RECLAMATION

Managing Water in the West

Flow Characterization Study

Instream Flow Assessment Hawley Creek and Eighteenmile Creek, Idaho

United States Department of the Interior

The mission of the Department of the Interior is to protect and provide access to our Nation's natural and cultural heritage and honor our trust responsibilities to Indian tribes and our commitments to island communities.

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The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

June 2007

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Prepared for:

U.S. Department of the Interior
Bureau of Reclamation
Snake River Area Office
Boise, Idaho

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Abbreviations

BIA	Bureau of Indian Affairs
BiOp	Biological Opinion
BLM	Bureau of Land Management
DPS	Distinct Population Segment
ESA	Endangered Species Act
ESU	Evolutionary Significant Unit
FCRPS	Federal Columbia River Power System
FWS	Fish and Wildlife Service
GPS	Global Positioning System
HABTAE	Habitat program option in PHABSIM for Windows
HC	Hydraulic control
HSC	Habitat Suitability Criteria
IDEQ	Idaho Department of Environmental Quality
IDFG	Idaho Department of Fish and Game
MANSQ	Mannings equation
NMFS	National Marine Fisheries Service
NOAA	National Oceanic Atmospheric Administration
PHABSIM	Physical Habitat Simulation System
Q	Discharge (flow)
Q.20	Daily mean discharge exceeded 20 percent of the time during a specified month
Q.50	Daily mean discharge exceeded 50 percent of the time during a specified month (same as median discharge)
Q.80	Daily mean discharge exceeded 80 percent of the time during a specified month
Reclamation	Bureau of Reclamation
RPA	Reasonable and Prudent Alternative
SI	Suitability index
STGQ	Stage-discharge relation
TMDL	Total Maximum Daily Load
TSC	Technical Service Center
USFS	U.S. Forest Service
USGS	U.S. Geological Survey
VAF	Velocity adjustment factor
WSL	Water surface elevation
WSP	Water surface profile
WUA	Weighted usable area

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Summary

The Bureau of Reclamation conducted flow characterization and habitat studies on Hawley Creek and Eighteenmile Creek, located in the Lemhi River sub-basin in Idaho, to identify stream flow needs to support relevant life history stages of summer steelhead (*Oncorhynchus mykiss*), spring Chinook salmon (*O. tschawytscha*), and bull trout (*Salvelinus confluentus*). Average snowpack level in the Salmon River Basin on April 1, 2006 was 107 percent, compared to 60 percent of the average snowpack in 2005. Hawley Creek and Eighteenmile Creek flows were continuously recorded using a stage recorder during the 2006 irrigation season. Hawley Creek gaged flows ranged from 24 cfs on May 25, 2006 to 11 cfs on September 14, 2006. Eighteenmile Creek gaged flows ranged from 31 cfs on June 9, 2006 to 1.5 cfs on September, 14, 2006. Water temperatures were also monitored in 2006. Reclamation characterized flow needs for various life stages of the selected species using the Physical Habitat Simulation (PHABSIM) model at each study site. To address food resources of salmonids, streamflow needs for aquatic macroinvertebrates were assessed. Data were collected at a total of 10 study sites: four on Hawley Creek and six on Eighteenmile Creek. Study sites were selected in accessible areas to represent mesohabitat types within each stream reach distinguished by unique hydrology, channel morphology, slope, or land use characteristics. Low, medium, and high flow measurements were attempted during the irrigation season at most sites downstream from the reference sites. In most cases, only medium and low flow conditions were measured because most of the high flows were diverted for irrigation. However, medium and low flows typically occur during the summer irrigation season with the diversions. Habitat modeling results reflected differences in stream channel hydraulics among study sites. Flows that produced optimal habitat in Hawley Creek ranged from 5 cfs for bull trout adult to over 30 cfs for bull trout adult. Minimum discharge required for adult salmonid passage using 0.6 foot depth criterion ranged from 5 to 15 cfs at Study Sites 1 and 2, respectively. At Eighteenmile Creek, flows that produced optimal habitat ranged from 4 cfs for macroinvertebrates to over 46 cfs for steelhead, Chinook, and bull trout adults. The minimum discharges required for adult salmonid passage using 0.6 foot depth criterion at Study Sites 1 and 6 were 9 and 16 cfs, respectively.

1.0 INTRODUCTION

The National Oceanic Atmospheric Administration (NOAA) National Marine Fisheries Service (NMFS) issued a Biological Opinion (BiOp) in December 2000 on continued operation and configuration of the Federal Columbia River Power System (FCRPS) (NMFS 2000). Without taking actions identified in the Reasonable and Prudent Alternative (RPA) of the BiOp, a jeopardy opinion could have been issued for continued operation of the FCRPS. As part of the RPA, NMFS identified the need to improve migration, spawning, and rearing habitat in priority subbasins as part of an off-site mitigation program. In part to address that need, RPA Action 149 of the BiOp required that the Bureau of Reclamation (Reclamation) "shall initiate programs in three priority sub-basins (identified in the Basinwide Recovery Strategy) per year over 5 years, in coordination with NMFS, Fish and Wildlife Service (FWS), the states and others, to address all flow, passage, and screening problems in each sub-basin over ten years." Thus, the objective of Action 149 was to restore flows needed to avoid jeopardy to listed species, screen all diversions, and resolve all passage obstructions within 10 years of initiating work in each sub-basin.

The 2000 BiOp identified priority sub-basins where addressing flow, passage, and screening problems could produce short term benefits. In addition to six other Columbia River sub-basins in Oregon and Washington, Reclamation committed to work in three Salmon River sub-basins in Idaho, including the Lemhi River sub-basin and the "Upper Salmon River sub-basin", which is defined through the BiOp as the Salmon River basin upstream from the confluence of the Pahsimeroi and Salmon Rivers, but excludes the Pahsimeroi River basin.

On November 30, 2004, NMFS issued a new BiOp for the FCRPS in response to a court order in June of 2003. Action 149 objectives were restated in terms of specific metric goals in selected subbasins for entrainment (screens), stream flow, and channel morphology (passage and complexity) in the 2004 BiOp. The work described in this report addresses Reclamation obligations to improve stream flow in selected subbasins under both the 2000 and 2004 BiOps.

To support this work, Action 149 stated that NMFS would supply Reclamation with "passage and screening criteria and one or more methodologies for determining instream flows that will satisfy Endangered Species Act (ESA) requirement." One of the methodologies recommended in NMFS protocol for estimating tributary streamflow to protect salmon listed under the ESA was the Physical Habitat Simulation System (PHABSIM) (Arthaud et al. 2001). The only other method suggested was the hydrology-based Tennant method (Arthaud et al. 2001). However, PHABSIM was considered a more appropriate methodology since it considers the biological requirements of the fish. The NMFS draft protocol describes methods to estimate annual flow regimes and minimum flow conditions necessary to protect sensitive salmonid life stages using PHABSIM results for Pacific and interior northwest streams (Arthaud et al. 2001).

PHABSIM predicts changes in relationships between instream flows and fish habitat for individual species and life stages. PHABSIM is best used for decision-making when alternative flows are being evaluated (Bovee et al. 1998). Stream flow and habitat data are used in a group of computer models called PHABSIM. Hydraulic models are used to calculate water surface elevations and depths and to simulate velocities for specific discharges. Depth, velocity, substrate material, and cover data are used to determine available habitat. The model outputs proportions of suitable and unsuitable reaches of the stream and shows how often a specified quantity of suitable habitat is available. This methodology is scientifically tested and is generally an accepted technique for determining flows needed for fish. It is, however, data intensive and it does take time to achieve results. The habitat requirements of a number of species are not known; therefore, application can be limited unless emphasis is placed on developing habitat suitability criteria (HSC) for species of interest. The output of the model, habitat versus flow relationship, must be integrated with species life history knowledge.

Priority streams have been identified in the Lemhi River sub-basin based on inventory and assessment needs. Reclamation's objective in 2006 was to conduct habitat studies on Hawley Creek and Eighteenmile Creek to identify stream flow needs to support relevant life history stages of summer steelhead (*Oncorhynchus mykiss*), spring/summer Chinook salmon (*O. tschawytscha*), and bull trout (*Salvelinus confluentus*). Previous similar studies conducted by Reclamation (Sutton and Morris 2004; 2005; 2006) and U.S. Geological Survey (USGS) (Maret et al. 2004; 2005; 2006) are available at the following web site: http://id.water.usgs.gov/projects/salmon_streamflow/index.html. Information obtained from these studies can be used by the public, State, and Federal agencies to help formulate management actions to address stream flow needs of ESA-listed anadromous and resident native fish. Study results can be used to help determine target flow objectives to improve passage, spawning, and adult holding conditions for salmon, steelhead, and bull trout.

1.1 Background

Rivers and streams in the Lemhi River sub-basin historically provided significant spawning and rearing habitat for anadromous spring/summer Chinook salmon, sockeye salmon, and steelhead trout. However, anadromous fish populations have plummeted in the last 100 years and led in the 1990s to listing of these salmon and steelhead stocks as threatened under the ESA. Wild salmon and steelhead continue to migrate into the area and depend on spawning and rearing habitat in the basin. Bull trout also inhabit many of these rivers and streams. However, human development has modified the original flow and habitat conditions thereby affecting migration and/or access to suitable spawning and rearing habitat for all of these fish.

Many Federal, State, Tribal, local, and private parties work together to protect and restore ESA-listed anadromous and native fish species in the basin. One part of this work involves providing enough stream flow for these fish. Although sufficient stream flows are essential for fish to thrive, flows in the basin are also used for agricultural, domestic, commercial, municipal, industrial, recreational and other purposes. There is considerable information available that can be used to identify the amount of stream flow needed and used by people; however, there is little information about how much stream flow is needed to support various life history stages of ESA-listed fish. A reliable identification of stream flow needs for these fish will provide a basis that the public and Federal, State, Tribal, and local parties can use to determine how to make the available water supply meet both the needs of ESA-listed fish and the needs of the people who live in these areas.

Some river reaches are more vulnerable than others to limitations in available stream flow. Fishery biologists with the Idaho Department of Fish and Game (IDFG), Bureau of Land Management (BLM), U.S. Forest Service (USFS), and Shoshone-Bannock Tribes compiled professional biological recommendations and known anadromous and resident fish population densities and Chinook redd counts (Upper Salmon Basin Watershed Project Technical Team 2005). They used this information to prioritize 11 sub-basins and to develop a list of 30 river reaches in the basin for immediate inventory and assessment for mitigation efforts (http://www.modelwatershed.org/Library.html). The geographic area covered in their report included the entire Upper Salmon River Basin upstream from the confluence of the Middle Fork and main stem of the Salmon River.

1.2 Species of Interest

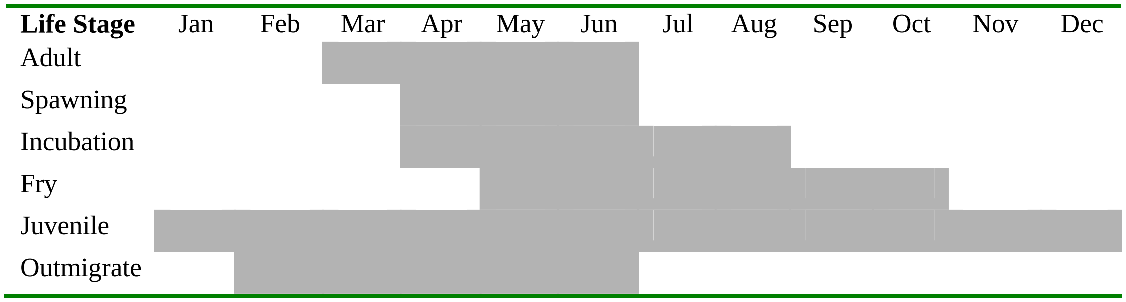
Federal ESA listed species addressed in this section include the anadromous Snake River spring/summer Chinook salmon ESU; Snake River steelhead ESU; and resident Columbia River Basin bull trout DPS.

1.2.1 Steelhead

The Snake River Basin Ecologically Significant Unit (ESU) of steelhead trout was listed as threatened under ESA on August 18, 1997 (Federal Register, Vol. 62 , No. 159). Critical habitat for this ESU was designated February 16, 2000 (Federal Register, Vol. 65, No. 32), and includes all accessible portions of the project area. This critical habitat designation has been withdrawn and is currently being reviewed by NMFS, pursuant to a consent decree on April 30, 2002 (NMFS 2002).

The Lemhi River Sub-basin summer steelhead are classified as A-run steelhead (early migrators and spawners). Specific data on spawning populations of steelhead within Lemhi River sub-basin are very limited. These fish arise from stocks that were introduced by IDFG but are now considered natural populations. Periodicity for steelhead in the Lemhi River Sub-basin is summarized in Table 1.

Table 1 Periodicity chart for steelhead in Lemhi River Sub-basin (EA Engineering 1991a).



Steelhead migrate inland towards spawning areas, overwinter in larger rivers, resume migration to natal streams in early spring, and then spawn (Nickelson et al.1992). Steelhead are widely distributed throughout the sub-basin, and juveniles are present year-round. The lower 27 miles of the mainstem Lemhi River from the mouth to Agency Creek serve mainly as a migration corridor. The 11-mile reach between Agency and Hayden Creeks provides rearing and limited spawning habitat. Tributary streams also provide spawning habitat.

Irrigation, grazing, and road construction have affected habitat conditions throughout the Lemhi Sub-basin (NPPC 2001). Limiting factors on the mainstem Lemhi River can be grouped based on three distinct river segments, each having its own limiting factors. The lower 27-mile mainstem reach is degraded because of the lack of riparian vegetation and lack of pools for rearing and adult holding. The next segment, an 11-mile reach between Agency and Hayden Creeks, provides habitat, but riparian degradation has led to elevated water temperatures and unstable banks. The third mainstem segment, 28 miles from Hayden Creek to Leadore, has fluctuating summer temperatures, unstabilized banks, and few high quality pools. Salmonid habitat threats in the tributary streams include bank erosion leading to sedimentation, elevated temperatures, and degraded riparian habitat. Irrigation withdrawals have resulted in dewatered lower reaches in most tributaries. Water does not flow into the Lemhi River from many of the tributaries except during spring runoff, substantially reducing downstream migrations of fish and creating migration barriers. Most irrigation diversions on lower reaches of tributaries are not screened to protect migrating fish.

During a 2005 elecroshocking fisheries survey of ten transects within the Hawley Creek watershed, Warren and Bliss (2006) found steelhead/rainbow trout to be distributed primarily in the lower reaches of the watershed tributaries. However, with access to Hawley Creek being blocked off to anadromous and fluvial fish migrating upstream to and from the Lemhi River, the fish residing in Hawley Creek are most likely following a resident life history.

A November 4, 2005 BLM fishery survey of Eighteenmile Creek found poor habitat in much of the lower reaches and good habitat for anadromous and resident trout about four miles upstream of Leadore. During this survey, biologists only captured eastern brook trout and numerous sculpin.

1.2.2 Spring/Summer Chinook Salmon

Spring/summer Chinook salmon are Federally listed as threatened under the ESA and by the State of Idaho. Chinook salmon are part of the federally threatened Snake River Chinook "Spring/Summer Run" ESU (Federal Register Vol. 57, No. 78, April 22, 1992) in the Lemhi River sub-basin. Designated critical habitat for this ESU occurs in the Lemhi hydrologic unit (Federal Register Vol. 64, No. 205, October 25, 1999).

The two "races" of spring/summer Chinook salmon in the Salmon River are classified by the season of adult passage at Bonneville Dam on the Columbia River during upstream migration. Spring/summer Chinook enter the Columbia River March through July. Chinook that pass over Bonneville Dam from March 1 to May 31 are considered "spring Chinook" and those that pass from June 1 to July 31 are considered "summer Chinook." Spring Chinook are the most prevalent and are found within the upper drainages of the Salmon basin. Summer Chinook are more limited in their distribution, being found in mainstem reaches of the upper Salmon basin (R2 Resource Consultants 2004). Spawning occurs in August through October. Eggs hatch in April and May, and the fry emerge approximately one month later. Juveniles rear for one year before out-migrating to the ocean (Simpson and Wallace 1982). Periodicity for Chinook salmon in the Lemhi River Sub-basin is summarized in Table 2.

Spring Chinook salmon spawn in the Lemhi River upstream from Hayden Creek. Over 95 percent of the salmon spawning and rearing in this sub-basin takes place in the upper 28 miles of the mainstem between Hayden Creek and Leadore (Bureau of Reclamation 2003). Most spring/summer Chinook salmon enter the sub-basin from May through September. Spawning occurs in late summer and early fall. All spawning is natural, as hatchery releases from Hayden Creek were suspended in 1982 (Bureau of Reclamation 2003). Juveniles reside in rearing areas for approximately 12 months before migrating downstream the following April and May (Bugert et al. 1990; Cannamela 1992). Other threats to Chinook salmon are the same as those discussed for steelhead in the Lemhi Sub-basin.

During the 2005 electroshocking survey of Hawley Creek watershed, there were no Chinook salmon sampled within the area (Warren and Bliss 2006). There is no known spawning or rearing in the watershed due to low water levels or the dewatering of the lower section of the stream during the irrigation season. Reconnecting Hawley Creek and Eighteenmile Creek to the Lemhi River could potentially reestablish fluvial life history forms of bull trout and provide access to juvenile Chinook and steelhead salmon searching for thermal refugia in tributaries during the warmer summer months (Warren and Bliss 2006).

Table 2 Periodicity chart for Chinook salmon in Lemhi River Sub-basin (EA Engineering 1991a).

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult					■	■	■	■	■	■		
Spawning							■	■	■	■		
Incubation	■	■	■	■	■		■	■	■	■	■	■
Fry			■	■	■	■	■					
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■
Outmigrate			■	■	■	■						

1.2.3 Bull Trout

Bull trout are listed as threatened under the Federal ESA (Federal Register, Vol. 63, No. 111, June 10 1998) and as a species of concern by the State of Idaho. In 2002, FWS proposed critical habitat for bull trout in the Columbia River basin (Federal Register, Vol. 67, No. 230, November 29, 2002). In 2003, FWS reopened the comment period for the proposal to designate critical habitat for Columbia River Distinct Population Segments (DPS) of bull trout (Federal Register Vol. 68, No. 28, February 11, 2003). Final critical habitat designation by the FWS does not include the Lemhi River Sub-basin (Federal Register, Vol. 69, No. 193, October 6, 2004).

Bull trout in the Lemhi Sub-basin are considered fluvial stock, as they migrate between streams and larger rivers. Bull trout typically spawn in September and October but may begin their spawning migration as early as April. Spawning occurs in clean gravels, with areas of groundwater upwelling preferred. Fry emerge from early April through May. Small juveniles tend to remain in the gravels and cobbles. After reaching 4 inches (10 cm) in length, they move to backwater and sidewater channels, eddies, or pools (Goetz 1989). Periodicity for bull trout in the Lemhi River Sub-basin is summarized in Table 3.

Table 3 Periodicity chart for bull trout in Lemhi River Sub-basin (EA Engineering 1991a).

Life Stage	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Adult			■	■	■	■	■	■	■	■		
Spawning									■	■		
Incubation	■	■	■	■	■				■	■	■	■
Fry			■	■	■	■	■	■	■	■		
Juvenile	■	■	■	■	■	■	■	■	■	■	■	■

Within the project area, bull trout are widely distributed. They are present year-round. Bull trout are found in Big Eightmile, Big Timber, Eighteenmile, Geertson, Hawley, Hayden, Kenny, Bohannon, Kirtley, Little Eightmile, Mill, Pattee, and Texas Creeks; their tributaries; and in the Lemhi River (NPPC 2001).

Threats to bull trout and their habitat are the same as listed for steelhead in the Lemhi Sub-basin. Of particular concern to fluvial bull trout is dewatering of lower tributary reaches, elevated water temperatures, and un-screened diversion structures that inhibit downstream migration into mainstem waters.

