	E4b	--	Observation
Basin Area	sqmi	--	6.89	--	StreamStats
Precip	in	--	34.1	--	StreamStats
Valley Grade	ft/ft	--	2.7%	--	LiDAR
Chan Grade	ft/ft	--	1.9%	--	LiDAR
Sinuosity	ft/ft	--	1.4	--	Calculated
Valley W	ft	297.5	230.8	170.0	LiDAR
BF W	ft	22.0	14.0	13.0	Field Measured
Entrenchment	ft/ft	13.5	16.5	13.1	Calculated
BF D	ft	--	2.8	--	Field Measured
Max D	ft	--	4.9	--	Field Measured
BF W:D	ft/ft	8.0	5.1	4.7	Calculated
Wavelength	ft	303.4	269.2	188.7	LiDAR
Radius	ft	56.0	30.6	20.1	LiDAR
Beltwidth	ft	185.9	146.9	125.9	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	77	--	N/A
Relative Bank Stability	n/a	Very Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Tributary			Field Observation



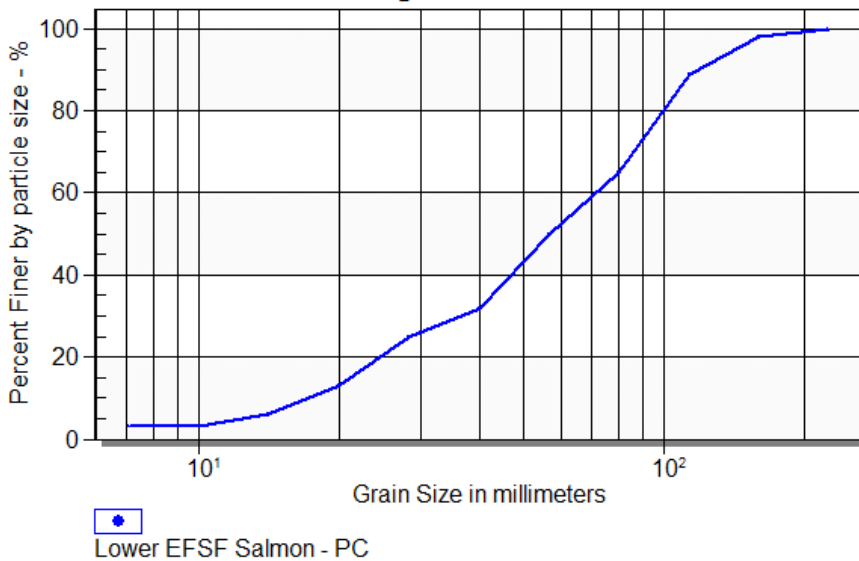
Representative Pool Cross Section



Glide Cross Section



Semi-log Gradation Plot



Discharge Summary

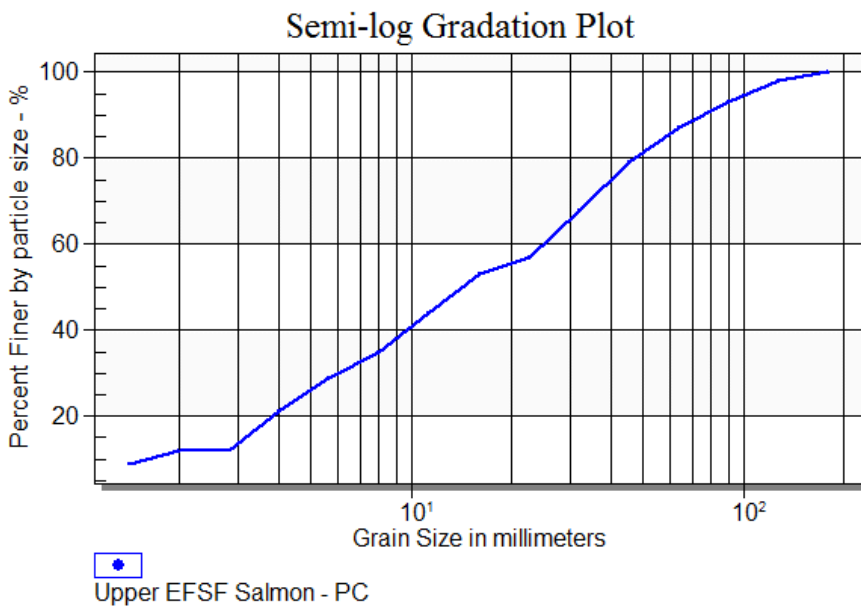
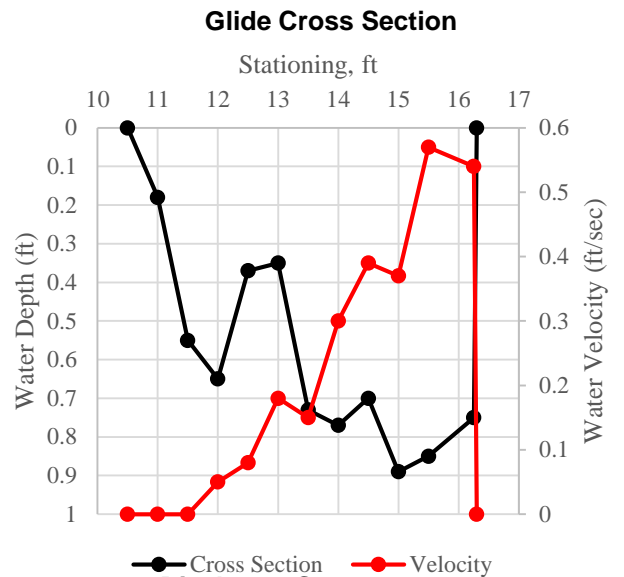
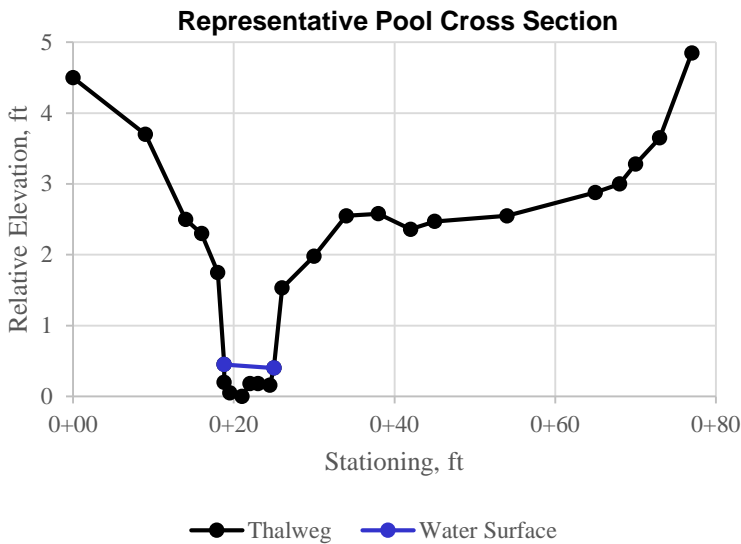
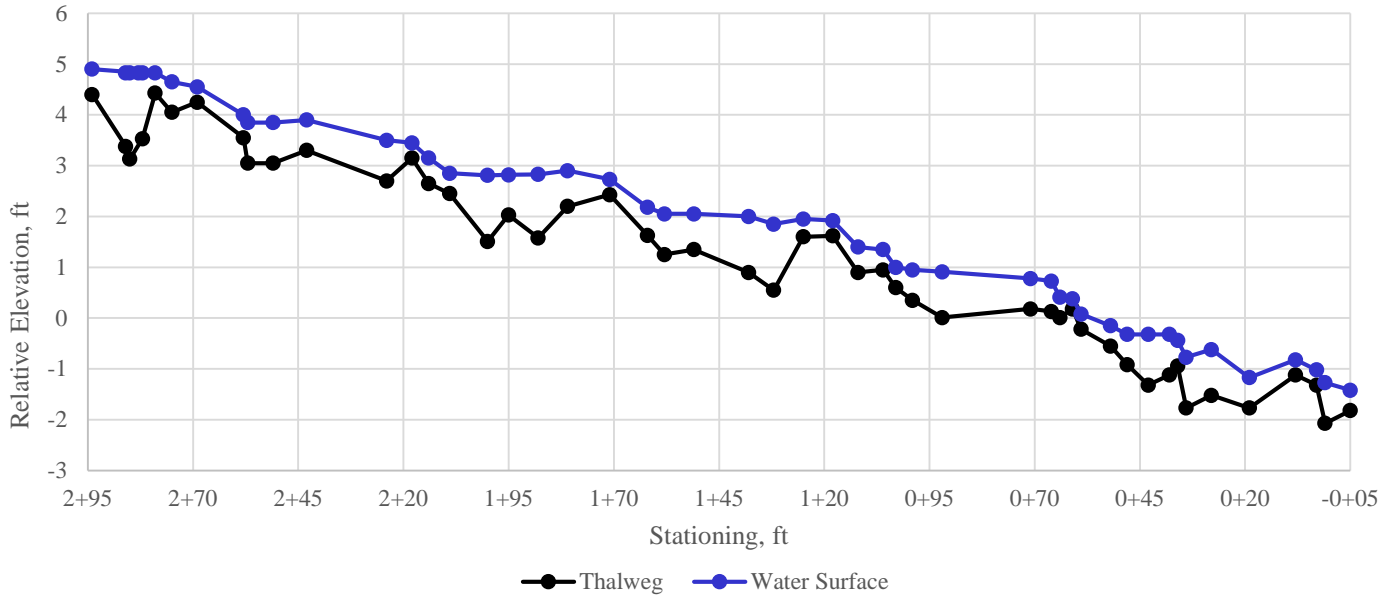
Date: 9/12/17
 Time: 3:00 pm
 Wetted Cross Sectional Area = 8.5 ft²
 Average Velocity = 0.4 ft/sec
 Discharge = 3.7 ft³/sec
 Note: Discharge was measured in a glide to obtain adequate flow depth.