Any migratory populations of bull trout are non-existent in Hawley Creek because of lack of connectivity and diminished cold water habitat (Warren and Bliss 2006). Any remaining bull trout populations exist only in the upper reaches of the tributaries of Hawley Creek (Warren and Bliss 2006). It is likely that Hawley Creek at one time supported either resident or fluvial life history forms of bull trout. An electrofishing survey conducted in the summer of 2005 within the Hawley Creek watershed yielded low numbers of bull trout (Warren and Bliss 2006). Bull trout were present in 29% of the sample sites and most of their distribution was within the Big Bear Creek tributary of the Hawley Creek watershed. A fishery survey was conducted in July and August of 2004 by the Leadore Ranger District of the Salmon-Challis National Forest, where bull trout were among the species collected (Rose 2004).

2.0 STUDY REGION

The following definitions apply to the following discussion:
Study area – The study area is defined as one or more stream reaches impacted by flow alteration. Typically, a study area consists of stream reaches that represent small portions of each stream.
Stream segment – The portion of the study area that has a homogeneous stream flow and geomorphology (Bovee 1997). A study area may have one or more hydrologic segments (+/- 10% of the mean monthly flow Q).
Reach (*Study Site*) – A physical aspect of the channel within a stream segment that affects the microhabitat versus flow relationship (e.g., channel morphology, slope, or land use); contains multiple mesohabitat units (riffle, run, pool) within a stream segment.
Mesohabitat – Habitat types delineated by localized slope, channel shape, and structure (e.g., riffles, runs, pools).
Microhabitat – Habitats that represent relatively homogeneous area of about the size utilized by an individual fish (e.g., tree snags, undercut banks, velocity shelters).

Investigations were performed on two separate study regions/areas of the Lemhi SubBasin during the summer and fall of 2006. The study area consisted of four study sites on Hawley Creek and six study sites on Eighteenmile Creek. Field reconnaissance, topographic maps, and interviews with IDFG indicated that these streams could be broken up into distinct hydrologic stream segments, defined as follows:

- Hawley Creek: between the upstream confluence of Eighteenmile Creek and the upper-most diversion in the upper valley of Hawley Creek and the Diversion site bracketed by two lower most diversions.
- Eighteenmile Creek: upstream from confluence with Whitefish Ditch.

Using USGS topographic maps, longitudinal gradient was plotted for each stream (Figures 1-2). Within the different stream segments, several study sites were identified in accessible reaches, distinguished primarily by differences in stream channel morphology and locations of major diversions for each stream. These were distributed sequentially proceeding upstream. Each study site is described below and in Appendix A and identified on Figures 1 and 2:

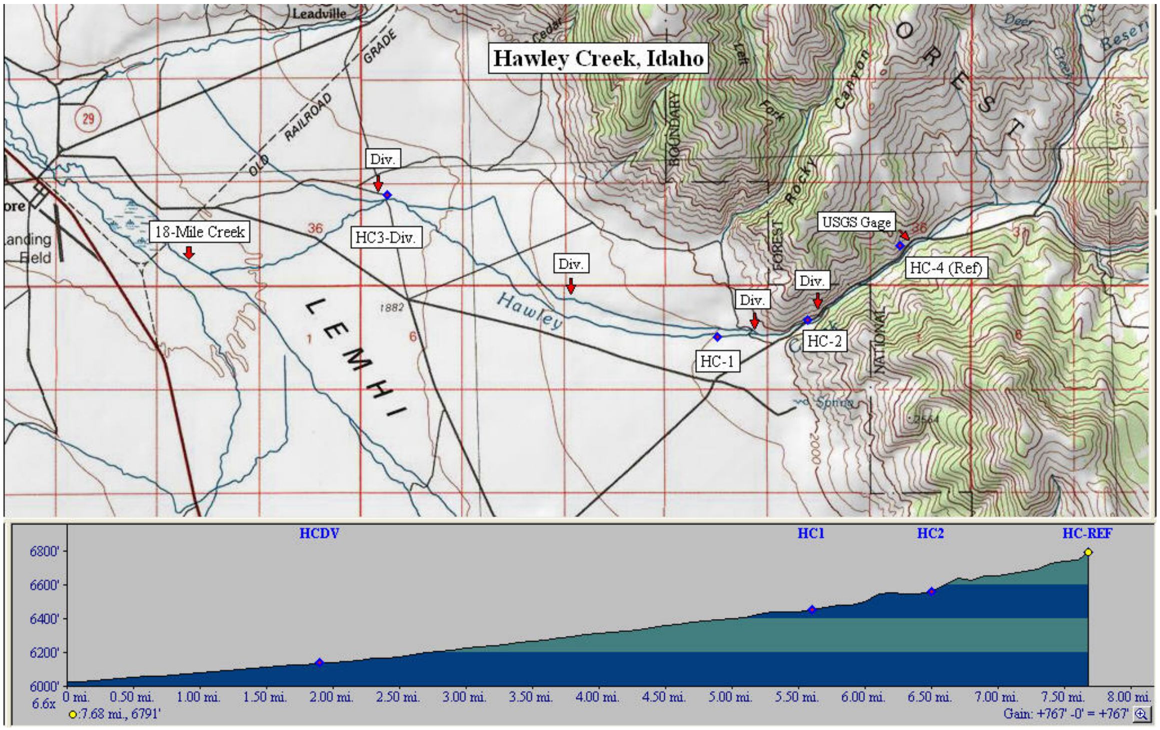


Figure 1 Hawley Creek study area for flow characterization study and locations of study sites 1-4.

Hawley Creek, Study Site 1 (HC-1): This reach was the most downstream segment in Hawley Creek located in a formerly dry stream channel. The reach is now only dewatered during the irrigation season.. It was characterized mainly by low gradient riffles glides and pools, and located on BLM property.

Hawley Creek, Study Site 2 (HC-2): This reach primarily consisted of glides, riffles and pools in a moderately vegetated area. This study site was located on BLM property.

Hawley Creek, Study Site 3 (Diversion) (HC3-Div): This reach was located on private land, and includes a structure that diverts Hawley Creek water. Until 2005, this reach flowed year round but is currently dewatered in the non irrigation season. The study site was a mixture of riffle, glide and pool habitat types.

Hawley Creek, Study Site 4 (Reference) (HC-4 (Ref)): This study site for this reach was located on USFS property. The stream channel consisted of glides, riffles and pools with natural heavy vegetation. A USGS gage was placed at this site to monitor flows during the study.

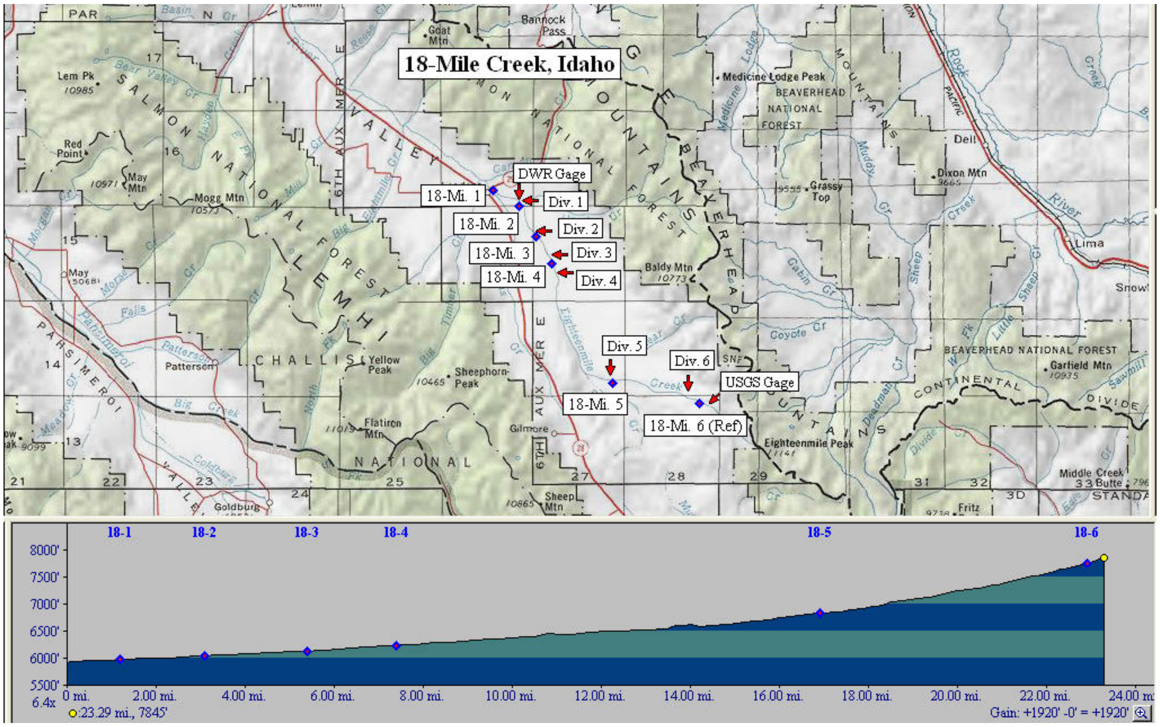


Figure 2 Eighteenmile Creek study area for flow characterization study and locations of study sites 1-6.

Eighteenmile Creek, Study Site 1 (18-Mi 1): This reach extended from the upper confluence with Whitefish Ditch at SH-29 upstream to the first major diversion. The stream channel consisted primarily of riffles and glides and was located on private property.

Eighteenmile Creek, Study Site 2 (18-Mi 2): This reach was located on private property; it was bracketed by two major diversions. It primarily consisted of riffles and glides. This reach appeared to have been channelized.

Eighteenmile Creek, Study Site 3 (18-Mi 3): This reach was located on private property and between two major diversions that defined the upstream and downstream boundaries of 2 and 4, respectively. The study site was a mixture of pool, riffle and glide habitat types.

Eighteenmile Creek, Study Site 4 (18-Mi 4): This study site for this reach was located on private property and represented a mixture of riffle and run habitat types. The upper and lower boundaries of this reach were two diversions, separating reaches 3 and 5, respectively.

Eighteenmile Creek, Study Site 5 (18-Mi 5): This reach was located on Bureau of Land Management (BLM) land. The upper and lower boundaries of this reach were two diversions. The study site was a mixture of riffle, pool and glide habitats.

Eighteenmile Creek, Study Site 6 (Reference) (18-Mi 6 (Ref): This reach was located on BLM land, upstream of a major diversion. Habitat consisted of pools, riffles, and glides. The study site represented natural flow conditions immediately upstream from the major diversions on Eighteenmile Creek.

3.0 LIMITING FACTORS ANALYSIS

The main components in this analysis were existing fish population, hydrology, and water quality data. Existing fish population data were used as an index of fish occurrence in the study streams (see Section 1.2). Existing USGS natural streamflow estimates and measured streamflows during 2006 were used to determine recent historic hydrology. Additionally, any existing water quality data, including water temperature, were evaluated to determine if water quality was limiting. Water temperature was monitored continuously at one location in Hawley Creek (near Study Site 2) and one location in Eighteenmile Creek (near Study Site 1) by Reclamation between June and September, 2006 using Onset TidBit data loggers.

3.1 Climatic and Hydrologic Conditions

The average snowpack level in the Salmon River Basin on April 1, 2006 was 107 percent (Natural Resources Conservation Service 2007). The April 1 value is the most commonly used indicator of snowpack conditions since, in most years, it is the final value calculated before snowmelt begins. Streamflow forecast on April 1, 2006 called for extended high flows for the Lemhi River (102 %), the Salmon River (125 %) and its tributaries (Natural Resources Conservation Service 2007). The mean April 2006 air temperature at Leadore, Idaho was 4.9°C (40.8°F) (Western Regional Climate Center 2007).

Natural streamflow estimates characterize seasonal flow variability in each stream segment. Large fluctuations in flow during the year are products of variable weather and the free-flowing conditions of Hawley Creek and Eighteenmile Creek, upstream from the major diversions. An exceedance flow is defined as the flow that is equaled or exceeded a certain percentage of time. Flows estimated for 20, 50, and 80 percent exceedance for each creek at two separate locations are summarized in Tables 4-5. Flows were based on regional regression equations developed by USGS in Boise for the Forest Service (Hortness and Berenbrock 2001) (http://water.usgs.gov/osw/streamstats/). Information on the accuracy of the regression equations is available in Hortness and Berenbrock (2001). Tables 6 and 7 are streamflows measured at temporary gage stations maintained by USGS on Hawley Creek and Eighteenmile Creek during 2006.

The hydrology of Hawley Creek and Eighteenmile Creek has changed dramatically since the mid-1840s because of diversions that resulted in a lack of stream connectivity to the floodplain or the Lemhi River. During the irrigation season water is diverted off-channel through diversion headgates and either used for flood or sprinkler irrigation. For many years until recently, the lower portion of the historic Hawley Creek channel had been completely abandoned and diverted into an irrigation ditch due to a permanent diversion berm placed at a location just upstream from Study Site 1 (HC-1) (Figure 1). This ditch eventually reconnected with Eighteenmile Creek just upstream of Eighteenmile Creek, Study Site 2; although irrigation diversion onto adjacent fields, conveyance loss, and freezing winter temperatures prevented establishment of a year round hydraulic connection with Eighteenmile Creek or the Lemhi River. In 2005, the earthen berm at the head of the ditch was removed and a headgate/check structure installed to allow for the diversion of Hawley Creek water into the ditch during the irrigation season only. In the non-irrigation season the headgate is closed and streamflow is re-directed into what remains of the historic natural channel. This natural channel of Hawley Creek gradually vanishes a short distance downstream from Hawley Creek Study Site 1. Freezing temperatures, absence of a confined channel, and natural conveyance loss limits Hawley Creek water from reaching Eighteenmile Creek in the non-irrigation season.

Study Site 2 in Eighteenmile Creek is located in a reach that was historically relocated (i.e., channelized) to allow for establishment of an irrigated field. This lower reach of Eighteenmile Creek also no longer directly connects to the Lemhi River. At a location downstream of a culvert under SH-29, the Eighteenmile Creek channel has been re-directed into a channel known locally as the Whitefish Ditch. Whitefish Ditch intersects with Canyon Creek where a headgate-check structure has been placed to allow for the diversion of all of the water from Whitefish Ditch and Canyon Creek to be directed into an irrigation ditch. Frequently, the lower reach of the Canyon Creek channel below this structure to the confluence with the Lemhi is dry except during periods of high flow in the spring and during the non-irrigation season (Sutton and Morris 2006). Figures 3-7 are graphical representations of flows for Hawley Creek and Eighteenmile Creek in summer 2006 using continuous gaging data and natural flow exceedance estimates.

Water withdrawals have degraded the aquatic resources in the Lemhi River sub-basin by reducing flow in the river channels. Inadequate flow in the river results in conditions unfavorable to either upstream migration of spawning adults, or out-migration of juveniles (Bureau of Reclamation 2003). Intensive diversion of water for agriculture can disconnect tributaries from the mainstem river. In the Lemhi, it is estimated that fish production has been lost from at least 10 tributary creeks that previously supported anadromous fish populations (ISCC 1995), eliminating significant stretches of spawning habitat due to dewatering.

Even main river channels can be dewatered for short stretches, downstream from major diversions before any water is returned to the main channel. For example, in the past as much as a 3-mile long stretch of the lower Lemhi was vulnerable to dewatering for part of the summer during low flow years (ISCC 1995). It is not necessary for the river to be entirely dewatered for the channel to become impassable. Depending on river bottom conditions, flow can occur predominantly through river gravels during times of extremely low flow, effectively preventing fish passage.

In some river systems, much of the water flowing through tributaries is lost directly to alluvial gravels, where it sinks into underground flows. This is estimated to be the case in the Lemhi River sub-basin. Of the estimated annual water yield of 1.055 million acre-feet in the subbasin, an estimated 0.875 million acre feet (MAF) are lost to evaporation, plant transpiration, and underground flows (ISCC 1995) by the time it reaches the town of Salmon at the confluence with the Salmon River.

Table 4 Monthly exceedance flows on Hawley Creek using USGS regional regression equations (Hortness and Berenbrock 2001).

Month		**Flow Value (cfs)**	
		Study Site 1	**Study Site 4**
January	Q.80=	4.82	4.37
	Q.50=	5.89	5.36
	Q.20=	8.54	7.88
February	Q.80=	4.71	4.26
	Q.50=	6.02	5.48
	Q.20=	8.68	8.02
March	Q.80=	4.87	4.41
	Q.50=	7.10	6.52
	Q.20=	10.3	9.54
April	Q.80=	8.53	7.91
	Q.50=	13.5	12.7
	Q.20=	25.2	23.8
May	Q.80=	18.6	17.8
	Q.50=	42.0	40.3
	Q.20=	84.3	80.9
June	Q.80=	26.6	22.9
	Q.50=	62.4	56.2
	Q.20=	118.0	108.0
July	Q.80=	15.0	14.3
	Q.50=	27.6	26.4
	Q.20=	48.2	46.2
August	Q.80=	8.94	8.49
	Q.50=	13.1	12.5
	Q.20=	21.9	21.1
September	Q.80=	7.32	6.90
	Q.50=	10.2	9.58
	Q.20=	15.6	14.9
October	Q.80=	4.81	4.36
	Q.50=	8.15	7.38
	Q.20=	12.5	11.6
November	Q.80=	6.01	5.45
	Q.50=	7.55	6.88
	Q.20=	11.2	10.4
December	Q.80=	5.13	4.66
	Q.50=	6.49	5.91
	Q.20=	9.43	8.71
Average annual Q average=		**19.42**	**18.11**

Table 5 Monthly exceedance flows on Eighteenmile Creek using USGS regional regression equations (Hortness and Berenbrock 2001).

Month		Flow Value (cfs)	
		Study Site 1	**Study Site 6**
January	Q.80=	15.4	0.69
	Q.50=	20.1	0.86
	Q.20=	36.3	1.27
February	Q.80=	15.7	0.65
	Q.50=	21.4	0.84
	Q.20=	38.1	1.30
March	Q.80=	16.6	0.67
	Q.50=	29.4	1.02
	Q.20=	48.2	1.56
April	Q.80=	42.2	1.26
	Q.50=	76.4	2.10
	Q.20=	136.0	4.24
May	Q.80=	54.0	4.46
	Q.50=	121.0	10.7
	Q.20=	236.0	22.7
June	Q.80=	48.2	8.43
	Q.50=	149.0	18.4
	Q.20=	306.0	34.0
July	Q.80=	26.1	4.81
	Q.50=	63.6	8.29
	Q.20=	128.0	13.9
August	Q.80=	17.4	2.72
	Q.50=	26.3	3.93
	Q.20=	62.9	6.41
September	Q.80=	16.8	1.86
	Q.50=	23.7	2.58
	Q.20=	52.4	3.83
October	Q.80=	14.3	0.72
	Q.50=	23.2	1.24
	Q.20=	51.2	1.93
November	Q.80=	19.6	0.85
	Q.50=	26.5	1.09
	Q.20=	50.6	1.69
December	Q.80=	16.2	0.75
	Q.50=	22.2	0.94
	Q.20=	42.2	1.39
Average annual Q average=		**58.1**	**4.84**

Table 6 Water resource records for upper Hawley Creek above all diversions, 2006 (source: USGS).

U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES
STATION NUMBER 13303030 HAWLEY CREEK NR LEADORE ID STREAM SOURCE AGENCY USGS STATE 16 COUNTY 059
LATITUDE 444010 LONGITUDE 1131110 NAD83 DRAINAGE AREA 40.9* CONTRIBUTING DRAINAGE AREA DATUM
Date Processed: 2007-01-22 09:32 By jddoyle
Lowest aging status in period is IN REVIEW
DD #1
Discharge, cubic feet per second
WATER YEAR OCTOBER 2005 TO SEPTEMBER 2006
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	---	---	18	14	12	12
2	---	---	---	---	---	---	---	---	18	14	11	12
3	---	---	---	---	---	---	---	---	18	13	11	12
4	---	---	---	---	---	---	---	---	18	13	11	12
5	---	---	---	---	---	---	---	---	18	13	12	12
6	---	---	---	---	---	---	---	---	17	14	12	e12
7	---	---	---	---	---	---	---	---	17	14	12	e11
8	---	---	---	---	---	---	---	---	20	13	12	12
9	---	---	---	---	---	---	---	---	20	13	11	12
10	---	---	---	---	---	---	---	---	19	13	11	11
11	---	---	---	---	---	---	---	---	17	12	11	11
12	---	---	---	---	---	---	---	---	17	13	12	11
13	---	---	---	---	---	---	---	---	17	13	12	11
14	---	---	---	---	---	---	---	---	17	12	11	11
15	---	---	---	---	---	---	---	---	18	12	12	12
16	---	---	---	---	---	---	---	---	17	12	12	12
17	---	---	---	---	---	---	---	---	16	12	12	12
18	---	---	---	---	---	---	---	---	16	12	12	12
19	---	---	---	---	---	---	---	---	16	12	12	12
20	---	---	---	---	---	---	---	---	16	12	12	12
21	---	---	---	---	---	---	---	---	15	11	11	12
22	---	---	---	---	---	---	---	---	15	11	11	12
23	---	---	---	---	---	---	---	---	15	11	11	12
24	---	---	---	---	---	---	---	---	15	12	11	12
25	---	---	---	---	---	---	---	20	14	12	12	12
26	---	---	---	---	---	---	---	21	15	12	12	12
27	---	---	---	---	---	---	---	24	14	11	12	12
28	---	---	---	---	---	---	---	22	14	11	12	12
29	---	---	---	---	---	---	---	21	14	11	12	12
30	---	---	---	---	---	---	---	19	14	11	12	12
31	---	---	---	---	---	---	---	19	---	11	12	---
TOTAL	---	---	---	---	---	---	---	---	495	380	361	354
MEAN	---	---	---	---	---	---	---	---	16.5	12.3	11.6	11.8
MAX	---	---	---	---	---	---	---	---	20	14	12	12
MIN	---	---	---	---	---	---	---	---	14	11	11	11
AC-FT	---	---	---	---	---	---	---	---	982	754	716	702

e Estimated

Table 7 Water resource records for Eighteenmile Creek above Pass Creek (all diversions) near Leadore, ID, 2006 (source: USGS).

U.S. DEPARTMENT OF THE INTERIOR - U.S. GEOLOGICAL SURVEY - WATER RESOURCES

STATION NUMBER 13302600 EIGHTEENMILE CREEK ABV PASS CREEK NEAR LEADORE ID SOURCE AGENCY USGS STATE 16 COUNTY 059
LATITUDE 442906 LONGITUDE 1130444 NAD83 DRAINAGE AREA 6.27* CONTRIBUTING DRAINAGE AREA DATUM
Date Processed: 2007-01-22 09:31 By jddoyle
Lowest aging status in period is IN REVIEW
DD #1
Discharge, cubic feet per second
WATER YEAR OCTOBER 2005 TO SEPTEMBER 2006
DAILY MEAN VALUES

DAY	OCT	NOV	DEC	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP
1	---	---	---	---	---	---	---	---	15	8.6	3.1	1.8
2	---	---	---	---	---	---	---	---	14	8.2	3.0	1.7
3	---	---	---	---	---	---	---	---	16	9.2	3.0	1.6
4	---	---	---	---	---	---	---	---	17	8.1	2.9	1.6
5	---	---	---	---	---	---	---	---	18	8.3	2.8	1.6
6	---	---	---	---	---	---	---	---	18	8.0	2.7	1.6
7	---	---	---	---	---	---	---	---	20	8.1	2.6	1.7
8	---	---	---	---	---	---	---	---	27	6.7	2.4	1.7
9	---	---	---	---	---	---	---	---	31	6.5	2.4	1.9
10	---	---	---	---	---	---	---	---	29	6.1	2.3	1.8
11	---	---	---	---	---	---	---	---	25	5.8	2.2	1.6
12	---	---	---	---	---	---	---	---	23	5.8	2.6	1.5
13	---	---	---	---	---	---	---	---	22	5.4	2.6	1.5
14	---	---	---	---	---	---	---	---	24	5.0	2.4	1.5
15	---	---	---	---	---	---	---	---	22	4.7	2.3	1.8
16	---	---	---	---	---	---	---	---	19	4.5	2.2	2.2
17	---	---	---	---	---	---	---	---	17	4.2	2.2	2.4
18	---	---	---	---	---	---	---	---	16	4.0	2.1	2.3
19	---	---	---	---	---	---	---	---	15	3.9	1.9	2.3
20	---	---	---	---	---	---	---	---	15	3.7	1.8	2.4
21	---	---	---	---	---	---	---	---	14	3.6	1.8	2.4
22	---	---	---	---	---	---	---	---	13	3.3	1.7	2.4
23	---	---	---	---	---	---	---	---	12	3.4	1.7	2.3
24	---	---	---	---	---	---	---	---	12	3.6	1.8	2.2
25	---	---	---	---	---	---	---	24	11	4.1	1.9	2.1
26	---	---	---	---	---	---	---	25	11	3.7	2.0	2.0
27	---	---	---	---	---	---	---	24	11	3.4	1.8	2.0
28	---	---	---	---	---	---	---	22	10	3.2	1.7	1.9
29	---	---	---	---	---	---	---	20	9.5	3.0	1.5	1.8
30	---	---	---	---	---	---	---	18	8.9	2.9	1.5	1.8
31	---	---	---	---	---	---	---	16	---	3.1	1.8	---
TOTAL	---	---	---	---	---	---	---	---	515.4	162.1	68.7	57.4
MEAN	---	---	---	---	---	---	---	---	17.2	5.23	2.22	1.91
MAX	---	---	---	---	---	---	---	---	31	9.2	3.1	2.4
MIN	---	---	---	---	---	---	---	---	8.9	2.9	1.5	1.5
AC-FT	---	---	---	---	---	---	---	---	1020	322	136	114

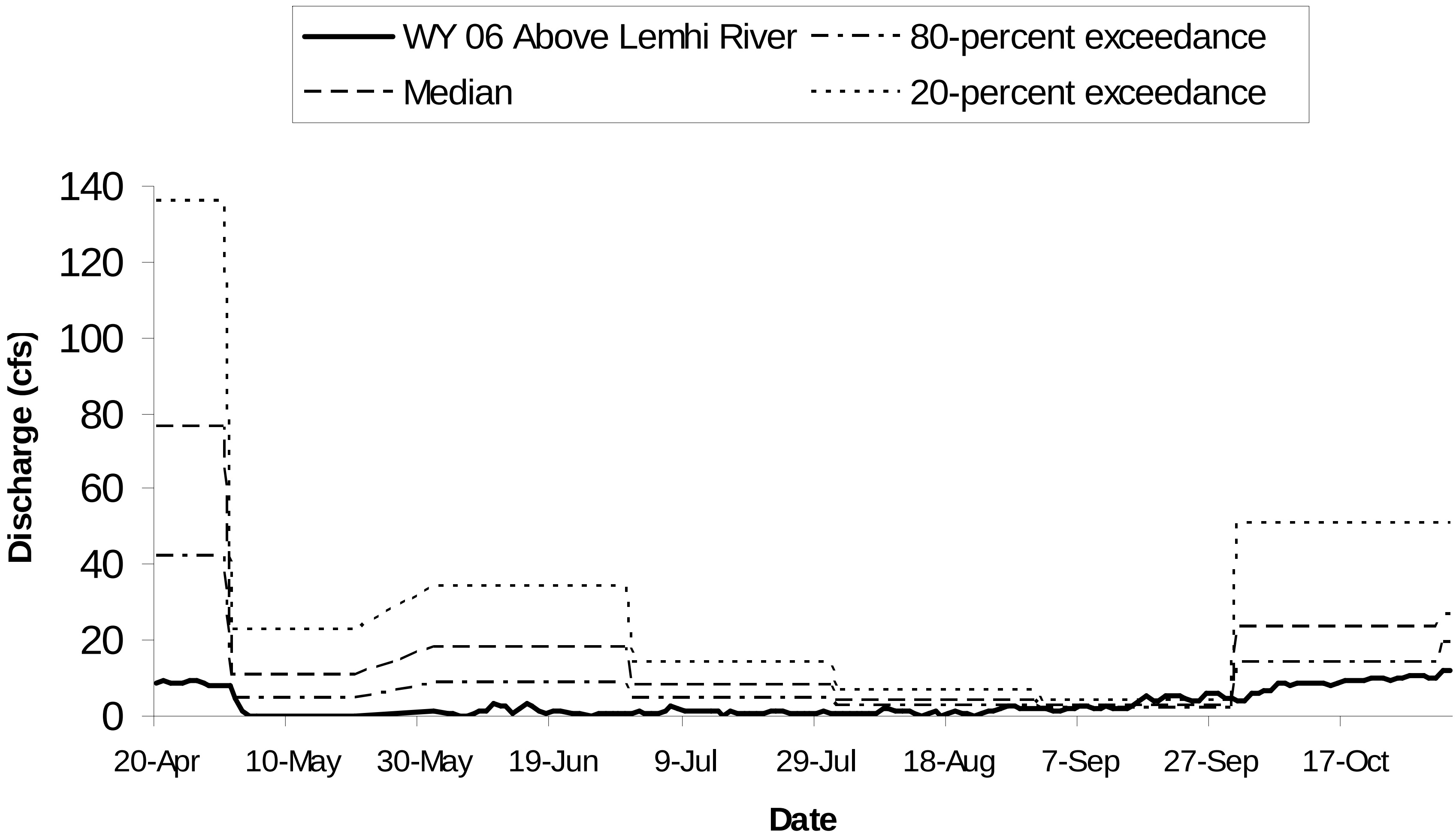


Figure 3 Daily flows (cfs) in the Eighteenmile Creek upstream from the confluence with the Lemhi River near Study Site #2, 2006 (source: IDWR)

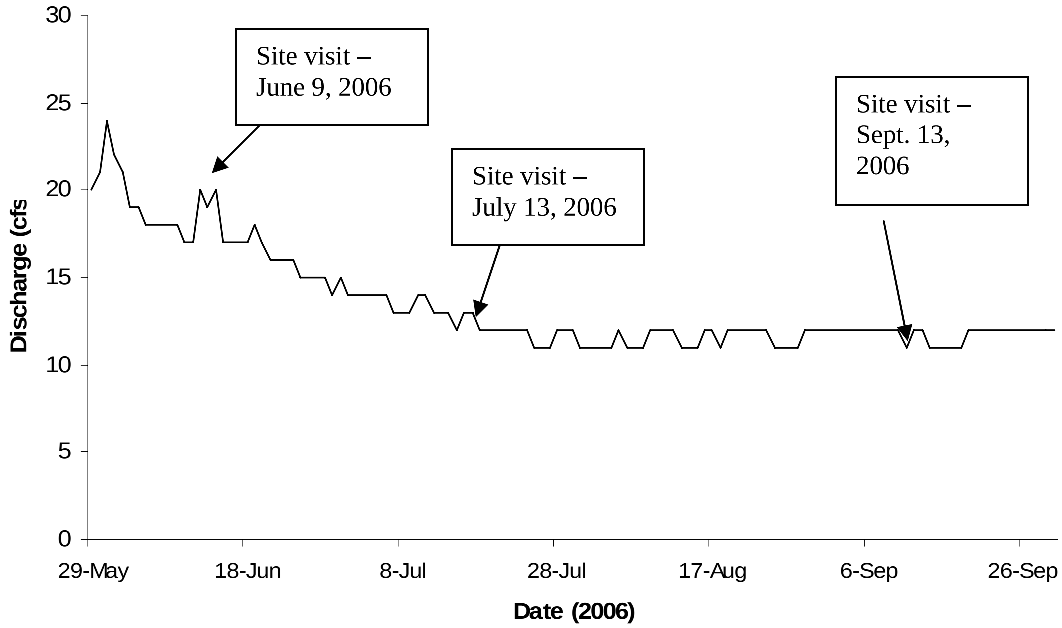


Figure 4 Graphical representation of data in Table 6 for discharge (cfs) recorded in Hawley Creek (2006).

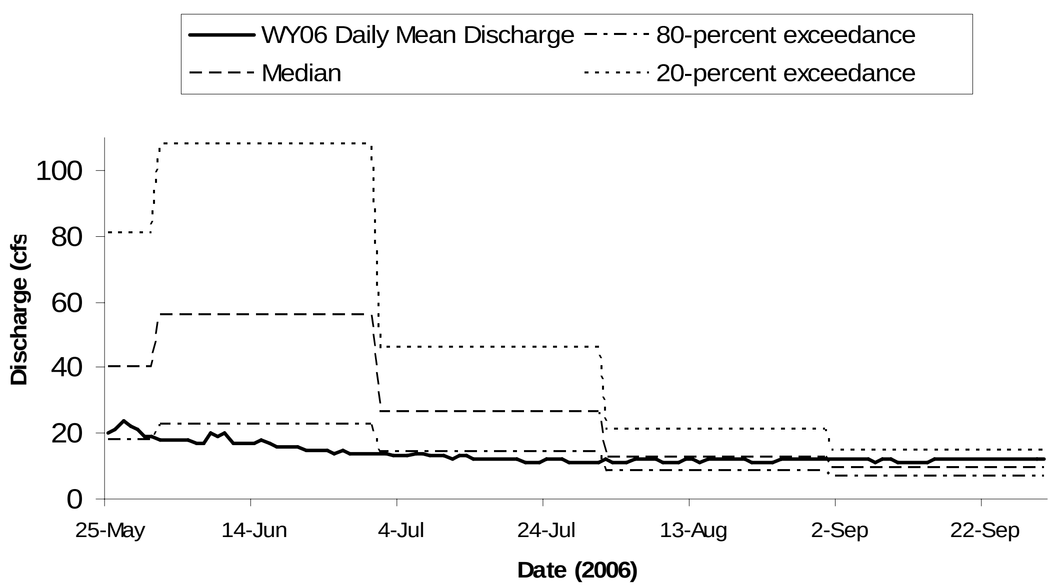


Figure 5 Graphical representation of Tables 6 and 4 for Hawley Creek discharge (cfs) in spring/summer, 2006 using continuous gaging data and exceedance estimates.

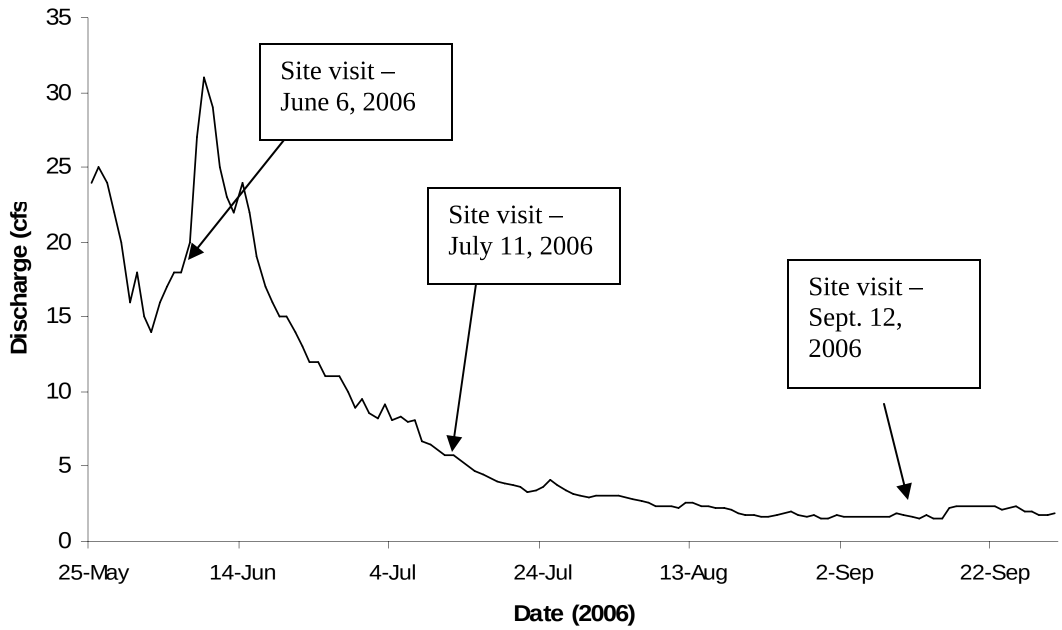


Figure 6 Graphical representation of data in Table 7 for unimpaired discharge (cfs) recorded in Eighteenmile Creek (2006).

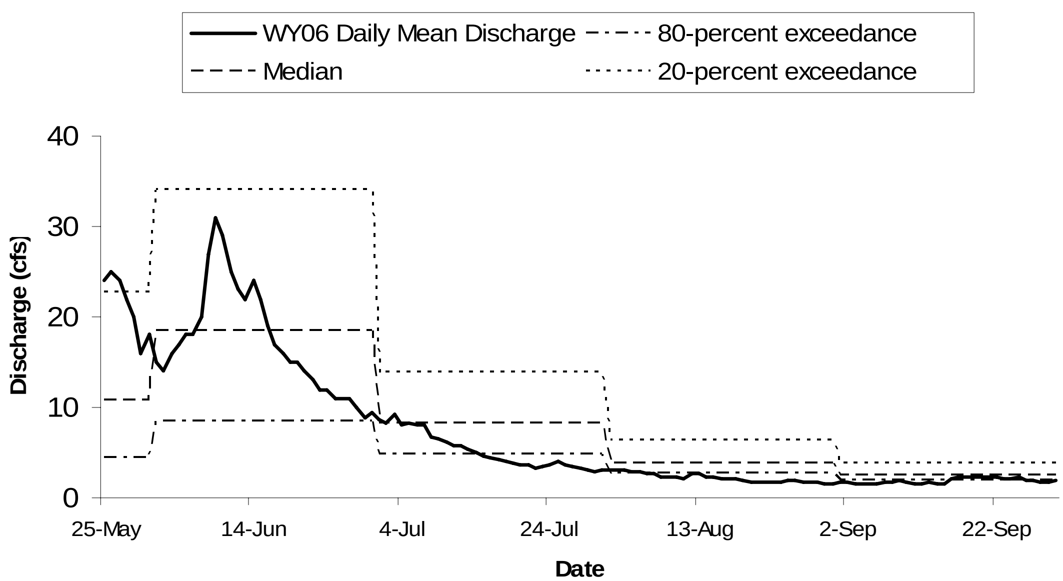


Figure 7 Graphical representation of Tables 7 and 5 for Eighteenmile Creek discharge (cfs) in spring/summer, 2006 using continuous gaging data and exceedance estimates.

3.2 Water Quality

Water bodies are designated in Idaho to protect water quality for existing or designated uses. Hawley Creek and Eighteenmile Creek are designated by Idaho Administrative Code (2005) - *58.01.02 - Water Quality Standards* as:

a. Cold water: water quality appropriate for the protection and maintenance of a viable aquatic life community for cold water species; and
b. Salmonid spawning: waters which provide or could provide a habitat for active self-propagating populations of salmonid fishes.

Eighteenmile Creek is on the U.S. Environmental Protection Agency's (EPA) 303(d) list for temperature from its confluence with Hawley Creek downstream to its mouth (U.S. EPA 2007). Stream temperature is driven by the interaction of many variables, including shade, geographic location, vegetation, climate, topography, and flow. Based on *Idaho Administrative Code 58.01.02 - Water Quality Standards, Surface Water Quality Criteria for Aquatic Life Use Designations*, Idaho waters designated for cold water aquatic life are not to vary from the following characteristic: water temperatures of 22°C (72°F) or less with a maximum daily average of no greater than 19°C (66°F). Hourly temperatures measured for Hawley Creek and Eighteenmile Creek are plotted in Figures 8-9, respectively. In 2006, the maximum daily average temperature standard was not exceeded (Figures 8 and 9). For the time period of June 7 – September 14, 2006, Hawley Creek lower reach averaged 11.2°C (8.1-14.5°C). Eighteenmile Creek averaged 10.3°C (4.6-19.5°C), holding the high temperature of 19.5°C for two hours on July 7, 2007 in the late afternoon (5-6 pm). Diel temperatures fluctuated less in Hawley Creek than Eighteenmile Creek (Figures 8 and 9). Dewatering, irrigation return flows, and lack of riparian shading may all act to increase water temperatures in the lower reaches of the study area. If there were little or no groundwater influence, the lower reaches may be unsuitable for salmonids. Groundwater and surface water temperatures would need to be measured and a thermal balance analysis conducted to account for groundwater effects.