Pebble Count Summary

D15 = 21 mm
 D50 = 57 mm
 D85 = 108 mm
 D100 = 226 mm



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool-Riffle	--	Observation
Rosgen	n/a	--	E4	--	Observation
Basin Area	sqmi	--	2.21	--	StreamStats
Precip	in	--	33.3	--	StreamStats
Valley Grade	ft/ft	--	2.3%	--	LiDAR
Chan Grade	ft/ft	--	1.7%	--	LiDAR
Sinuosity	ft/ft	--	1.4	--	Calculated
Valley W	ft	138.3	118.3	82.9	LiDAR
BF W	ft	8	8	8	Field Measured
Entrenchment	ft/ft	17.3	14.8	10.4	Calculated
BF D	ft	--	2.1	--	Field Measured
Max D	ft	--	3.0	--	Field Measured
BF W:D	ft/ft	3.9	3.9	3.9	Calculated
Wavelength	ft	103.4	72.4	47.7	LiDAR
Radius	ft	27.7	16.1	7.7	LiDAR
Beltwidth	ft	133.8	93.3	65.6	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Very Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation



Discharge Summary
 Date: 9/12/17
 Time: 1:00 pm
 Wetted Cross Sectional Area = 3.4 ft²
 Average Velocity = 0.3 ft/sec
 Discharge = 1.0 ft³/sec
 Note: Discharge was measured in a glide to obtain adequate flow depth.

Pebble Count Summary
 D15 = 3 mm
 D50 = 14 mm
 D85 = 59 mm
 D100 = 181 mm



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool-Riffle to Dune-Ripple	--	Observation
Rosgen	n/a	--	C4 to E5	--	Observation
Basin Area	sqmi	--	19.65	--	StreamStats
Precip	in	--	34.1	--	StreamStats
Valley Grade	ft/ft	--	0.3%	--	LiDAR
Chan Grade	ft/ft	--	0.3%	--	LiDAR
Sinuosity	ft/ft	--	1.2	--	Calculated
Valley W	ft	377.1	262.9	217.7	LiDAR
BF W	ft	25	18	15	Field Measured
Entrenchment	ft/ft	15.1	14.6	14.5	Calculated
BF D	ft	--	1.7	--	Field Measured
Max D	ft	--	7.5	--	Field Measured
BF W:D	ft/ft	14.7	10.6	8.8	Calculated
Wavelength	ft	363.5	245.6	186.7	LiDAR
Radius	ft	215.8	71.5	22.1	LiDAR
Beltwidth	ft	320.2	205.7	124.0	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Very Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation

**Site #14 – Riordan
Creek (Lower)**

Reference Site Summary

Figure B-15.1

Candidate Reference Site
No detailed profile or cross section data collected



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Step-Pool	--	Observation
Rosgen	n/a	--	F3	--	Observation
Basin Area	sqmi	--	17.49	--	StreamStats
Precip	in	--	34.7	--	StreamStats
Valley Grade	ft/ft	--	3.1%	--	Calculated
Chan Grade	ft/ft	--	2.8%	--	LiDAR
Sinuosity	ft/ft	--	1.1	--	LiDAR
Valley W	ft	92.1	78.0	53.0	LiDAR
BF W	ft	--	23	--	Field Measured
Entrenchment	ft/ft	4.0	3.4	2.3	Calculated
BF D	ft	--	1	--	Field Measured
Max D	ft	--	2.5	--	Field Measured
BF W:D	ft/ft	--	23	--	Calculated
Wavelength	ft	370.2	273.7	191.7	LiDAR
Radius	ft	135.4	115.7	79.3	LiDAR
Beltwidth	ft	97.5	85.3	69.3	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Mixed			Field Observation
Wetland Interaction	n/a	Minimal Floodplain			Field Observation

Candidate Reference Site
No detailed profile or cross section data collected



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool - Riffle	--	Observation
Rosgen	n/a	--	E4 to E5	--	Observation
Basin Area	sqmi	--	7.49	--	StreamStats
Precip	in	--	38	--	StreamStats
Valley Grade	ft/ft	--	1.2%	--	LiDAR
Chan Grade	ft/ft	--	0.8%	--	LiDAR
Sinuosity	ft/ft	--	1.6	--	Calculated
Valley W	ft	705.9	391.3	106.3	LiDAR
BF W	ft	15	14	13	Field Measured
Entrenchment	ft/ft	47.1	28.0	8.2	Calculated
BF D	ft	--	1.7	--	Field Measured
Max D	ft	--	4	--	Field Measured
BF W:D	ft/ft	8.8	8.2	7.6	Calculated
Wavelength	ft	166.7	114.9	66.6	LiDAR
Radius	ft	58.6	30.1	15.5	LiDAR
Beltwidth	ft	168.9	119.7	84.4	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation

**Site #16 – Riordan
Creek (Upper Middle)**

Reference Site Summary

Figure B-17.1

Candidate Reference Site
No detailed profile or cross section data collected



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool - Riffle	--	Observation
Rosgen	n/a	--	C4	--	Observation
Basin Area	sqmi	--	7.02	--	StreamStats
Precip	in	--	38.5	--	StreamStats
Valley Grade	ft/ft	--	2.0%	--	LiDAR
Chan Grade	ft/ft	--	1.2%	--	LiDAR
Sinuosity	ft/ft	--	1.7	--	LiDAR
Valley W	ft	314.8	285.1	239.6	LiDAR
BF W	ft	24	21	18	Field Measured
Entrenchment	ft/ft	--	13.3	--	Calculated Average
BF D	ft	--	1.5	--	Field Measured
Max D	ft	--	4.5	--	Field Measured
BF W:D	ft/ft	16.0	14.0	12.0	Calculated
Wavelength	ft	143.9	110.1	78.5	LiDAR
Radius	ft	59.1	28.8	18.9	LiDAR
Beltwidth	ft	289.1	210.9	174.4	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation

**Site #17 – Riordan
Creek (Upper)**

Reference Site Summary

Figure B-18.1

Candidate Reference Site
No detailed profile or cross section data collected

Site omitted – No data collected

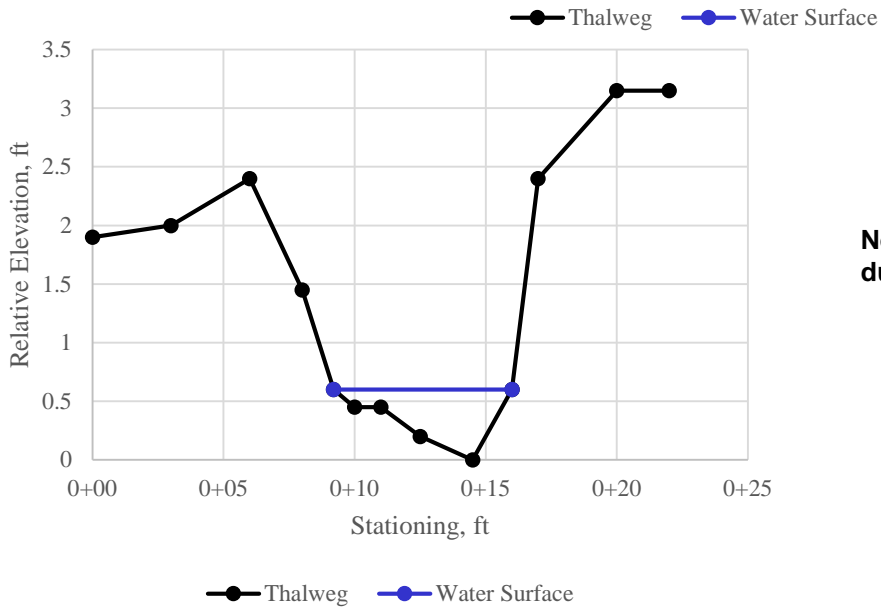
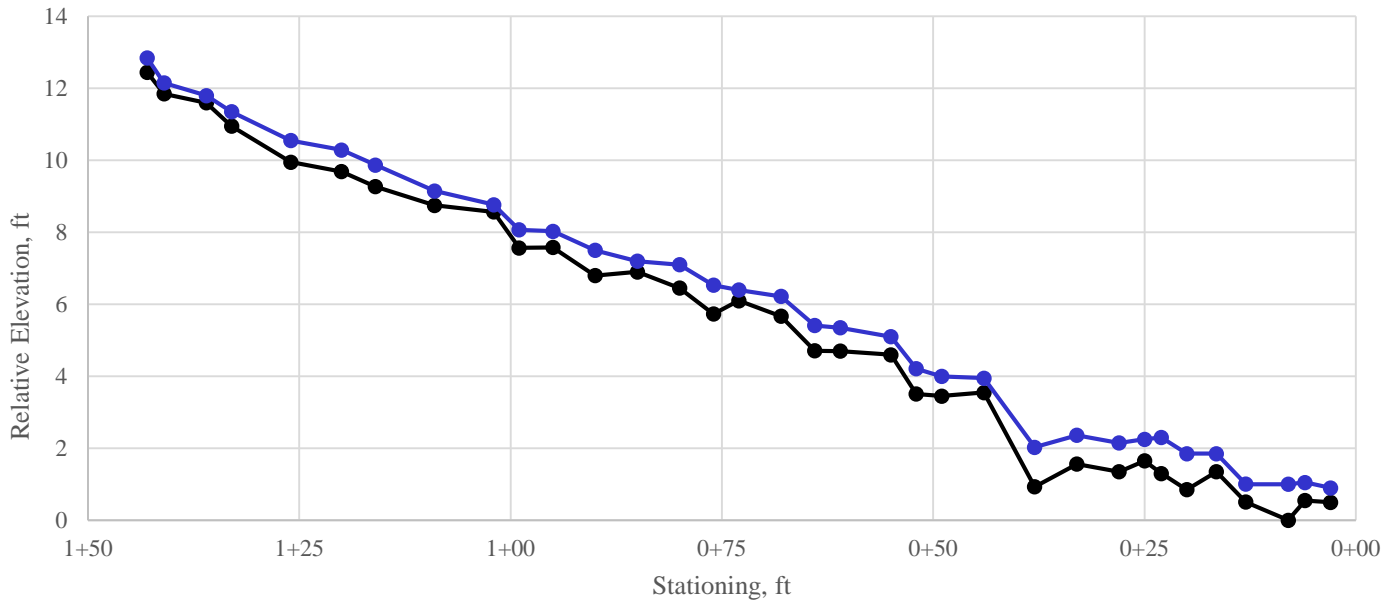


Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Cascade to Step-Pool	--	Observation
Rosgen	n/a	--	A2	--	Observation
Basin Area	sqmi	--	1.74	--	StreamStats
Precip	in	--	28.5	--	StreamStats
Valley Grade	ft/ft	--	8.3%	--	Field Measured
Chan Grade	ft/ft	--	8.3%	--	Field Measured
Sinuosity	ft/ft	--	1.0	--	Calculated
Valley W	ft	88.5	79.2	67.3	LiDAR
BF W	ft	12	9.5	7	Field Measured
Entrenchment	ft/ft	7.4	8.3	9.6	Calculated
BF D	ft	--	1.8	--	Field Measured
Max D	ft	--	2.4	--	Field Measured
BF W:D	ft/ft	6.7	5.3	3.9	Calculated
Wavelength	ft	--	--	--	N/A
Radius	ft	--	--	--	N/A
Beltwidth	ft	--	--	--	N/A
Drop	ft	1.2	0.95	0.7	Field Measured
Riffle Spacing	ft	15	13.75	12.5	Field Measured
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Minimal			Field Observation

Site #19 – Fiddle Creek (Lower)

Reference Site Summary

Figure B-20.1



No discharge data were collected due to shallow water depths.

No pebble count were was collected.



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool - Riffle	--	Observation
Rosgen	n/a	--	E4	--	Observation
Basin Area	sqmi	--	1.16	--	StreamStats
Precip	in	--	29.6	--	StreamStats
Valley Grade	ft/ft	--	2.2%	--	Avg of LiDAR and Field Measured
Chan Grade	ft/ft	--	1.2%	--	Avg of LiDAR and Field Measured
Sinuosity	ft/ft	--	1.8	--	Avg of LiDAR and Field Measured
Valley W	ft	279.4	248.2	225.7	LiDAR
BF W	ft	11.4	8.65	5.9	Field Measured
Entrenchment	ft/ft	--	30.5	--	Calculated Average
BF D	ft	--	2.2	--	Field Measured
Max D	ft	--	3.25	--	Field Measured
BF W:D	ft/ft	5.2	3.9	2.7	Calculated
Wavelength	ft	107.5	83.3	47.0	LiDAR
Radius	ft	29.1	18.0	14.2	LiDAR
Beltwidth	ft	137.4	117.7	99.5	LiDAR
Drop	ft	--	--	--	N/A
Riffle Spacing	ft	--	--	--	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation

Site #20 – Fiddle Creek (Upper)