Flow levels are affected by weather, snowpack, rainfall, and water withdrawal. Diverted water can reduce water temperatures and oxygen levels. Shallow, slow water tends to warm faster than deep, fast water. Warmer water holds less dissolved oxygen than cooler water. The combination of warm water with less dissolved oxygen, especially water temperatures above 20°C (68°F) and dissolved oxygen below 5 milligrams per liter, can stress salmonids (Bjornn and Reiser 1991). Armour (1991) reported that, for juvenile Chinook salmon acclimated to an environment where water temperatures were maintained at a constant of 15°C (59°F), 50% mortality occurred when temperatures reached 25°C (77°F). The upper lethal limit is 24°C (75°F) for steelhead (Bell 1991).

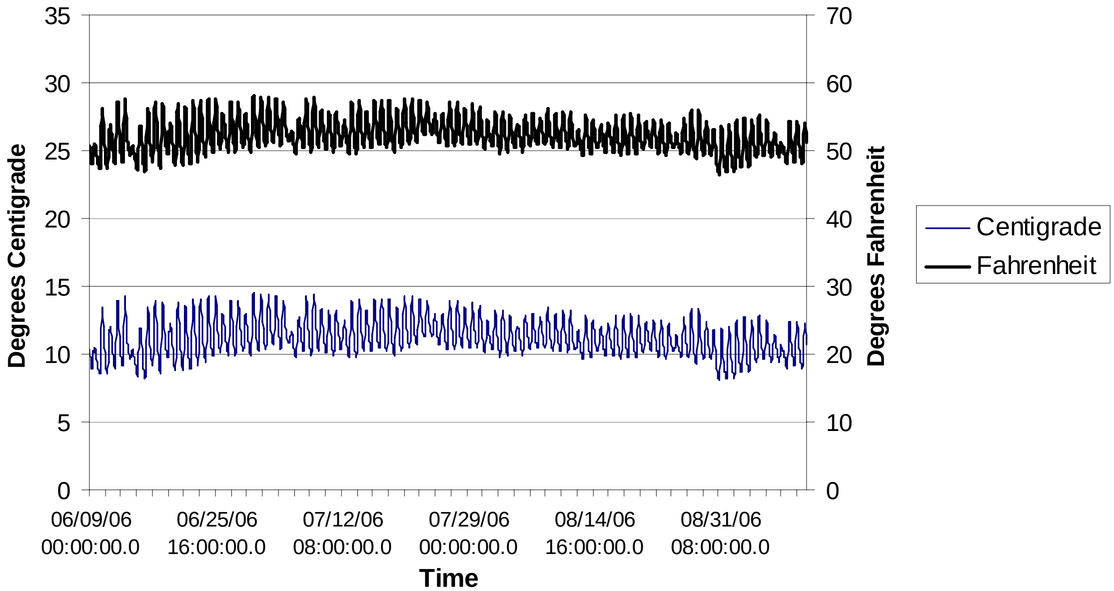


Figure 8 Hourly water temperatures in Hawley Creek during summer of 2006 near Study Site 2.

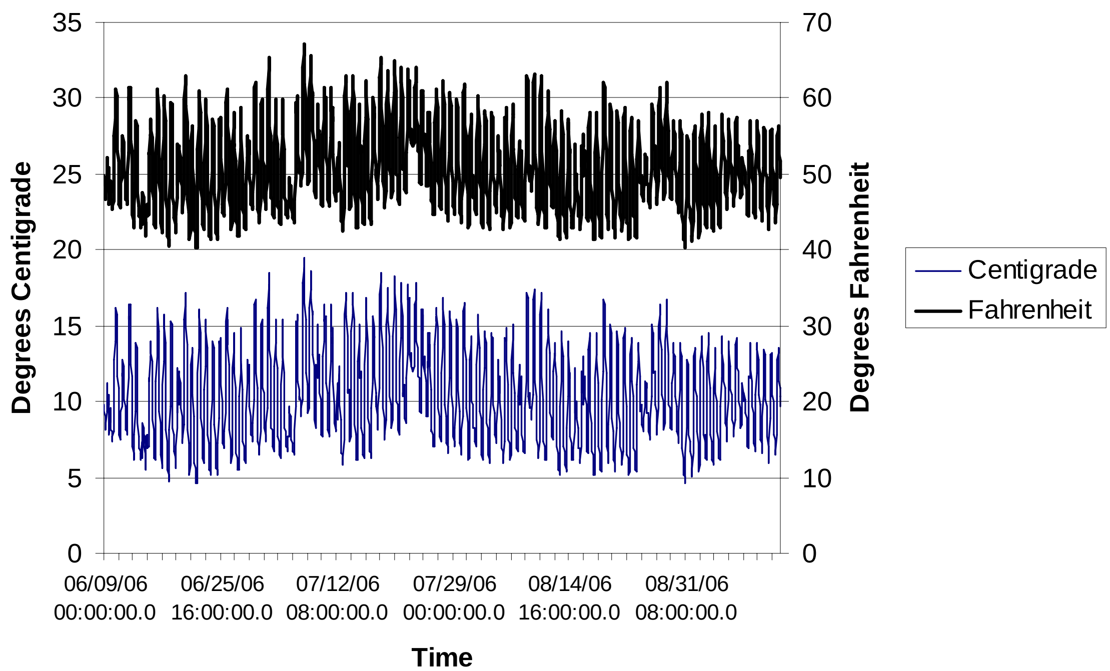


Figure 9 Hourly water temperatures in Eighteenmile Creek during summer of 2006 near Study Site 1.

Hawley Creek is on the 303d list for nutrients and sediment from its source to the confluence of Hawley Creek with Eighteenmile Creek (EPA 2007). Eighteenmile Creek is listed for sediment. In general, eutrophication is a partial result of nutrient enrichment from irrigation return flow (non-point source) and possibly cattle feedlots (point source). However, agricultural runoff presents a low level of potential impact to water quality. Excessive sedimentation has reduced the quality of spawning and rearing habitat for resident trout species and exceeded the same habitat parameters for anadromous species (IDEQ 2000).

3.3 Summary

Based on this analysis, the primary limiting factors for fisheries in Hawley and Eighteenmile Creek appear to be flow, summer temperature, and sedimentation in the lower reaches. Self-sustaining fish populations exist with no reported fish die-offs, and there is an available water supply throughout the year upstream from the major diversions. However, warm summer water temperatures are affected partly by water withdrawals, which also affect stream flows. Although high summer water temperature may limit the fisheries in late July and early August, fish populations continue to exist within available physical habitat throughout the year. Thermal modeling would help determine the benefits of additional flow, if any, to thermal regimes within the system. However, temperature modeling was beyond the scope of this study.

4.0 METHODS

The approach for characterizing flow needs in Hawley Creek and Eighteenmile Creek involved planning and execution of a PHABSIM study in the stream segments identified above. The Technical Service Center (TSC) of Reclamation in Denver, Colorado was responsible for (1) collecting and compiling existing hydrological and biological data for salmon, steelhead, and bull trout using these streams; (2) conducting the study; and (3) providing Reclamation's Snake River Area Office in Boise, Idaho with a final report and associated data. These tasks are briefly outlined below.

4.1 Microhabitat Analysis

Studies utilizing PHABSIM require extensive data collection and analyses. The steps in a PHABSIM study are briefly outlined below.

4.1.1 Mesohabitat Classification and Inventory

Specific procedures at each study site included:

- Locate study segments for study site selection.
- Map habitat features for stream segment. Habitat mapping, or mesohabitat typing, started at the upper segment boundary and proceeded downstream. The "cumulative-lengths approach" described by Bovee (1997) was used for habitat

mapping. Habitat types were defined based on the purpose of hydraulic modeling to capture hydraulic changes (e.g., backwater and slopes).

- Thus, Reclamation used the following mesohabitat classification scheme:
  - riffles (slope),
  - glides/runs (slope), and
  - pools (backwater).

Linear distance of each major habitat type was recorded and the total number of each habitat type and total length mapped were recorded at the end of each segment. The mapped data were used to determine percentages of each habitat type. Study sites were selected based on habitat mapping.

4.1.2 Collection of Hydraulic Data

PHABSIM requires hydraulic and habitat suitability data to determine the instream flow requirements for the species and/or life history stage of interest. Several hydraulic sub-models can be used with PHABSIM including Stage-Discharge Relation (STGQ), Step-Backwater (WSP), and Manning's Equation (MANSQ). Field data collection was designed to accommodate any of these models. PHABSIM data collection included several steps: study segment location, habitat mapping, transect (cross section) placement and data collection.

- Transects were placed in all habitat types that represented over 5 percent of the total available habitat. Transects were placed in homogeneous habitat types with the number of transects dependent upon the physical and hydraulic features of each habitat type. The number of transects necessary to capture the depth, velocity, cover and substrate distribution and variability is in large part a function of the specific river being worked on, the mesohabitat types present, and the HSCs.
- Additional non-habitat simulation transects were placed at hydraulic controls (HC) by professional judgment to aid in hydraulic calibrations. The shallowest path across riffles or shallow runs within the study site was used to address passage issues for adult salmonids.
- At each set of transects in each habitat type the following data were collected: establishment of horizontal reference points, distance between transects, field notes referencing general habitat and stream conditions in the transect areas, and reference photos of habitat at each transect within each habitat type.

Field data were collected according to Bovee (1997) using standard surveying equipment above the water surface and using depth measured from a wading rod for wet areas. An attempt was made to conduct the surveys at low, medium, and high discharges. Vertical elevations were established throughout each habitat type by using differential leveling with a total station instrument (Bovee 1997). A benchmark was established (with rebar) and assigned the arbitrary elevation of 100.00 feet. All differential leveling was referenced to this benchmark. Benchmark coordinates were recorded using a GARMIN Global Positioning System (GPS) Model 12 Navigator (NAD 83). Water surface elevations (WSL) were measured to the nearest 0.01 ft near the water's edge along each transect at all discharges. Channel cross sections were measured (vertical and horizontal) to the nearest 0.1 ft between headpins at each transect during low discharge. Discharge measurements at each transect were taken during the three surveys.

4.1.3 Depth, Velocity, Substrate, and Cover

Depths, mean velocities, substrates, and cover were measured at various points that defined cell boundaries along each transect. Although cover was measured, it was not used in the model. Stationing across transects was oriented with 0.0 on the left bank looking upstream for modeling purposes. Depths were measured using a top-setting wading rod. Streambed elevations and water depths were measured to the nearest 0.1 ft. Mean column water velocity was measured to the nearest 0.1 ft/sec using a Marsh McBirney Flo-Mate 2000 velocity meter attached to the wading rod. Substrate and cover for PHABSIM were visually assessed using a system developed by EA Engineering (1991b) and Raleigh et al. (1986) (Table 8). A temporary staff gage was installed at each site so that fluctuations in WSL could be monitored during data collection.

Table 8 Lemhi Sub-basin instream substrate and cover coding system.[1]

Code	SUBSTRATE	diameter (in)	diameter (mm)
1	Detritus	organic matter	
2	Silt	<0.0024	0-0.062
3	Sand	0.0024 - 0.125	0.062-3.2
4	Small Gravel	0.125 – 1.0	3.2-25
5	Coarse Gravel	1-3	25-76
6	Cobble	3-10	76-256
7	Boulder	>10	>256
8	Bedrock		
9	Aquatic Veg		
	COVER		
1	Woody debris		
2	Undercut	undercut bank	
3	Cobble/Boulder	(>3")	
4	Aquatic vegetation		
5	Large gravel	(2-3")	
6	Canopy	canopy or overhead structure	
7	Emergent vegetation		
8	No cover		

[1] Sources: EA Engineering (1991b); R2 Resource Consultants (2004); Raleigh et al. (1986)

Velocity calibration sets were collected at three different time periods between June and September, 2004 in an attempt to cover a range of flows.

Additional transect-specific data (i.e., flow and water surface elevations) were also collected during each of the velocity surveys at each site. These stage-discharge measurements provided the data necessary for model calibration. The applicability of the range of flows simulated to actual flows in the stream was dependent on the flows measured.

4.1.4 Habitat Suitability Criteria (HSC)

Species HSC are required for PHABSIM analyses. Habitat suitability criteria, or suitability curves, are interpreted using a suitability index (SI) on a scale of 0 to 1, with 0 being unsuitable and 1 being most utilized or preferred. Habitat suitability criteria that accurately reflect the habitat requirements of the life stages of interest are essential to developing meaningful and defensible instream flow recommendations. The recommended approach is to develop site specific criteria for each species and life stage of interest. An alternative approach is to use existing curves and literature to develop suitability criteria for the life stages of interest. No site-specific HSCs are available in the Lemhi River sub-basin and time and budgetary constraints precluded developing HSCs specific to Hawley Creek and Eighteenmile Creek. While such information may become available in the future through a separate study, HSC information was derived from previous Snake River Adjudication work by the Bureau of Indian Affairs (BIA) and USFS in the Salmon River Basin (EA Engineering 1991b; R2 Resource Consultants 2004; Rubin et al. 1991). Initially, upon review of this information, the Interagency Technical Workgroup (see "Acknowledgments" for list of members) recommended Reclamation to target the ESA-listed species bull trout, Chinook salmon, and steelhead trout for juvenile, adult, and spawning life stages. Results of the juvenile life stage (50-100 mm) modeling are not included in this report because of questionable HSCs that were developed during drought conditions (Rubin et al. 1991) and the potential inability to accurately measure microhabitat parameters at a scale that would be meaningful using PHABSIM. Until juvenile habitat modeling, including appropriate HSCs, can be improved, modeling results for the juvenile life stage will not be included in this report. To address food resources of salmonids, macroinvertebrate HSCs from Gore et al. (2001) were used to assess habitat for aquatic macroinvertebrates. Low gradient (<0.005 slope) macroinvertebrate HSCs were used.

4.1.5 Hydraulic Model Selection and Calibration

Reclamation used the USGS Windows version of PHABSIM (Waddle 2001). PHABSIM has several submodels available for hydraulic simulations. These include STGQ, WSP, and MANSQ (Waddle 2001), with STGQ being the most rigorous in terms of data requirements. Each hydraulic model requires multiple flow measurements for model calibration. Depending on model performance and site conditions, the predictive range may be restrictive, or wide ranging (i.e., 0.1 to 10 times the measured discharges) (Waddle 2001). Since water is diverted between April 1 and September 30 of each year for irrigation, the range of flows for the hydraulic simulations covered flows that typically occur during these months.

Field sampling was designed to collect data in formats suitable for application in any of the hydraulic models identified above. The following approach was used:

- Enter field data into appropriate format for water surface simulations
- Calibrate STGQ, MANSQ, or WSP (depending on site specific conditions) to measured WSL
- Document calibration procedure
- Simulate a range of flows to predict water surface elevations
- Simulate depths and velocities for range of flows that occur during the irrigation season
- Evaluate simulation range based on velocity adjustment factors (VAF's) and other calibration sub-models
- Document acceptable range of simulations
- Conduct velocity simulation production run for applicable range of flows that may occur during the irrigation season.

4.1.6 Habitat Modeling

Table 9 shows various life stages and variables used to describe microhabitat. Since the velocity HSC for adult bull trout was developed for nose velocities at 0.2 feet off the stream bottom (EA Engineering 1991b), the nose velocity option in the habitat model was used for this life stage of bull trout.

Table 9 Life stages for species of interest and microhabitat variables used to describe habitat.

Life Stage	Depth	Velocity	Substrate
Adult passage	X		
Adult	X	X	X
Adult spawning	X	X	X

The following example describes how habitat weighting factors (WF) were determined. In an example study site that had five cross sections: one deep run, three shallow runs, and one moderate gradient riffle. Within this example site, based on example habitat mapping percentages, the three shallow runs represented 340 ft (34%), the moderate gradient riffle 540 ft (54%), and the deep run represented 120 ft (12%) of a 1,000 ft idealized reach. The shallow run distance of 340 ft was divided equally by three (113', 113', and 114') to represent the three shallow runs at the example study site. Both the deep run and moderate gradient riffle distances remained the same. Weighting factors of 0.00-1.0 were calculated for each cross section to accurately represent the entire stream reach (Table 10).

Table 10 Example of setting cross section weighting factors for habitat modeling.

Cross section	Habitat type	Distance from previous cross section (ft)	Weighting factor
1	Riffle	0	1.0
2	Shallow run	540	1.0
3	Shallow run	114	1.0
4	Shallow run	113	0.48
5	Deep run	233	0.0
Total		1,000	

An assigned WF of 1.0 moved upstream, and an assigned WF of 0.0 moved downstream, or backwards from the cross section. Weighting factors greater than 0.0 up to 1.0 moved the habitat upstream in proportion to the value assigned. For instance, the X-sec 1 WF of 1.0 applied continually upstream to X-sec 2, the entire 540 ft. The same applied to X-sec 2 and 3. The final cross section was handled differently. Essentially, it was combined into one unit, and assigned two WFs to complete the study site. The distances of X-sec 4 and 5 were combined (113+120) for a total distance of 233 ft. The formula below was used for attaining a WF:

$$233(x) = 113$$

$$X = 113/233 = 0.48$$

where X represented the unknown WF, 233 ft was the combined distance (X-sec 4 & 5), and 113 ft was the distance of X-sec 4.

The WF of 0.48 applied the habitat weighting 48% upstream to represent the final run. A weighting factor of 0.0 applied the habitat weighting of the remaining area, or 52% downstream from cross section 5. Figure 10 illustrates this procedure.

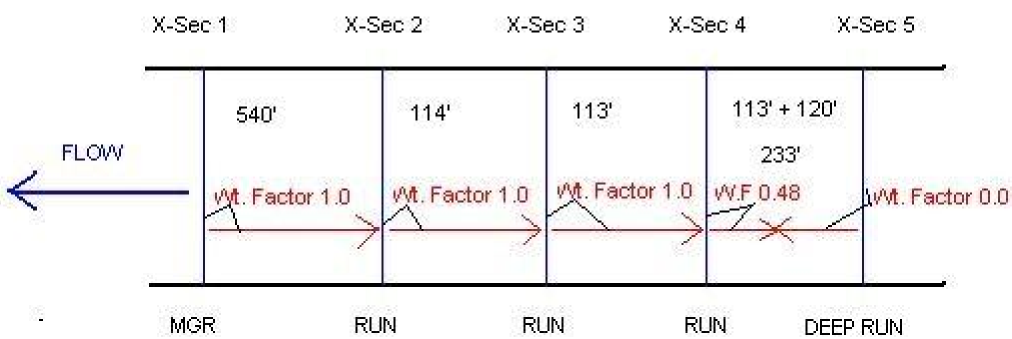


Figure 10 Example of weighting factor assignments at a PHABSIM study site.

If there was a HC cross section anywhere in the site it would not affect the habitat weighting. As for the distances (from previous cross section), the cross section immediately upstream from the HC would have a distance of '0 ft'; canceling out the HC in the model. For example, the distances and WF for the cross sections at another example study site are listed in Table 11.

Table 11 Example of setting cross section weighting factors for habitat modeling with hydraulic controls.

Cross section	Habitat type	Distance from previous cross section (ft)	Weighting factor (WF)
1	Run	0	1.0
2	Hydraulic Control (HC)	55	1.0
3	Pool	0	1.0
4	Pool	170	1.0
5	HC	170	1.0
6	Pool	0	1.0
7	Riffle	170	0.87
8	Run	435	0.0
Total		1,000	

Weighted usable area (WUA) within each representative stream reach was calculated for each discharge of interest for each species. Weighted usable area is an index of habitat availability or quantity for the selected species/life stage at each simulated flow. The WUA for each species was computed in the HABTAE sub-model of PHABSIM using the geometric mean option to multiply the depth, velocity, and substrate HSC values for a life stage at predicted hydraulic conditions, and cell surface area. The output from the HABTAE simulation was habitat area, expressed as WUA (ft^2/1,000 ft of stream). Weighted Usable Area was predicted for a range of discharges at the 10 study sites. For presentation purposes, WUAs were normalized as a percentage of maximum habitat. It should be noted that there is a level of uncertainty associated with the WUAs. Sources of uncertainty include errors in HSCs, hydraulic simulations, or selection of options to simulate microhabitat (e.g., geometric versus multiplicative means). Recognition that there is uncertainty in these sources is important in the interpretation and use of PHABSIM model results (Bovee et al. 1998).