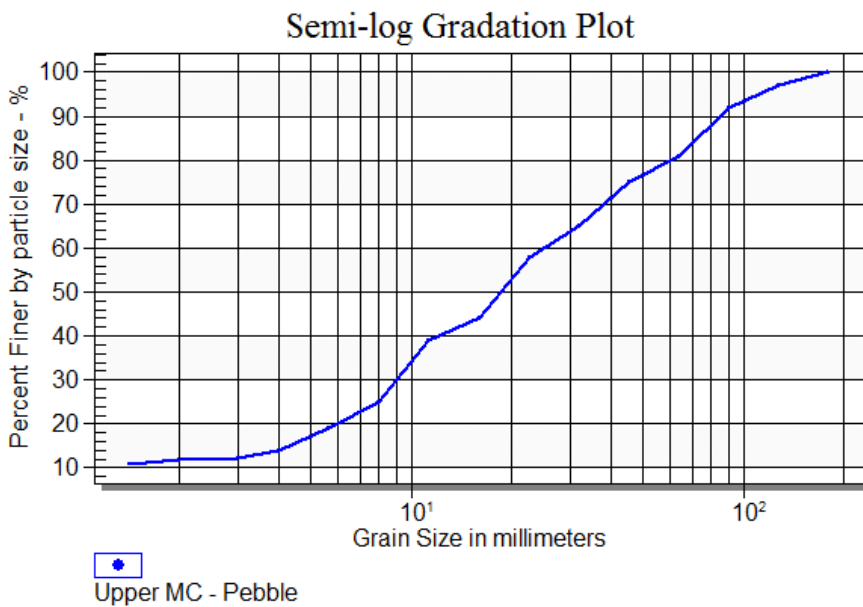
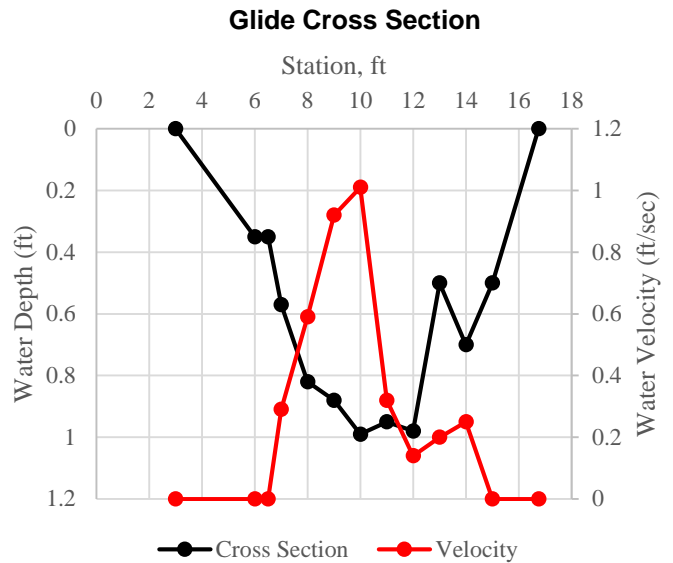
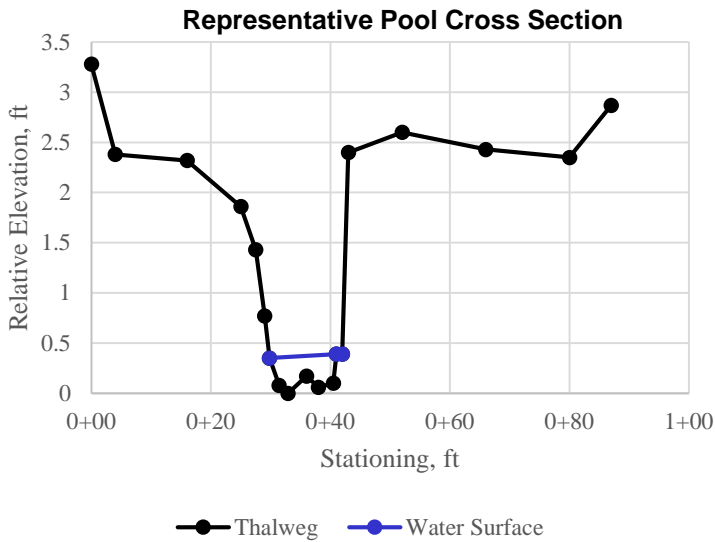
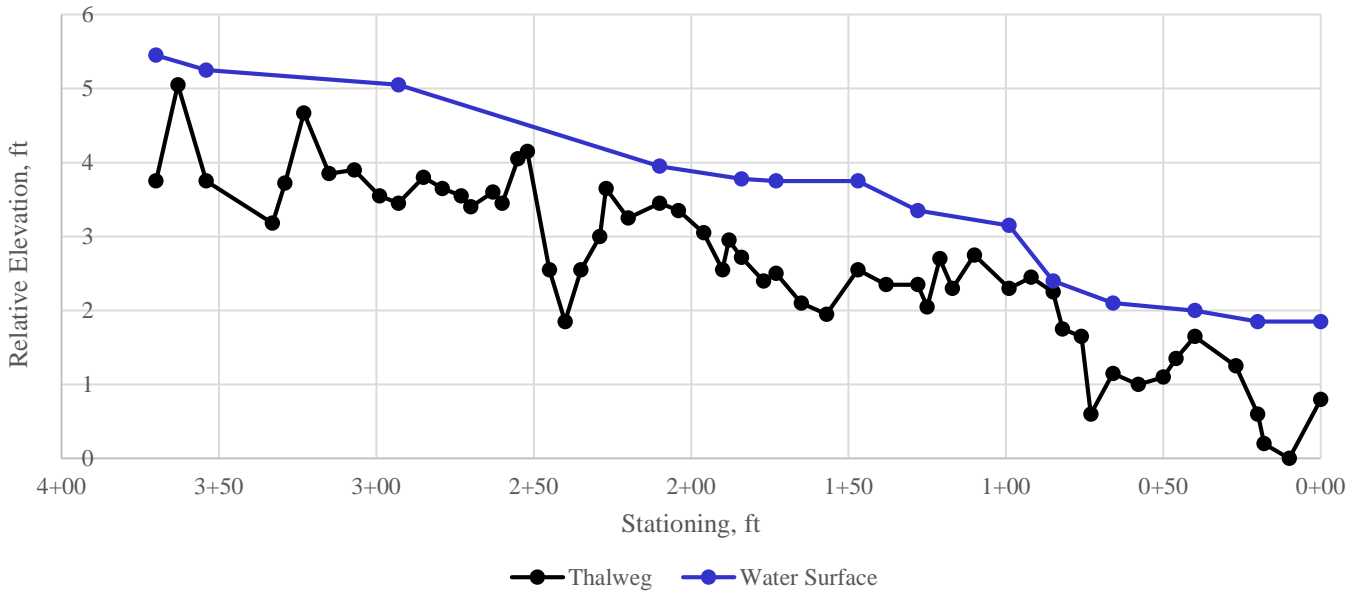
Reference Site Summary

Figure B-21.1

Candidate Reference Site
No detailed profile or cross section data collected



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool - Riffle	--	Observation
Rosgen	n/a	--	E4	--	Observation
Basin Area	sqmi	--	6	--	StreamStats
Precip	in	--	36.6	--	StreamStats
Valley Grade	ft/ft	--	2.1%	--	LiDAR
Chan Grade	ft/ft	--	1.0%	--	Field Measured
Sinuosity	ft/ft	--	2.0	--	Calculated
Valley W	ft	425.0	412.5	400.0	LiDAR
BF W	ft	20.0	15.0	10.0	Field Measured
Entrenchment	ft/ft	--	29.6	--	Calculated Average
BF D	ft	4	3.25	2.5	Field Measured
Max D	ft	--	4	--	Field Measured
BF W:D	ft/ft	6.2	4.6	3.1	Calculated
Wavelength	ft	287.0	243.5	200.0	LiDAR
Radius	ft	25.0	20.0	15.0	LiDAR
Beltwidth	ft	275.0	177.5	80.0	LiDAR
Drop	ft	0	0	0	N/A
Riffle Spacing	ft	0	0	0	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation



Discharge Summary
 Date: 9/11/17
 Time: 2:00 pm
 Wetted Cross Sectional Area = 7.9 ft²
 Average Velocity = 0.4 ft/sec
 Discharge = 3.1 ft³/sec
 Note: Discharge was measured in a glide to obtain adequate flow depth.