4.2 Passage

Suggested passage criteria for adult Chinook salmon, steelhead trout, and bull trout followed guidelines adopted by Oregon Department of Fish and Wildlife and taken from Thompson (1972) and Scott et al. (1981) (Table 12). To determine the recommended flow for passage, shallow bars most critical to passage of adult fish were located, and a linear transect was measured which followed the shallowest course from bank to bank. For each transect, a flow was computed for conditions which met the minimum depth criteria in Table 12 where at least 25% of the total transect width and a continuous portion equaling at least 10% of its total width, equal to or greater than the minimum depth, was maintained (Thompson 1972). Both width criteria must be met to insure passage.

Table 12 Suggested adult salmonid passage criteria (Thompson 1972; Scott et al. 1981).

Species	Minimum Depth (ft)	Maximum Water Velocity (ft/sec)
Steelhead Trout	0.6	8.0
Chinook Salmon	0.8	8.0
Bull Trout	0.4	4.0

4.3 Flow Recommendations Using PHABSIM

The NMFS draft protocol estimates idealized annual flow schedules for Pacific and interior northwest streams (Arthaud et al. 2001). The protocol identifies objectives for deriving minimum flow conditions necessary to protect sensitive salmonid life stages that can be quantified using PHABSIM methodologies. Results from this study can be used to help determine target flow objectives to improve passage, spawning, and adult holding conditions for salmon, steelhead, and bull trout. Table 13 provides suggested critical life stage assignments for each stream in this study which could be used to determine target flows from the PHABSIM analysis. This information was obtained through a survey of local biologists familiar with fish species of interest in these streams (J. Spinazola, Reclamation, written communication, January 12, 2005).

Table 13 Suggested critical life-stage assignments for applying flow recommendations in selected streams.

Stream	Steelhead	Chinook salmon	Bull trout
Hawley Creek	None	None	All life stages
Eighteenmile Creek	None	None	All life stages

5.0 RESULTS AND DISCUSSION

Results of the PHABSIM analysis are summarized for each stream in separate sections below. Written descriptions and photos of each selected study site are provided in Appendix A. Habitat mapping proportions are presented in Appendix B. Cross-sectional profiles, longitudinal profiles, and measured WSLs are illustrated in Appendix C. Hydraulic model calibration results are summarized in Appendix D. Simulated WSLs were within 0.055 ft or better of measured WSLs for all transects (Appendix D). The ability to simulate higher flows at some Hawley Creek and Eighteenmile Creek sites was restricted due to lack of higher calibration streamflows and simulation of high flows predicting water overflowing the banks and/or flowing ‘uphill’ regardless of model manipulation. In these circumstances, flows were simulated upward until bank full depths were achieved or until water started flowing ‘uphill’. Habitat suitability criteria (HSCs) are presented in Appendix E. Complete habitat modeling output results (i.e., WUA vs discharge and passage assessments) are summarized in Appendix F for each stream reach.

5.1 Hawley Creek

Measured discharges and dates of field surveys are summarized in Table 14. Low, medium, and high flow measurements were attempted during the irrigation season at most sites downstream from the reference site (Study Site 4). In most cases, only medium and low flow conditions were measured because most of the high flows were diverted for irrigation. However, medium and low flows typically occur during the summer irrigation season when diversions are normally operating. The most downstream site (Study Site 1) was completely dewatered on March 22, 2006 for the remainder of the season for irrigation purposes, cutting off the majority of any possible fisheries habitat.

Table 14 Discharges measured from highest to lowest at Hawley Creek study sites during field surveys in 2006.

Stream Site	Discharge (cfs)	Survey Dates
Study Site 1	14.1 cfs	March 21
	0.5 cfs	March 22
Study Site 2	10.8 cfs	June 06
	8.7 cfs	September 12
	7.2 cfs	July 11
Study Site 3 (Diversion)	3.6 cfs	July 11
	2.9 cfs	June 07
	2.6 cfs	September 12
Study Site 4 (Reference)	19.1 cfs	June 06
	12.9 cfs	July 11
	10.7 cfs	September 12

Graphical representations of final normalized WUA versus discharge relationships are presented in Figures 11-26 for each site. Passage flow results for total and contiguous widths at depths greater than the passage criteria (Table 12) are illustrated in Figures 27-30. Summary results, including flows required for optimal (i.e., maximum) WUAs and flows needed to meet the 0.6 feet deep passage criteria are presented in Table 15. Summary results reflected differences in stream channel hydraulics among study sites. In addition to the issues discussed above, the lack of higher calibration streamflows for some sites (e.g., Study Sites 4, and 5) limited model performance and prevented habitat simulation at higher discharges, resulting in many “>” values in Table 15.

Flows that produced optimal habitat ranged from 5 cfs for bull trout adult at Study Site 3 to over 30 cfs for bull trout adult at Study Site 2 (Table 15). Minimum discharge required for adult salmonid passage using 0.6 foot depth criterion ranged from 5 to 15 cfs at Study Sites 1 and 2, respectively.

Study Site 3 was located in a diversion ditch that from the late 1800s until 2005, served as a year round diversion and the stream channel. In 2005, an earthen berm was removed and a structure was installed that allows for the seasonal closure of the ditch and winter diversion of water back into the seasonally dewatered, historic stream channel. Establishment of Study Site 3 was suggested to compare habitat in the former ditch/stream channel with habitat in Site 1 (Al Simpson, Reclamation, personal communication). Figures 31-35 display results for the combined species of interest at Study Sites 1 (natural channel) and 3 (diversion). Figures 31-34 represent total WUA for the study sites. Figure 35 overlays total WUA for spawning and adult bull trout at Study Sites 1 and 3 at simulated flows up to 10 cfs. When compared at 9 cfs, Site 1 had more weighted usable area (habitat) for all species and lifestages except bull trout spawning. While Study Site 3 did contain highly suitable substrate for salmon and trout spawning (cobble and gravel material), Study Site 1 included more habitat complexity that provided diversity for the species of interest and increased the availability of habitat compared to Study Site 3. Also, Study Site 1 was a larger channel and had more total surface area at any given discharge than Study Site 3. For example, at 9 cfs Study Site 1 had a wetted surface area of 17,706 ft^2/1,000 ft and Study Site 3 had a surface area of 14,295 ft^2/1,000 ft (Appendix F). However, it should be noted that Study Site 1 was dewatered to the extent of 14.1 cfs to 0.5 cfs within a period of 24 hours (Table 14) for irrigation purposes, effectively eliminating any available fisheries habitat for the remainder of the season.

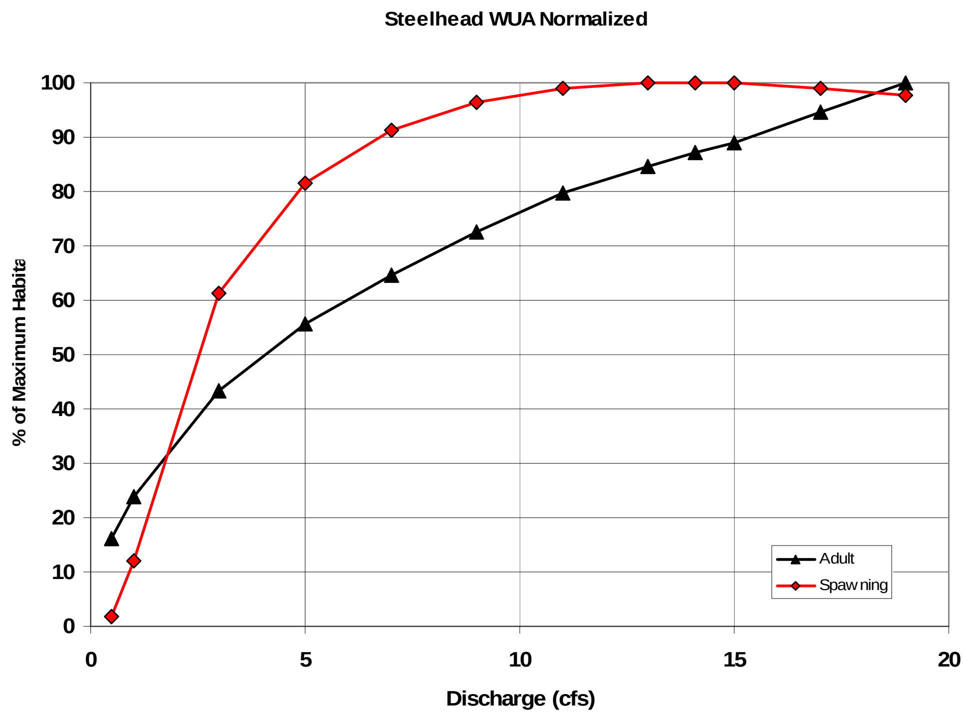


Figure 11 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Hawley Creek, Study Site 1.

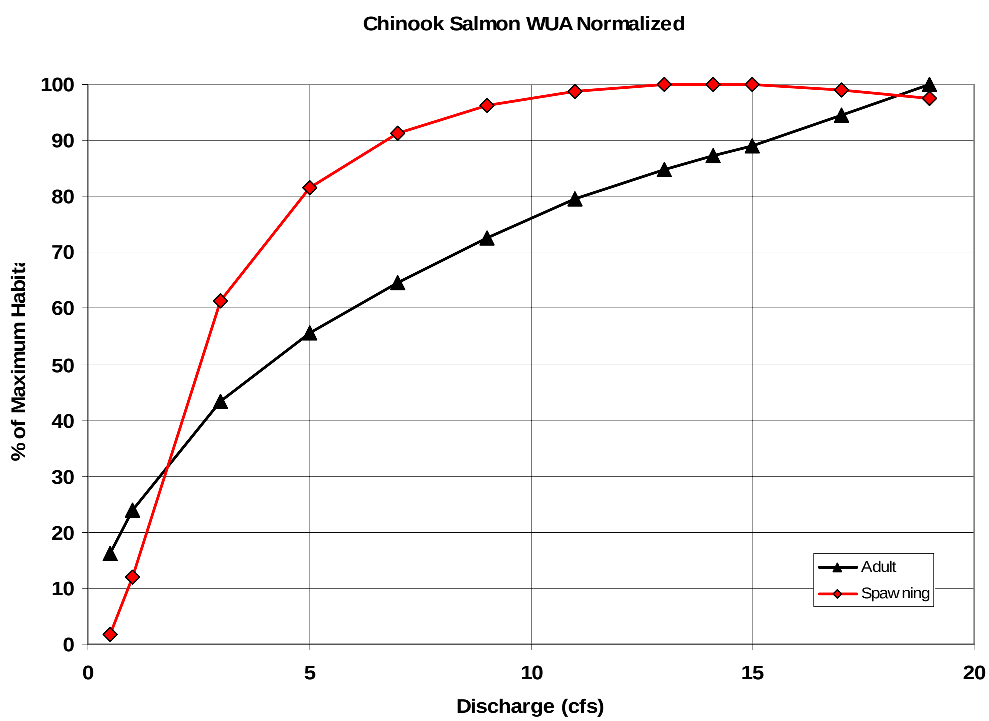


Figure 12 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Hawley Creek, Study Site 1.

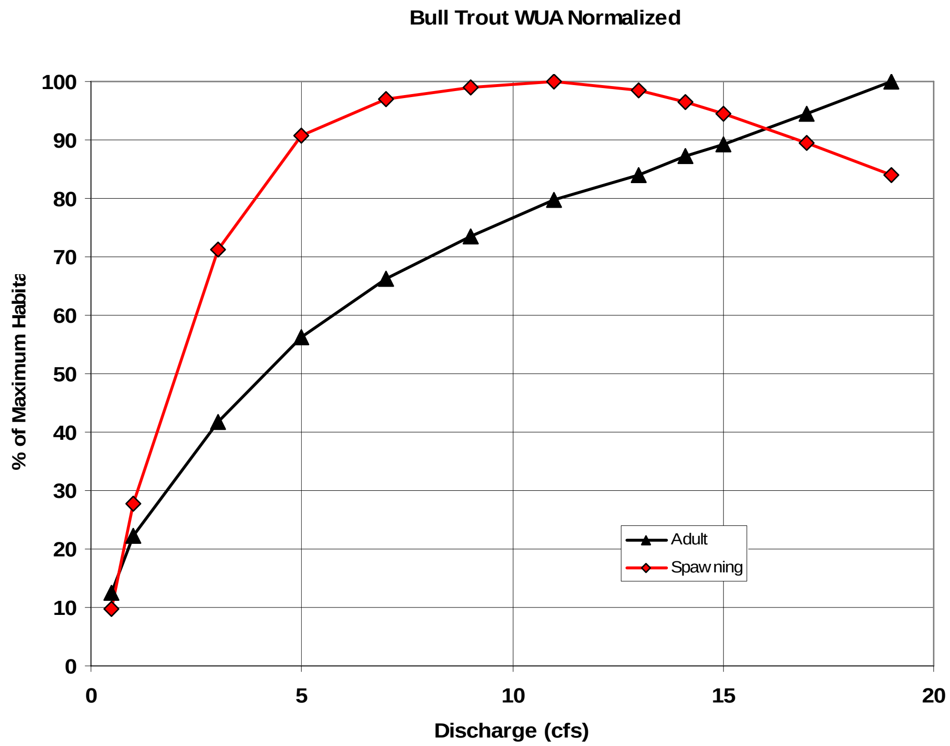


Figure 13 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Hawley Creek, Study Site 1.

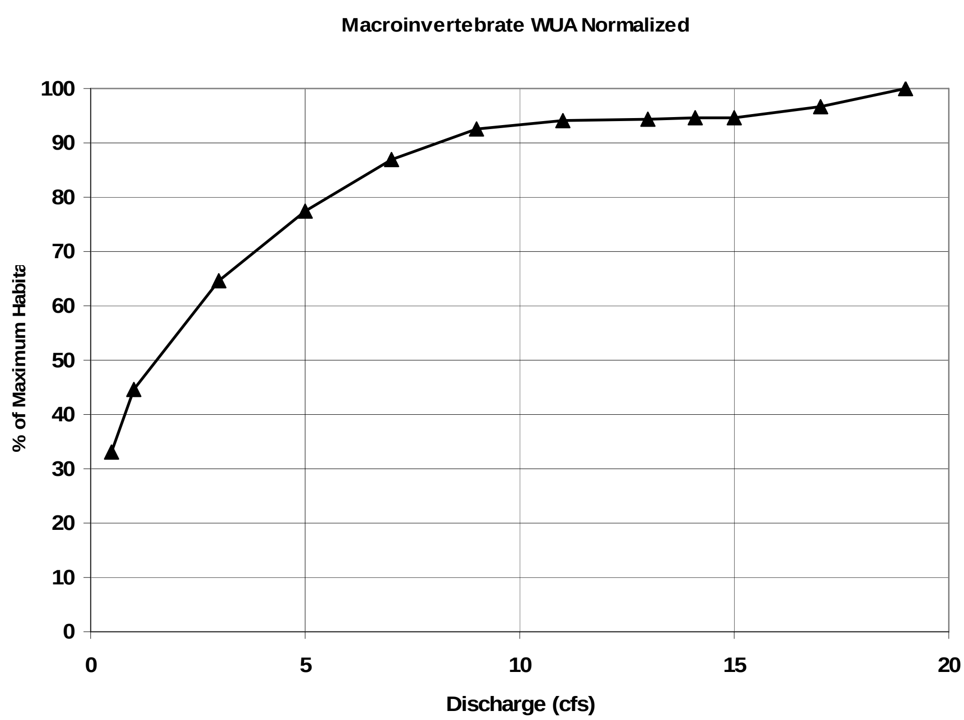


Figure 14 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Hawley Creek, Study Site 1.

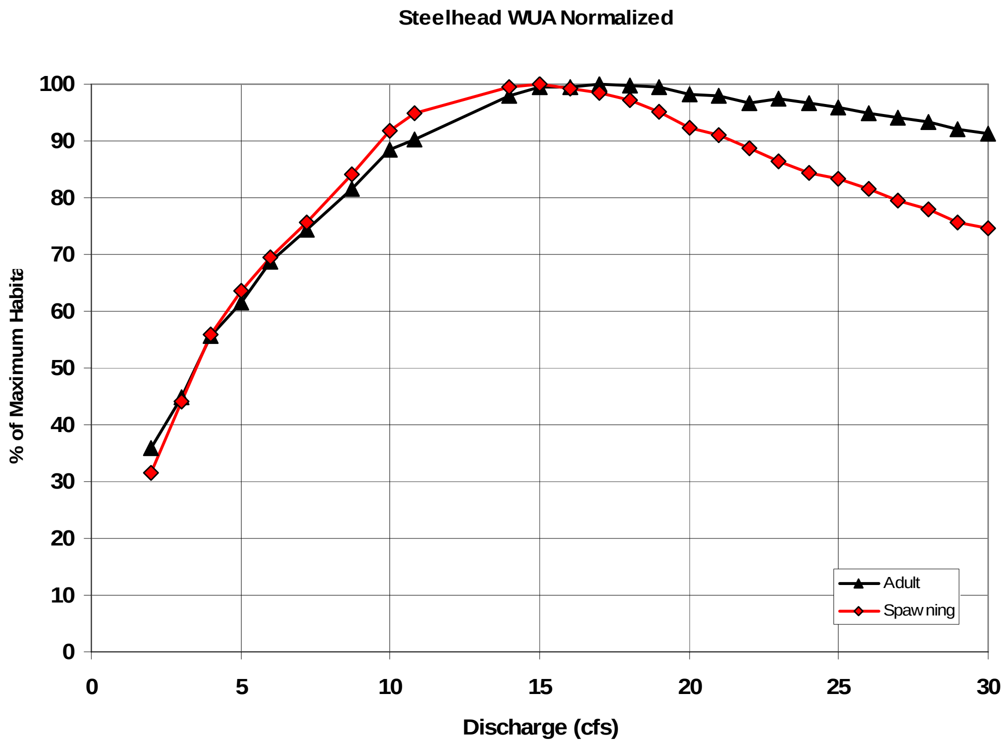


Figure 15 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Hawley Creek, Study Site 2.

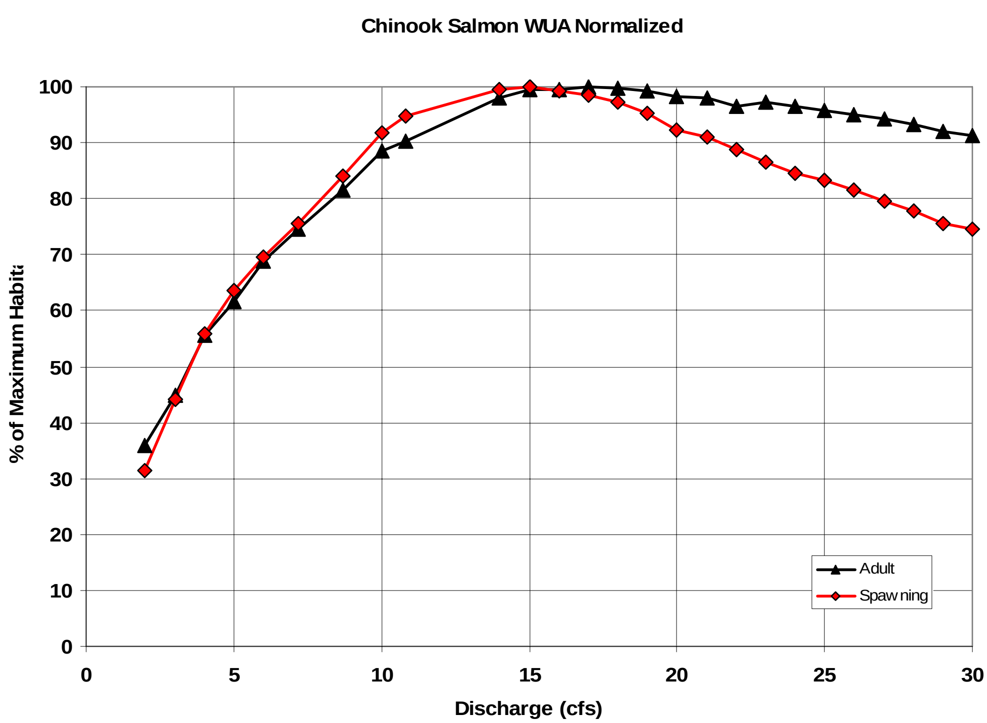


Figure 16 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Hawley Creek, Study Site 2.