Pebble Count Summary
 D15 = 4 mm
 D50 = 19 mm
 D85 = 74 mm
 D100 = 181 mm

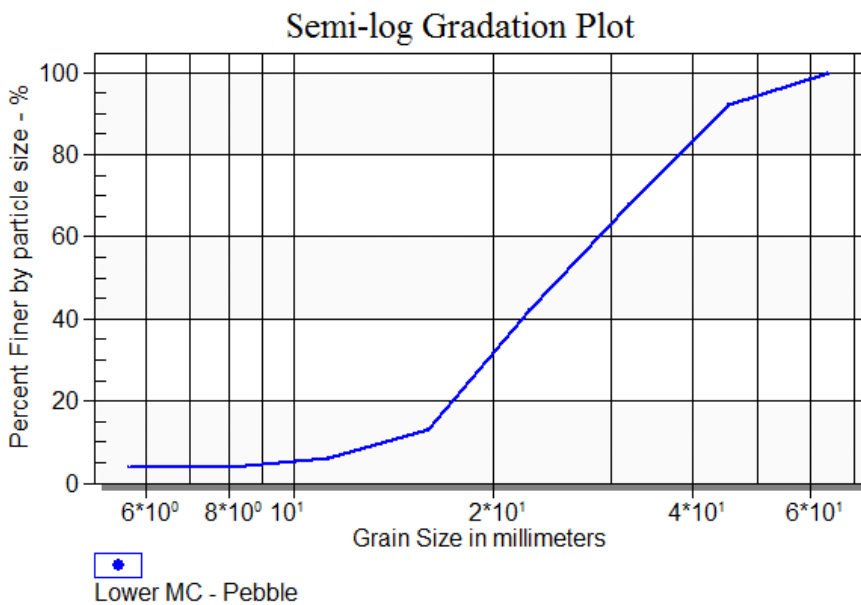
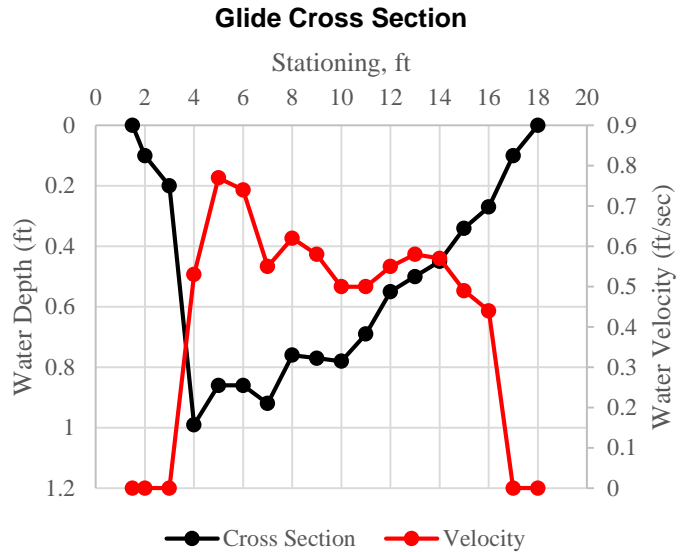
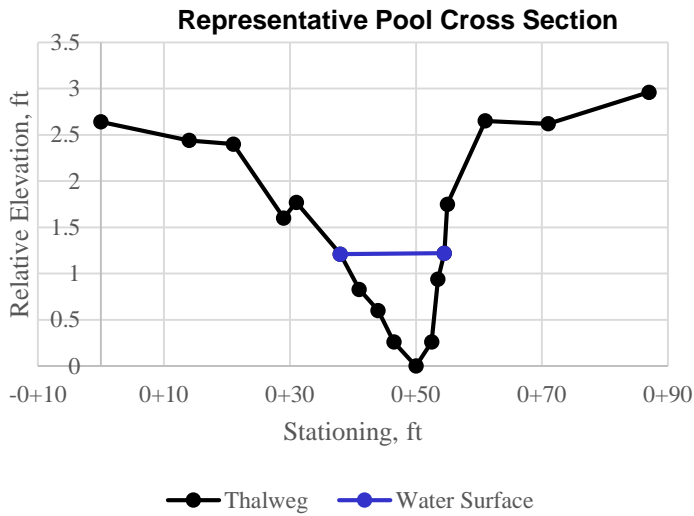
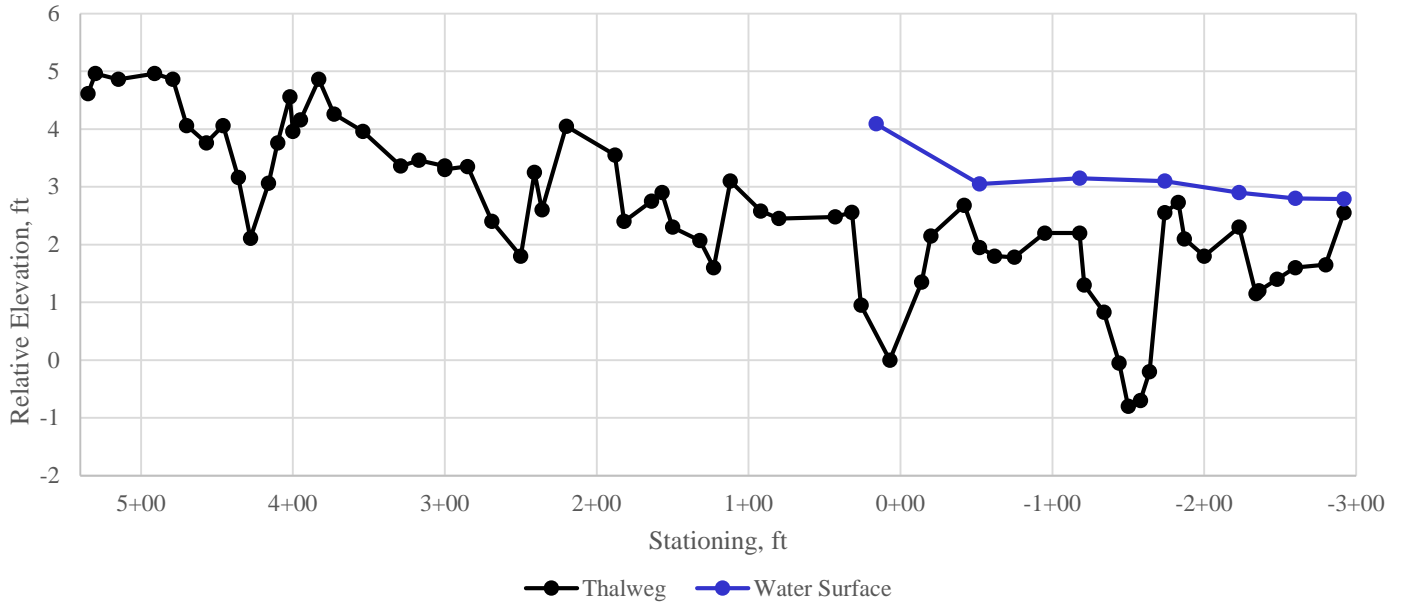
Site #21 – Meadow Creek (Upper)

Reference Site Summary

Figure B-22.2



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Pool - Riffle	--	Observation
Rosgen	n/a	--	C4	--	Observation
Basin Area	sqmi	--	9.5	--	StreamStats
Precip	in	--	35.7	--	StreamStats
Valley Grade	ft/ft	--	0.6%	--	LiDAR
Chan Grade	ft/ft	--	0.4%	--	Field Measured
Sinuosity	ft/ft	--	1.6	--	Calculated
Valley W	ft	200.0	145.0	90.0	LiDAR
BF W	ft	40.0	35.0	30.0	Field Measured
Entrenchment	ft/ft	--	4.0	--	Calculated Average
BF D	ft	5	3.9	2.8	Field Measured
Max D	ft	--	5	--	Field Measured
BF W:D	ft/ft	10.3	9.0	7.7	Calculated
Wavelength	ft	270.0	250.0	230.0	LiDAR
Radius	ft	32.0	26.0	20.0	LiDAR
Beltwidth	ft	125.0	107.5	90.0	LiDAR
Drop	ft	0	0	0	N/A
Riffle Spacing	ft	0	0	0	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation

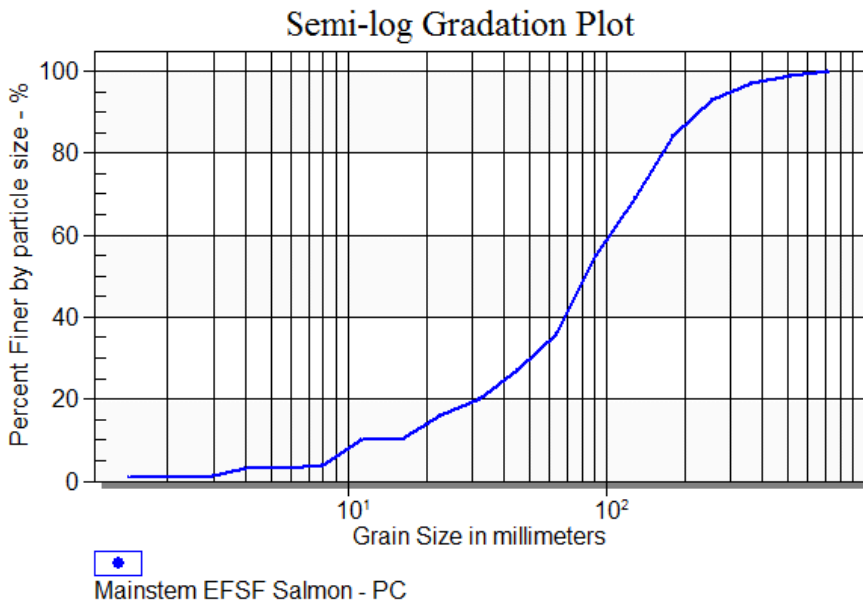
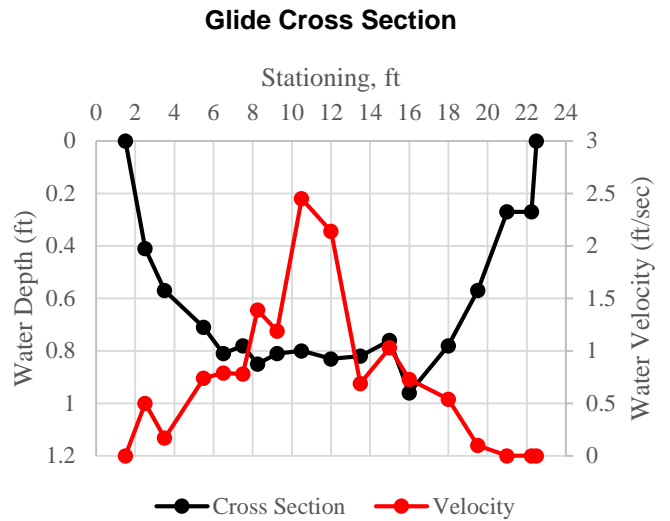
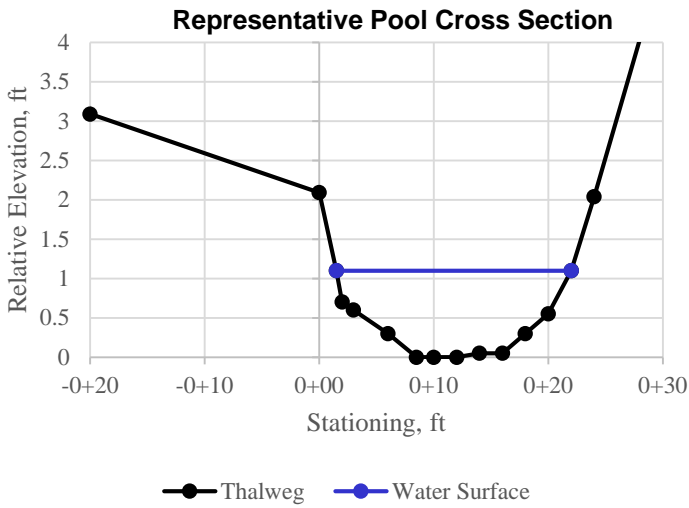
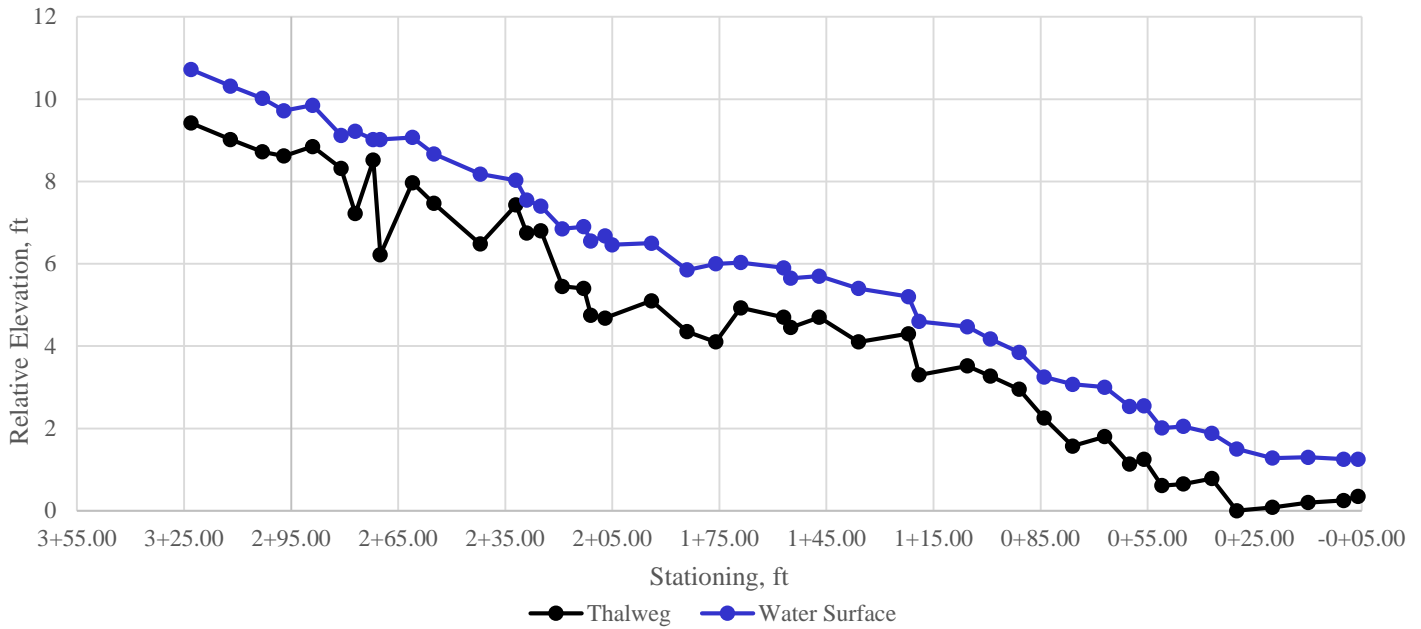