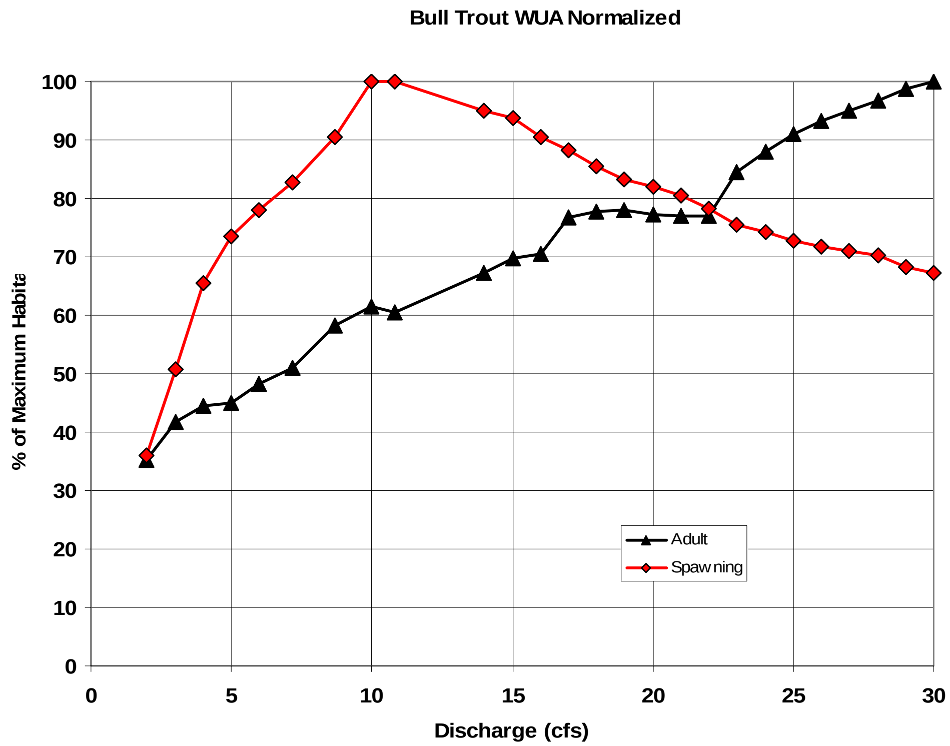


Figure 17 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Hawley Creek, Study Site 2.

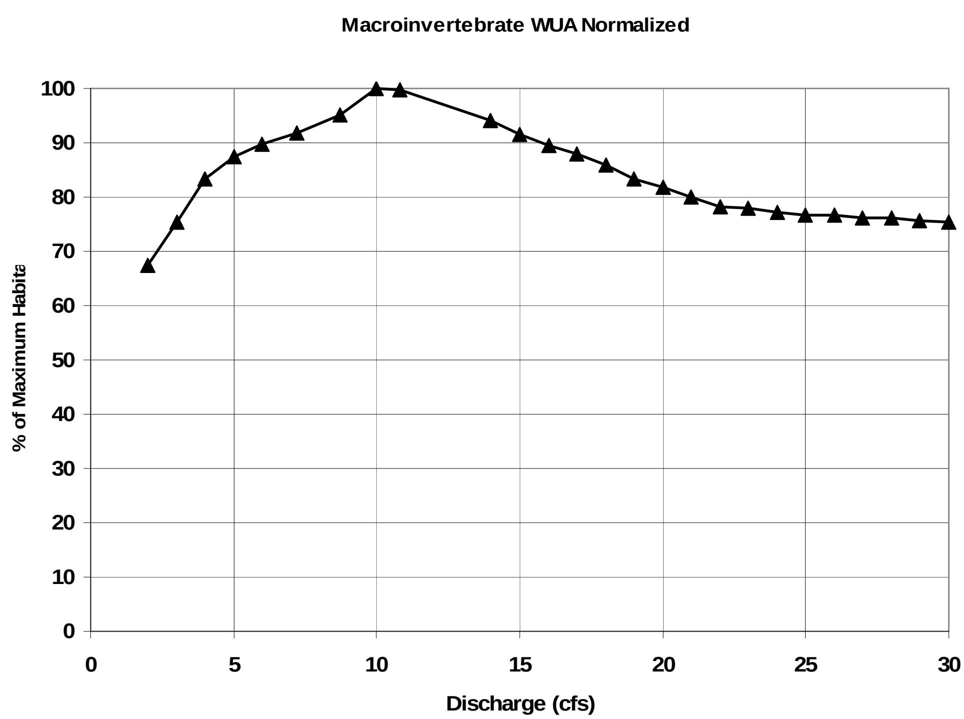


Figure 18 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Hawley Creek, Study Site 2.

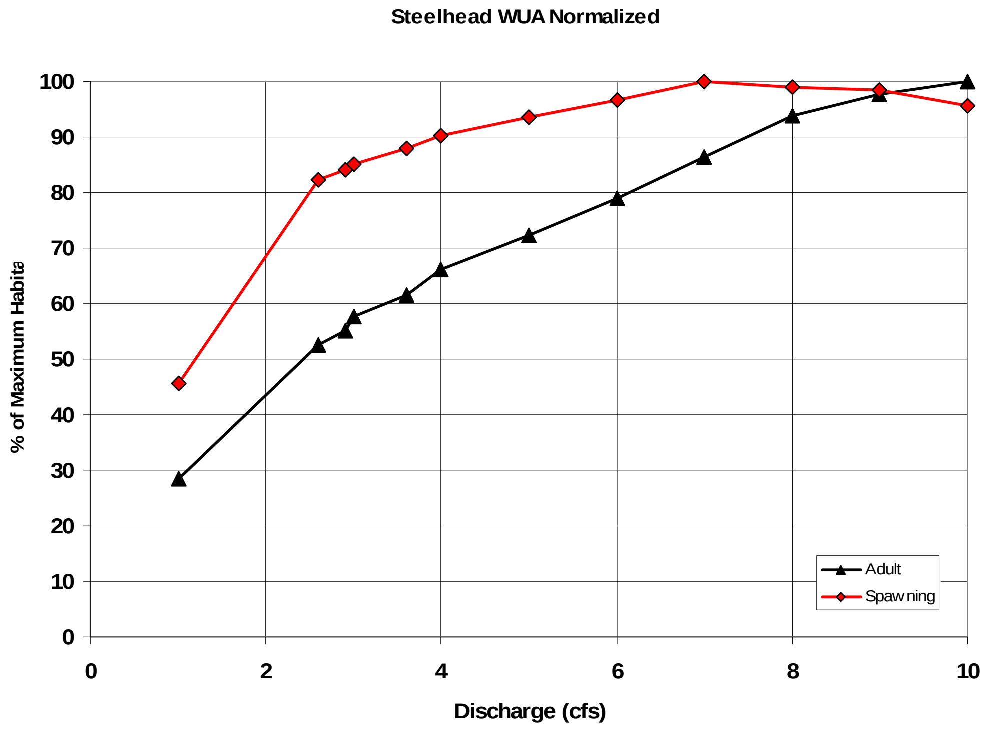


Figure 19 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Hawley Creek, Study Site 3.

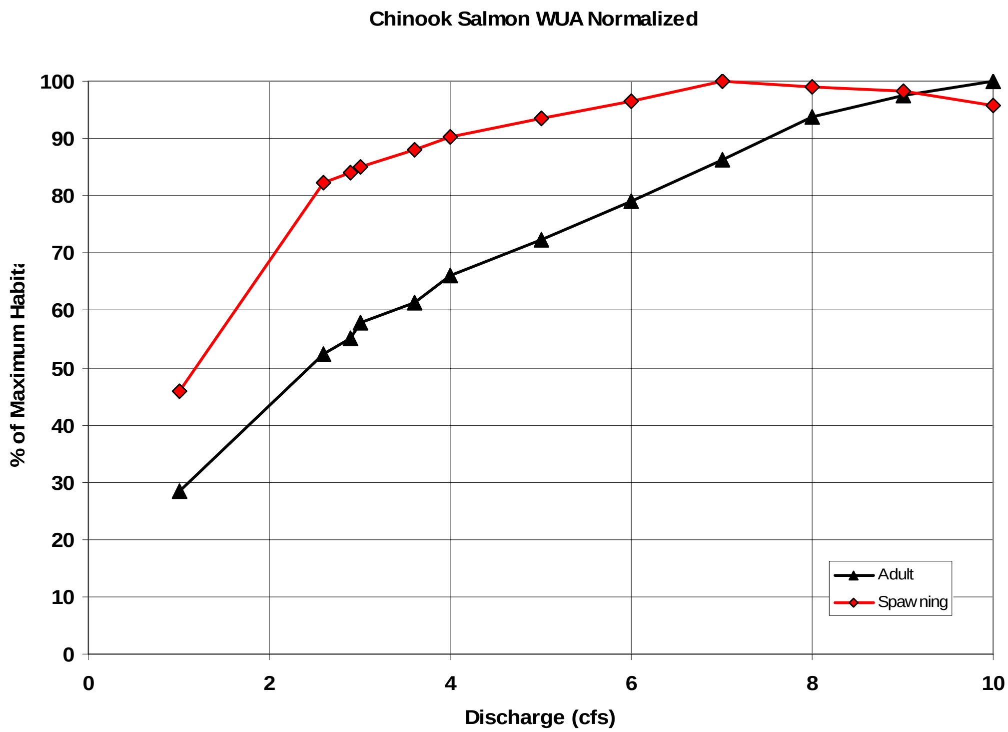


Figure 20 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Hawley Creek, Study Site 3.

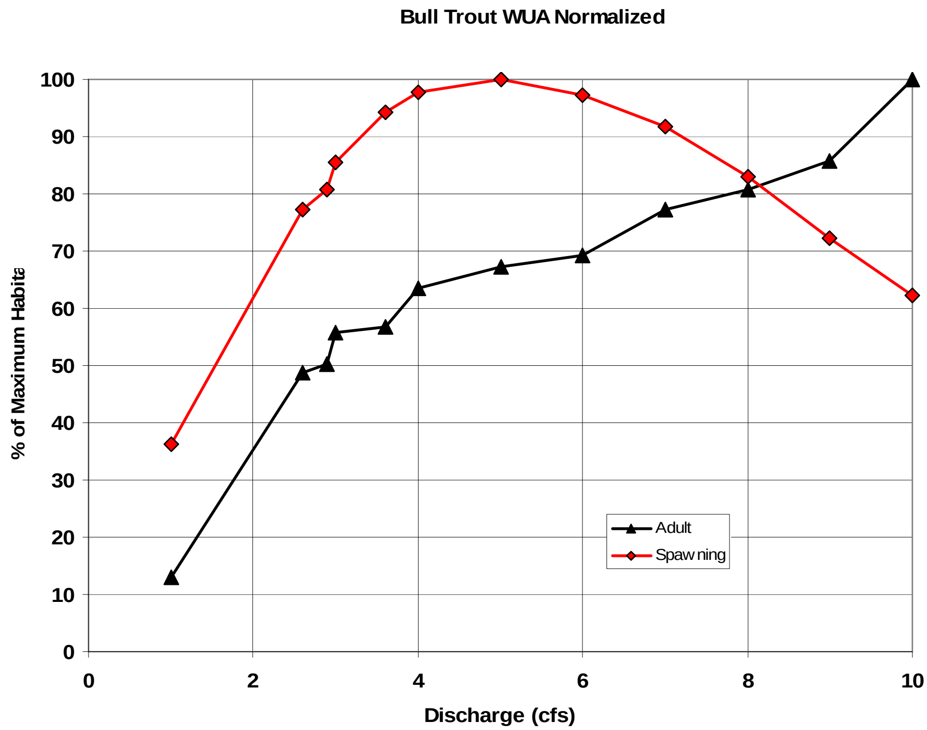


Figure 21 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Hawley Creek, Study Site 3.

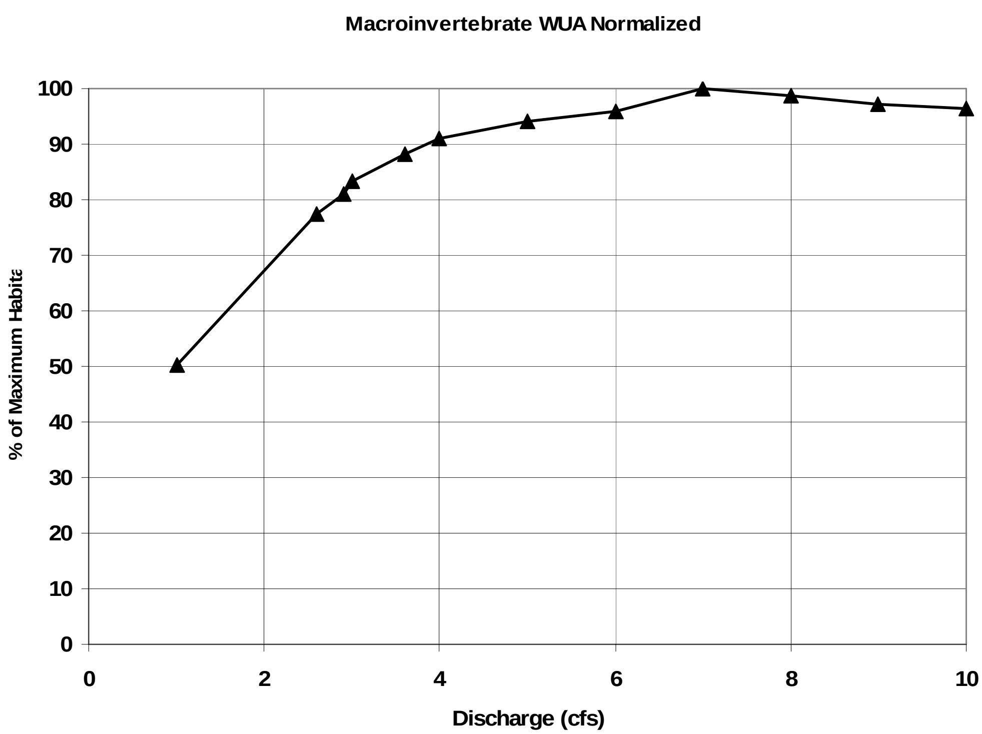


Figure 22 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Hawley Creek, Study Site 3.

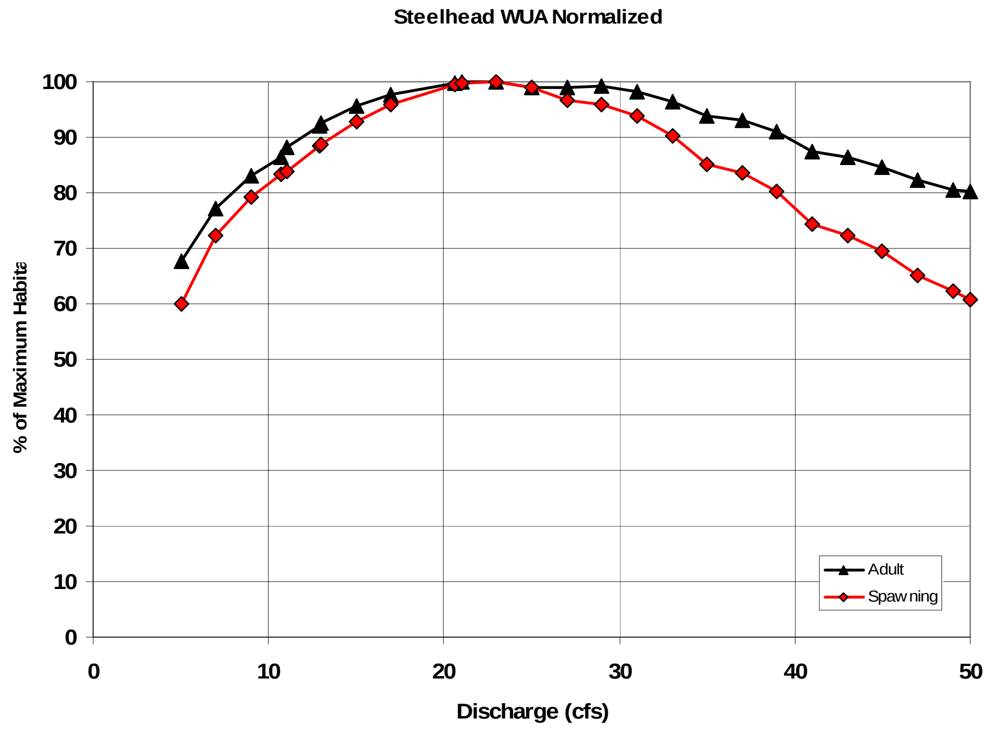


Figure 23 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Hawley Creek, Study Site 4.

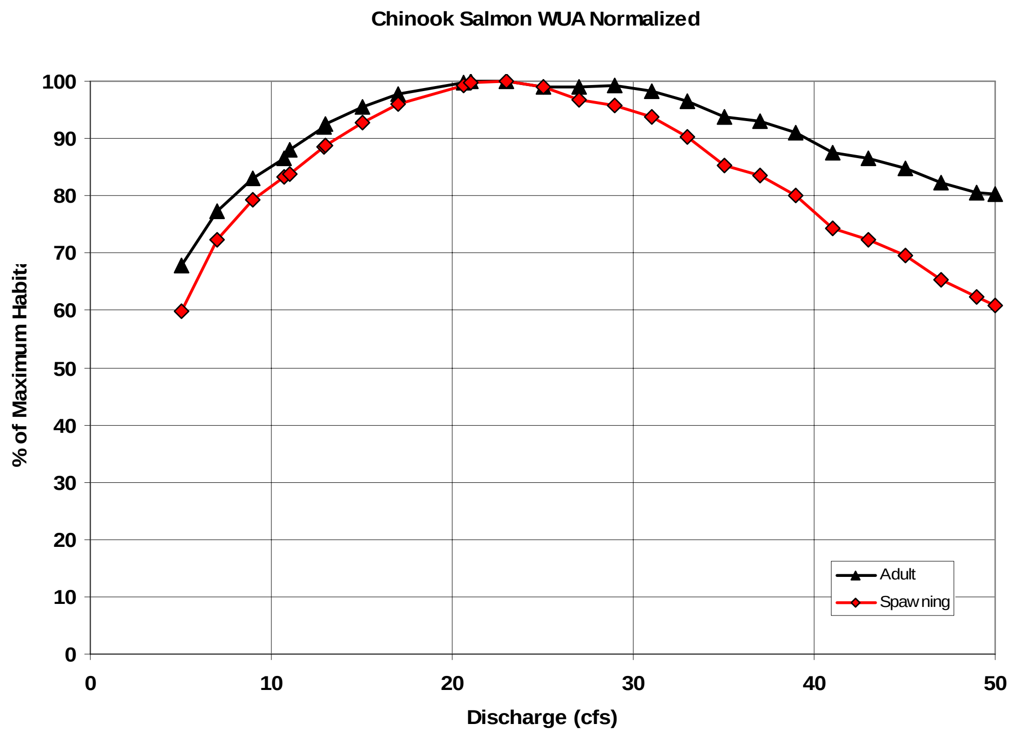


Figure 24 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Hawley Creek, Study Site 4.

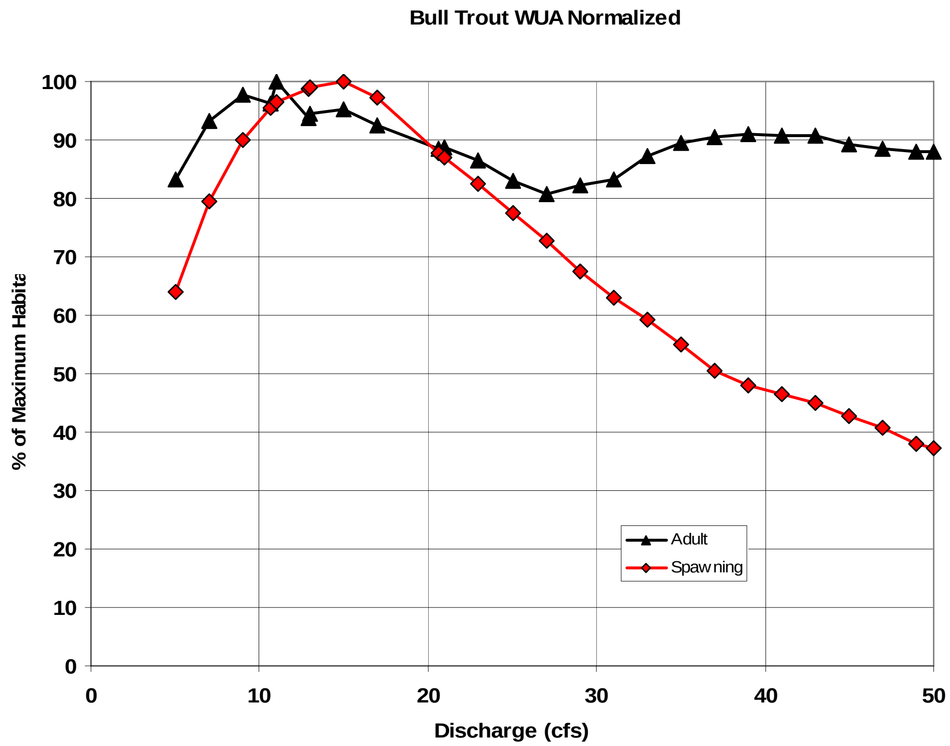


Figure 25 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Hawley Creek, Study Site 4.

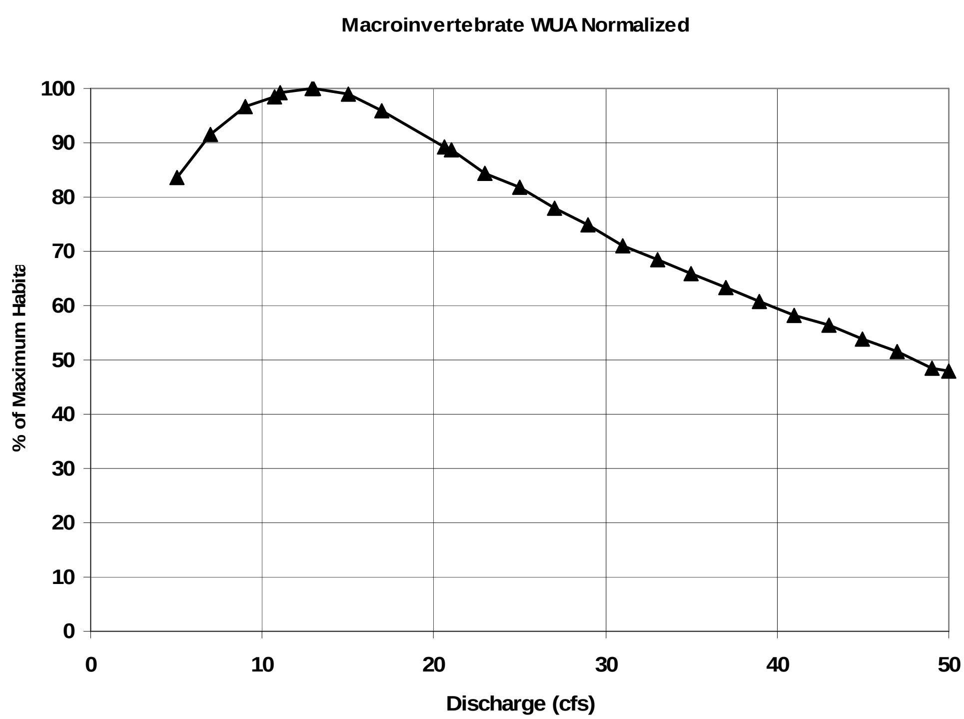


Figure 26 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Hawley Creek, Study Site 4.

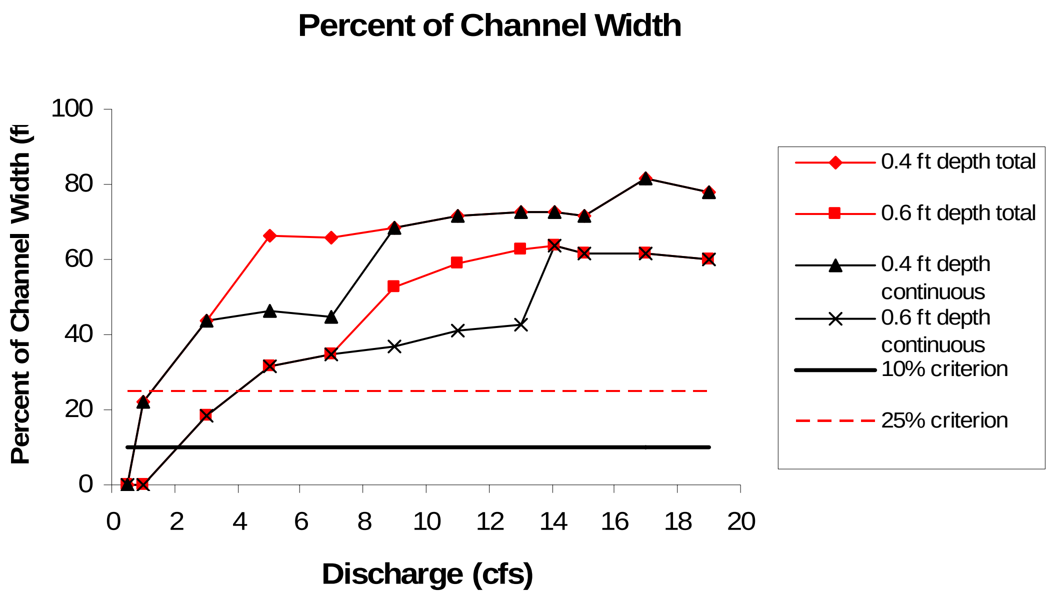


Figure 27 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Hawley Creek, Study Site 1.

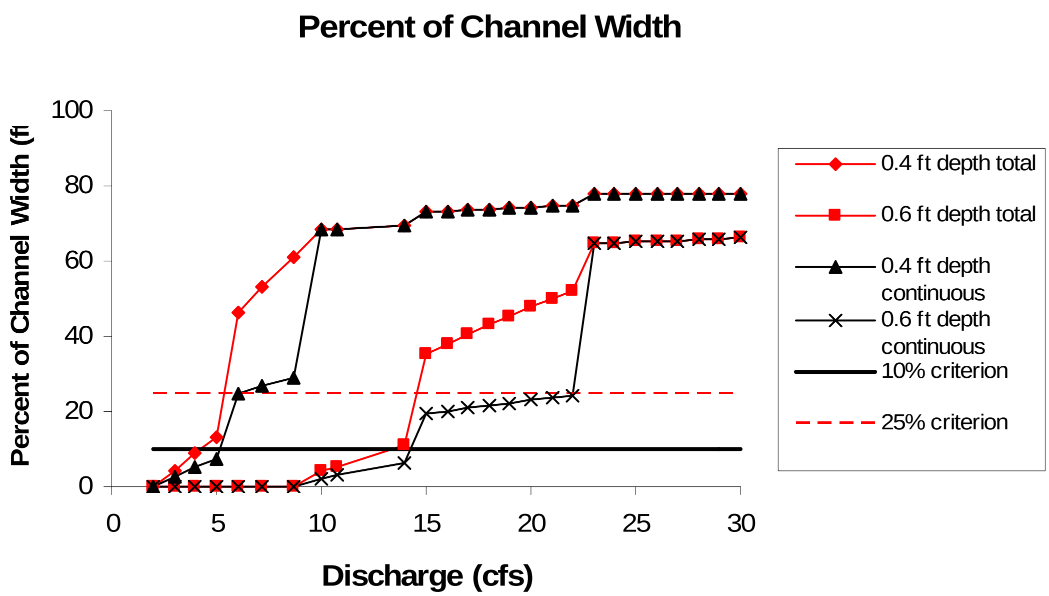


Figure 28 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Hawley Creek, Study Site 2.

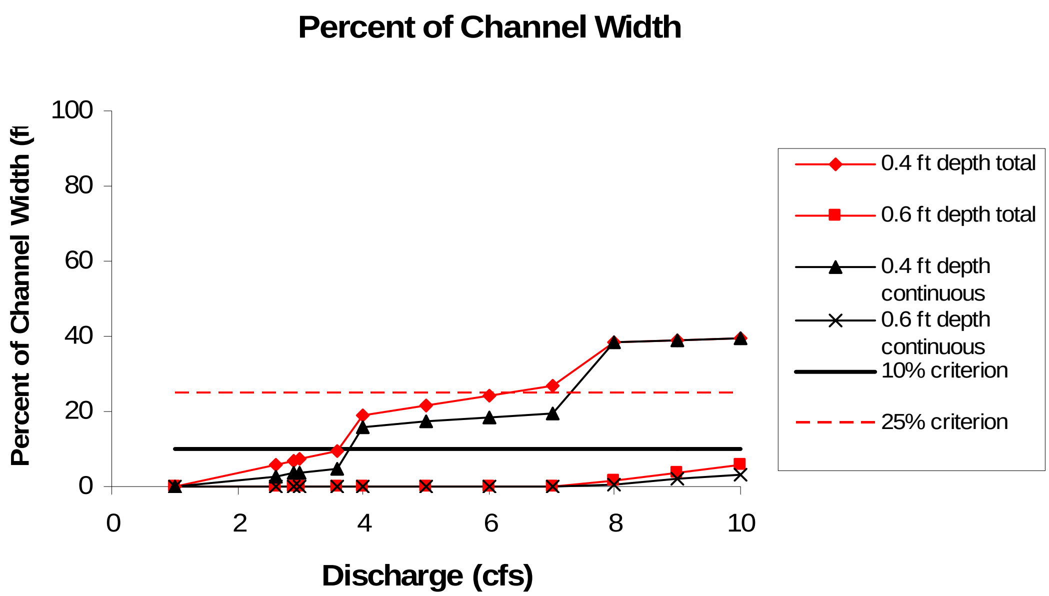


Figure 29 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Hawley Creek, Study Site 3.

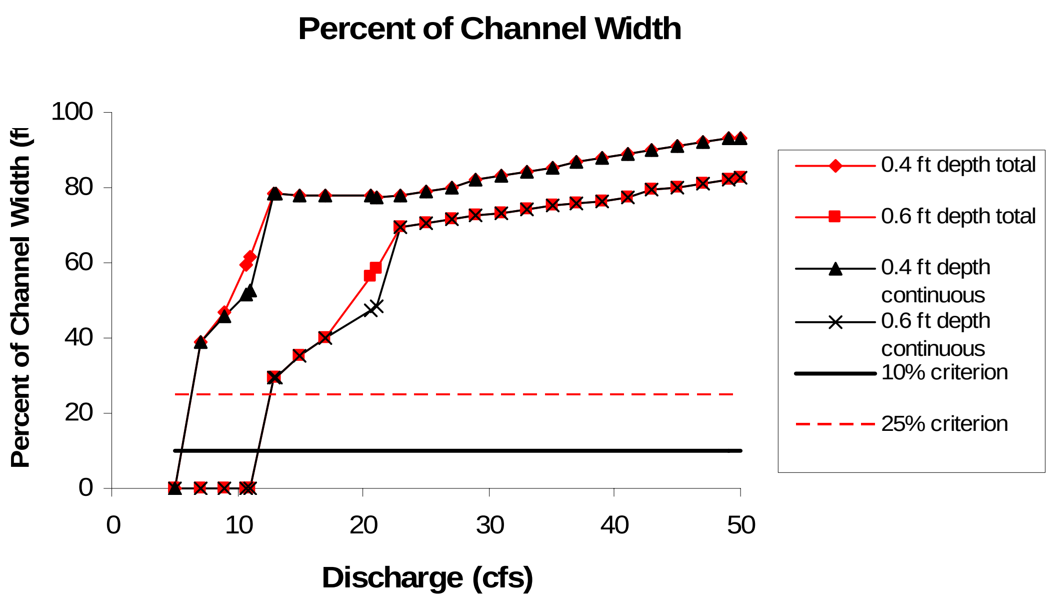


Figure 30 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Hawley Creek, Study Site 4.

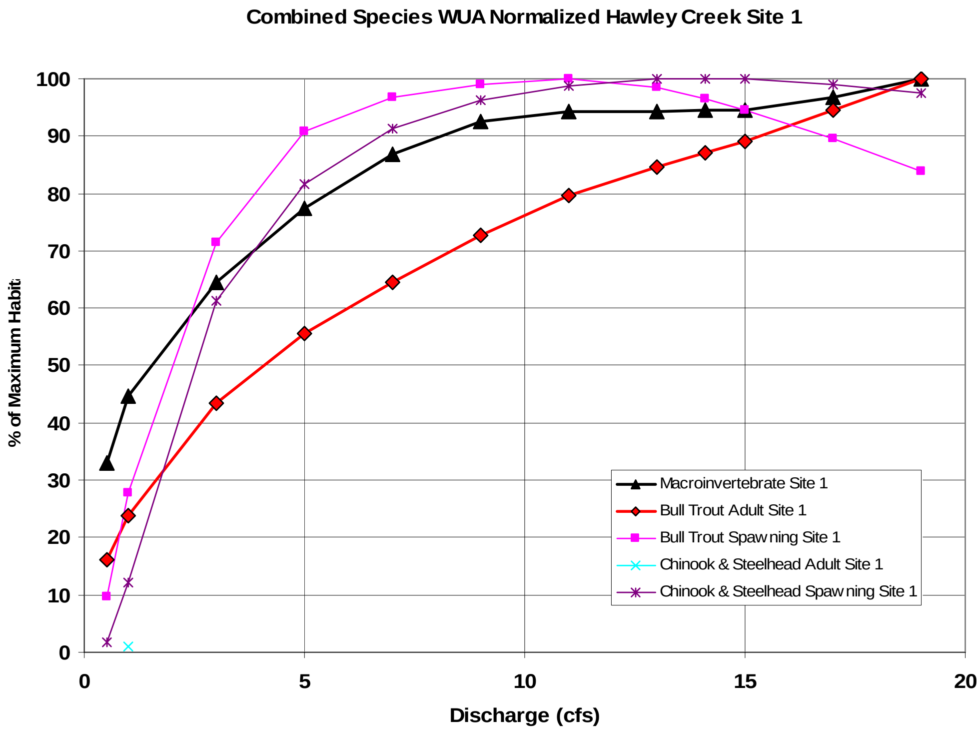


Figure 31 Combined Species Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships in Hawley Creek, Study Site 1.

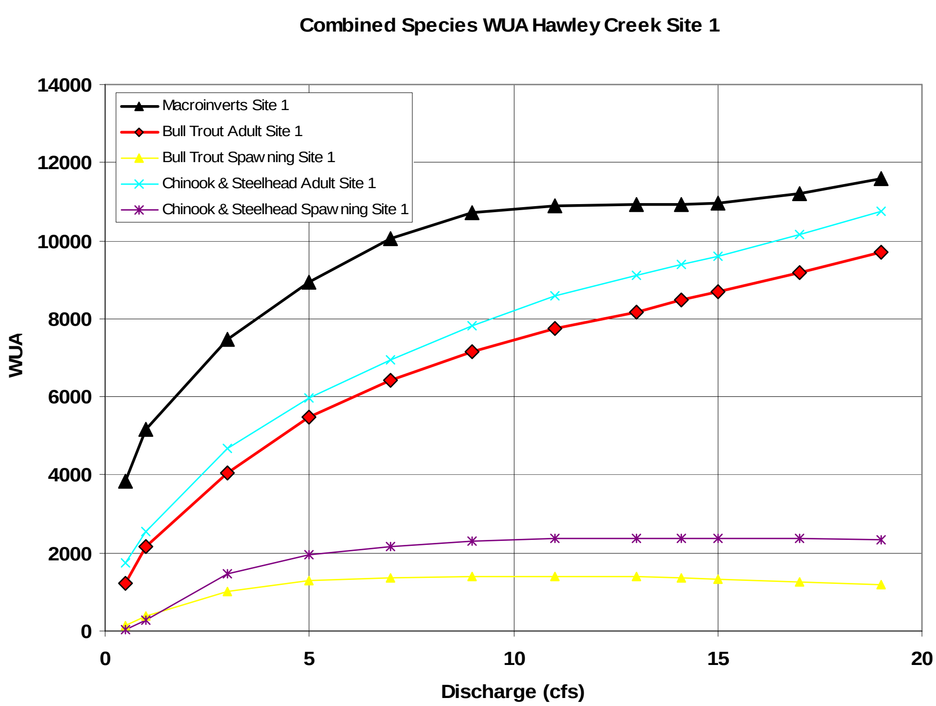


Figure 32 Combined Species weighted usable area (WUA) versus discharge relationships in Hawley Creek, Study Site 1.

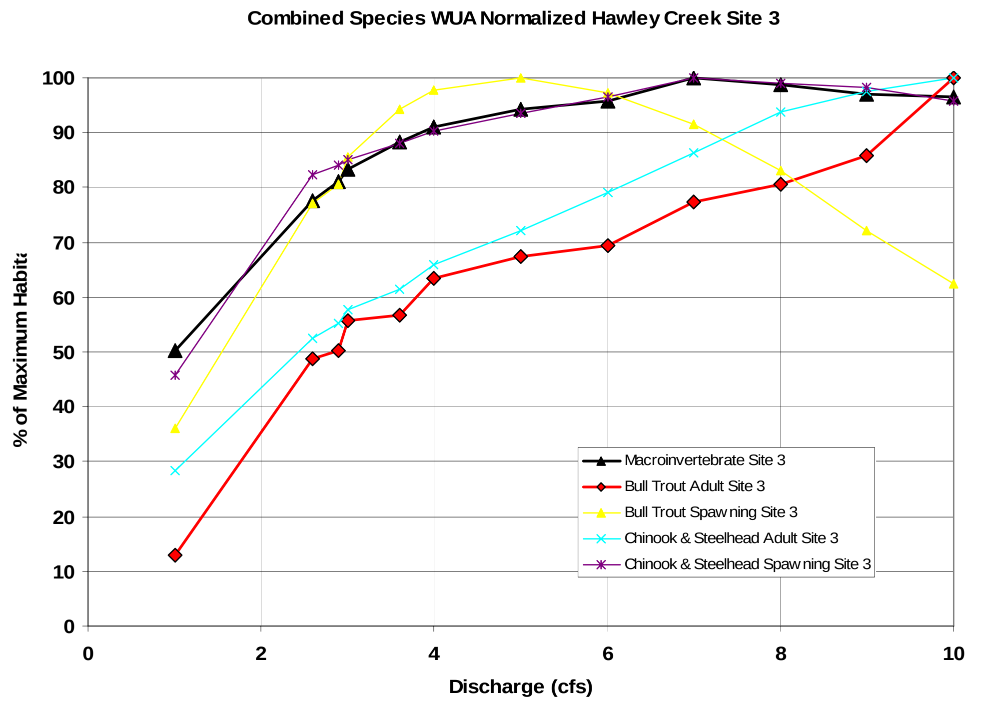


Figure 33 Combined Species Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships in Hawley Creek, Study Site 3.

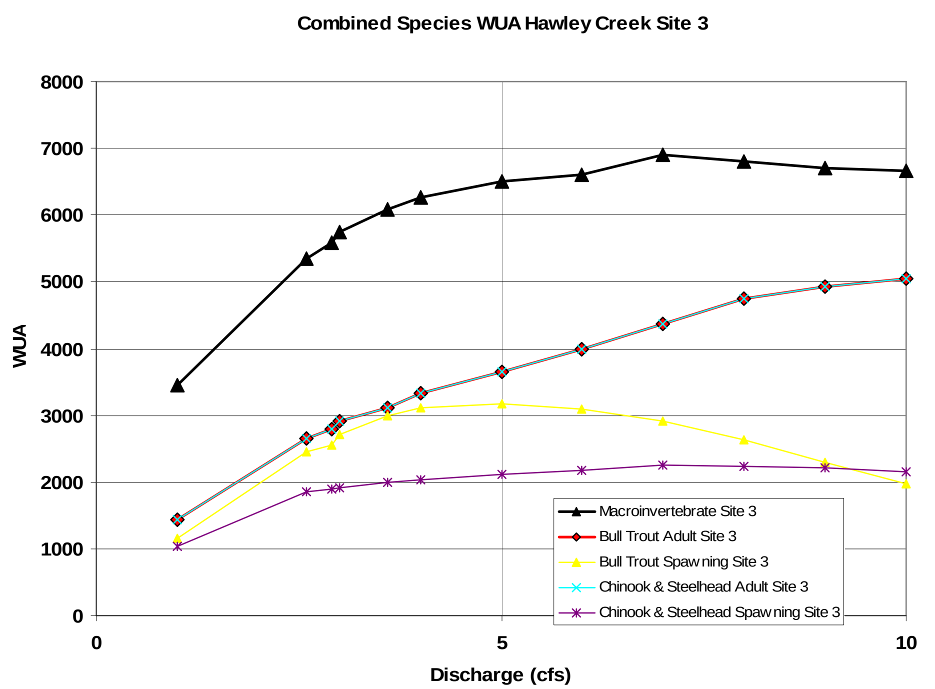


Figure 34 Combined Species weighted usable area (WUA) versus discharge relationships in Hawley Creek, Study Site 3.