Discharge Summary
 Date: 9/12/17
 Time: 9:00 am
 Wetted Cross Sectional Area = 9.1 ft²
 Average Velocity = 0.5 ft/sec
 Discharge = 5.0 ft³/sec
 Note: Discharge was measured in a glide to obtain adequate flow depth.

Pebble Count Summary
 D15 = 16 mm
 D50 = 26 mm
 D85 = 41 mm
 D100 = 64 mm



Feature	Units	Value			Data Source
		Max	Avg	Min	
Morphology	n/a	--	Plane Bed	--	Observation
Rosgen	n/a	--	B3	--	Observation
Basin Area	sqmi	--	20.1	--	StreamStats
Precip	in	--	34	--	StreamStats
Valley Grade	ft/ft	--	3.8%	--	LiDAR
Chan Grade	ft/ft	--	2.9%	--	Field Measured
Sinuosity	ft/ft	--	1.3	--	Calculated
Valley W	ft	60.0	52.5	45.0	LiDAR
BF W	ft	45.0	35.0	25.0	Field Measured
Entrenchment	ft/ft	--	1.5	--	Calculated Average
BF D	ft	3.5	2.75	2	Field Measured
Max D	ft	--	3.5	--	Field Measured
BF W:D	ft/ft	16.4	12.7	9.1	Calculated
Wavelength	ft	600.0	400.0	200.0	LiDAR
Radius	ft	70.0	60.0	50.0	LiDAR
Beltwidth	ft	100.0	75.0	50.0	LiDAR
Drop	ft	0	0	0	N/A
Riffle Spacing	ft	0	0	0	N/A
Relative Bank Stability	n/a	Stable			Field Observation
Riparian Condition	n/a	Dense			Field Observation
Wetland Interaction	n/a	Floodplain			Field Observation



Discharge Summary

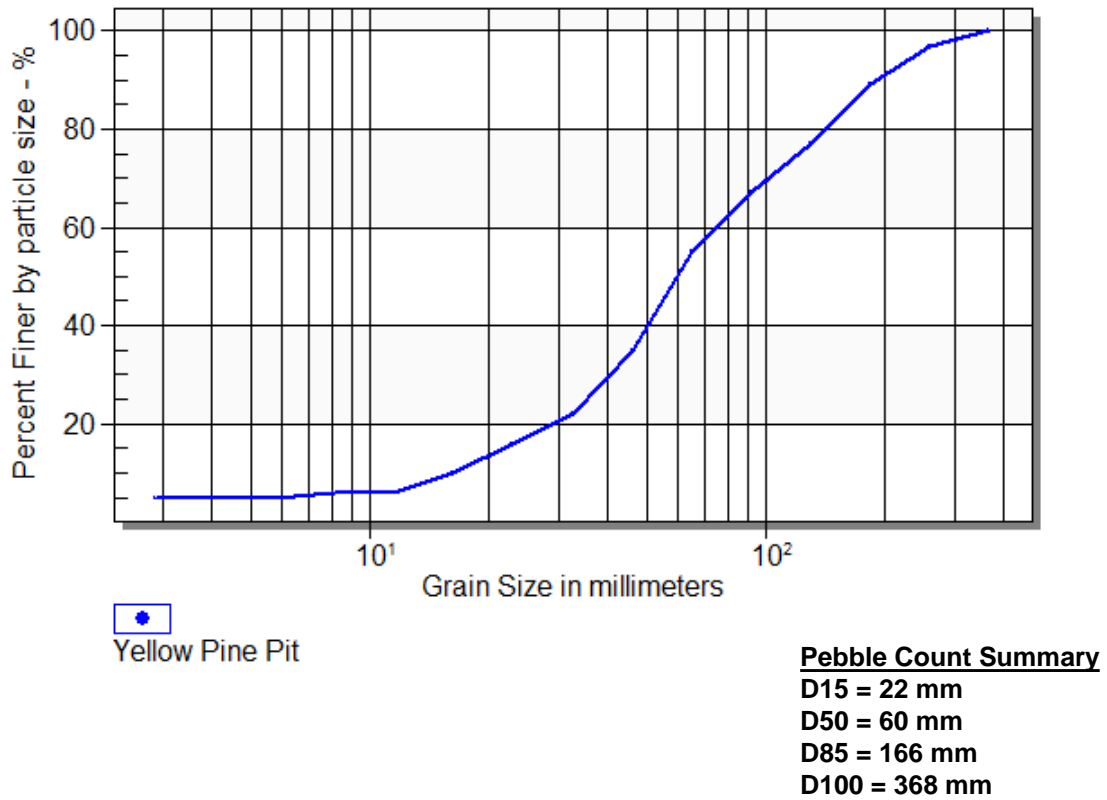
Date: 9/15/17
 Time: 9:20 am
 Wetted Cross Sectional Area = 14.2 ft²
 Average Velocity = 0.9 ft/sec
 Discharge = 13.4 ft³/sec

Pebble Count Summary

D15 = 22 mm
 D50 = 84 mm
 D85 = 189 mm
 D100 = 724 mm



Semi-log Gradation Plot



REFERENCES

HDR. (2016). Stream Functional Assessment: Stibnite Gold Project. Midas Gold Idaho, Inc.
Internal Publication.

Appendix C

Hydrology