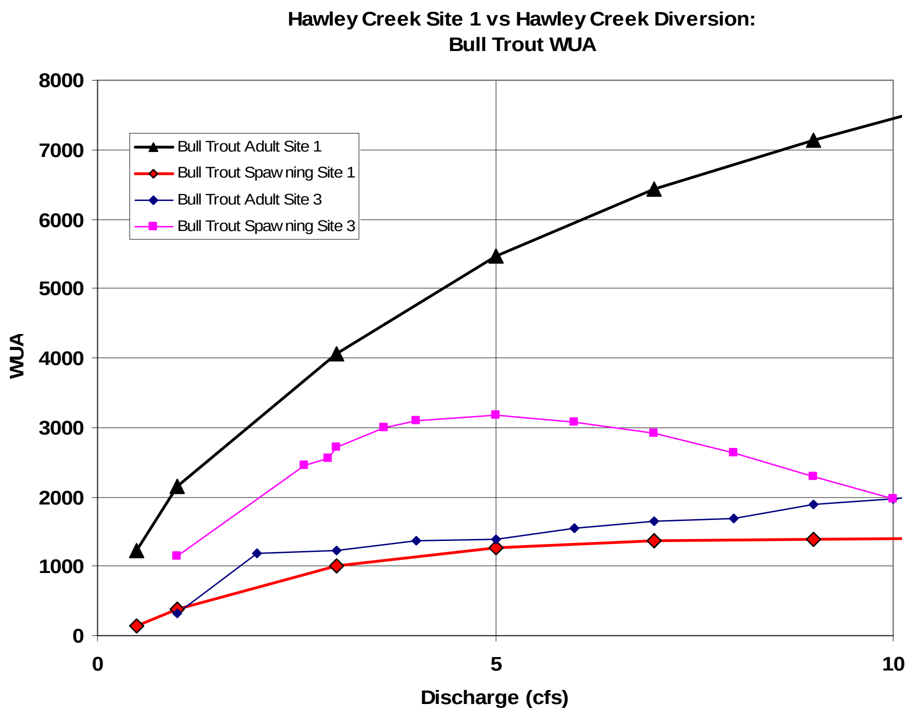


Figure 35 Combined Species (bull trout) weighted usable area (WUA) versus discharge relationships in Hawley Creek, Study Site 1 and 3.

Table 15 Habitat modeling summary on Hawley Creek.

Life Stage	Discharge (cfs) required for optimum weighted usable area (WUA)				Discharge (cfs) required for adult salmonid passage using 0.6 foot depth criterion[1]	
	Steelhead	Chinook salmon	Bull trout	Macroinvert	>25% of total channel width	>10% of contiguous channel width
Study Site 1				19		
Spawning	19	19	19		5	3
Adult	>19	>19	11			
Study Site 2				10		
Spawning	15	15	10		15	15
Adult	17	17	>30			
Study Site 3				7		
Spawning	7	7	5		>10	>10
Adult	>10	>10	>10			
Study Site 4 (Reference)				13		
Spawning	23	23	15		13	<13
Adult	23	23	11			

[1] Passage criteria taken from Thompson (1972) and Scott et al. (1981); both width criteria must be met to insure passage.

5.2 Eighteenmile Creek

Measured discharges and dates of field surveys are summarized in Table 16. Low, medium, and high flow measurements were attempted during the irrigation season at most sites downstream from the reference site in Eighteenmile Creek. In most cases, only medium and low flow conditions were measured because most of the high flows were diverted for irrigation. However, medium and low flows typically occur during the summer irrigation season with diversions.

Graphical representations of final normalized WUA versus discharge relationships are presented in Figures 36-59 for each site. Passage flow results for total and contiguous widths at depths greater than the passage criteria (Table 12) are illustrated in Figures 60-65. Summary results, including flows required for optimal WUAs and flows needed to meet the 0.6 feet deep passage criteria are presented in Table 17 and reflect differences in stream channel hydraulics among study sites. The lack of higher calibration streamflows for some sites (e.g., Study Sites 1, 3 and 4) limited model performance and prevented simulation of higher discharges, resulting in many “>” values in Table 17.

Flows that produced optimal habitat ranged from 4 cfs for macroinvertebrates at Study Site 4 to over 46 cfs for steelhead, Chinook, and bull trout adults at Study Site 6 (Table 15). The minimum discharges required for adult salmonid passage using 0.6 foot depth criterion at Study Sites 1 and 6 were 9 and 16 cfs, respectively.

Table 16 Discharges measured from highest to lowest at Eighteenmile Creek study sites during field surveys in 2006.

Stream Site	Discharge (cfs)	Survey Dates
Study Site 1	6.1 cfs	March 23
	2.5 cfs	July 12
	1.2 cfs	June 07
Study Site 2	1.7 cfs	July 12
	1.6 cfs	September 14
	0.4 cfs	June 17
Study Site 3	2.4 cfs	September 13
	2.0 cfs	July 12
	2.0 cfs	June 07
Study Site 4	2.8 cfs	June 08
	2.7 cfs	September 13
	1.8 cfs	July 12
Study Site 5	12.0 cfs	June 08
	2.3 cfs	July 12
	1.1 cfs	September 13
Study Site 6 (Reference)	29.3 cfs	June 09
	6.1 cfs	July 13
	2.0 cfs	September 13

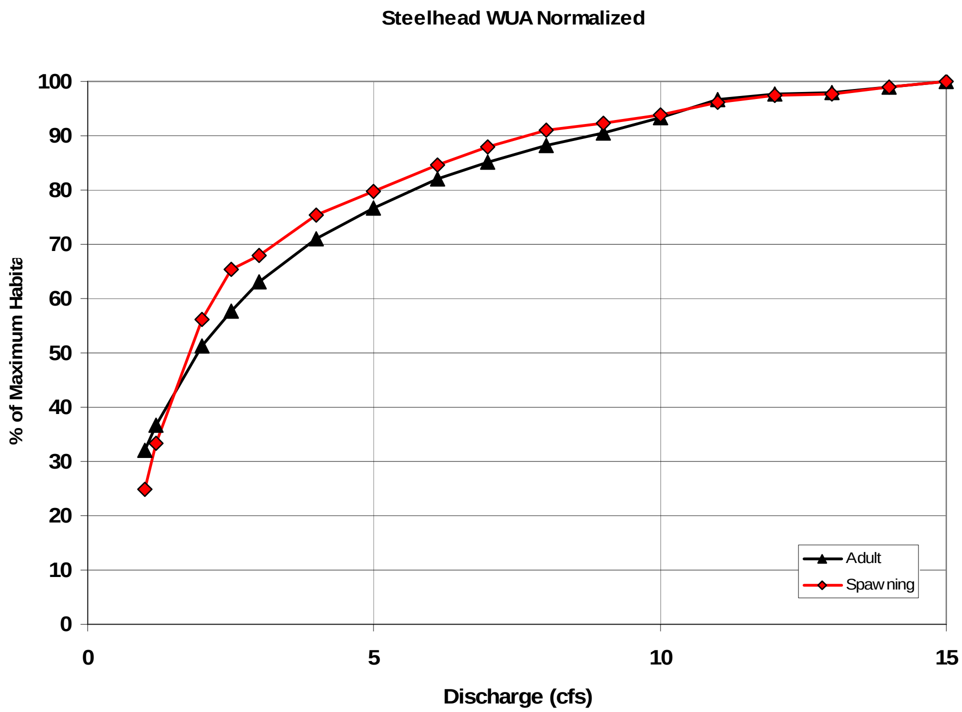


Figure 36 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Eighteenmile Creek, Study Site 1.

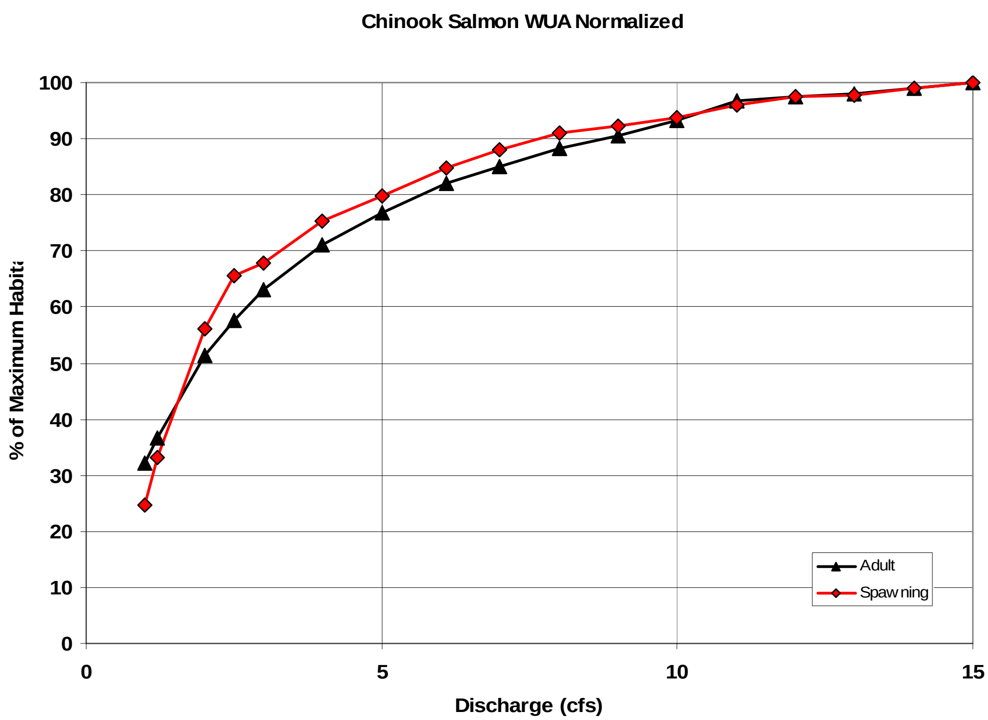


Figure 37 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Eighteenmile Creek, Study Site 1.

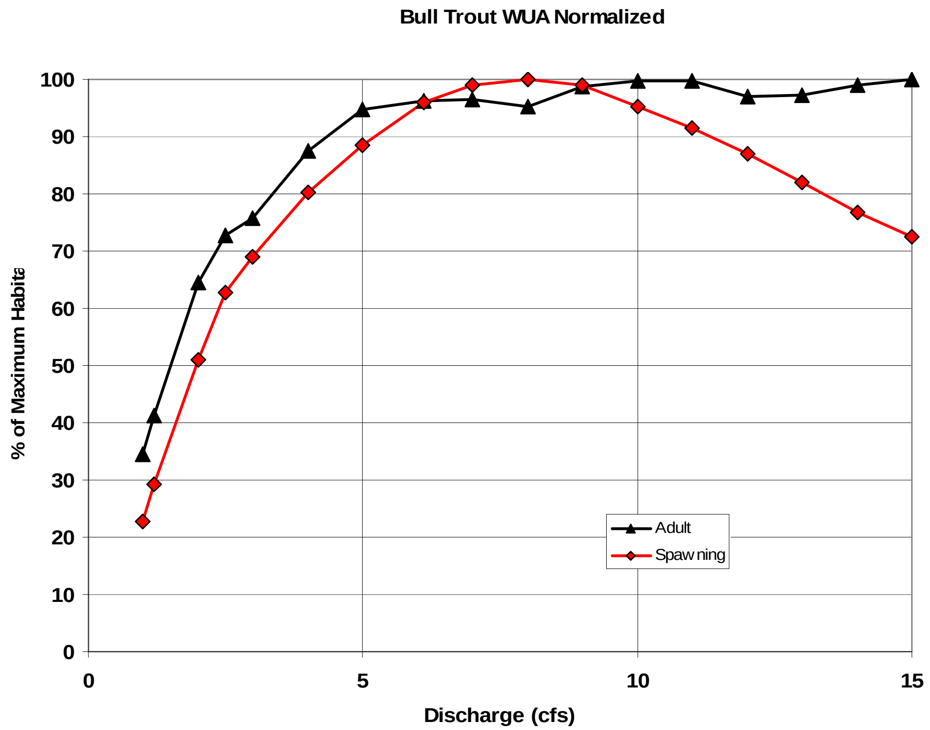


Figure 38 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Eighteenmile Creek, Study Site 1.

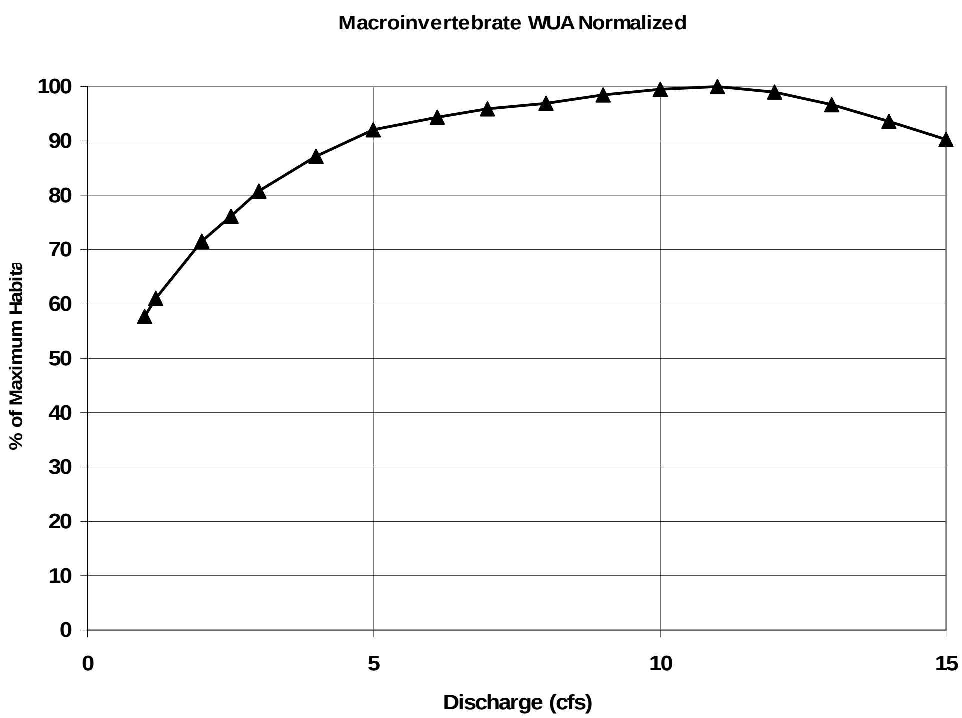


Figure 39 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Eighteenmile Creek, Study Site 1.

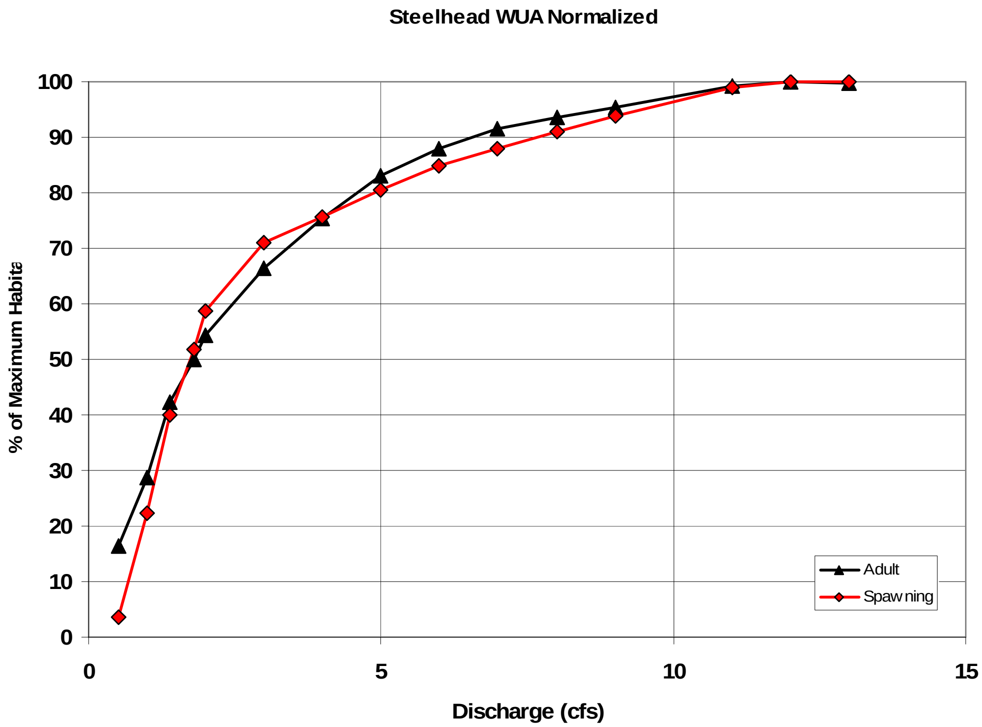


Figure 40 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Eighteenmile Creek, Study Site 2.

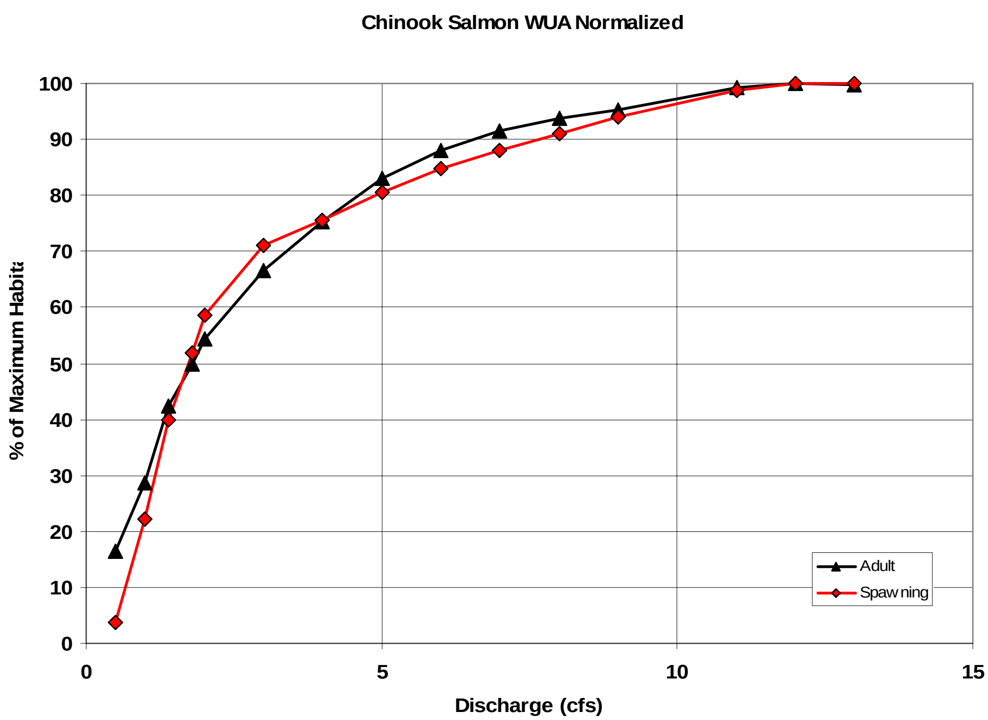


Figure 41 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Eighteenmile Creek, Study Site 2.

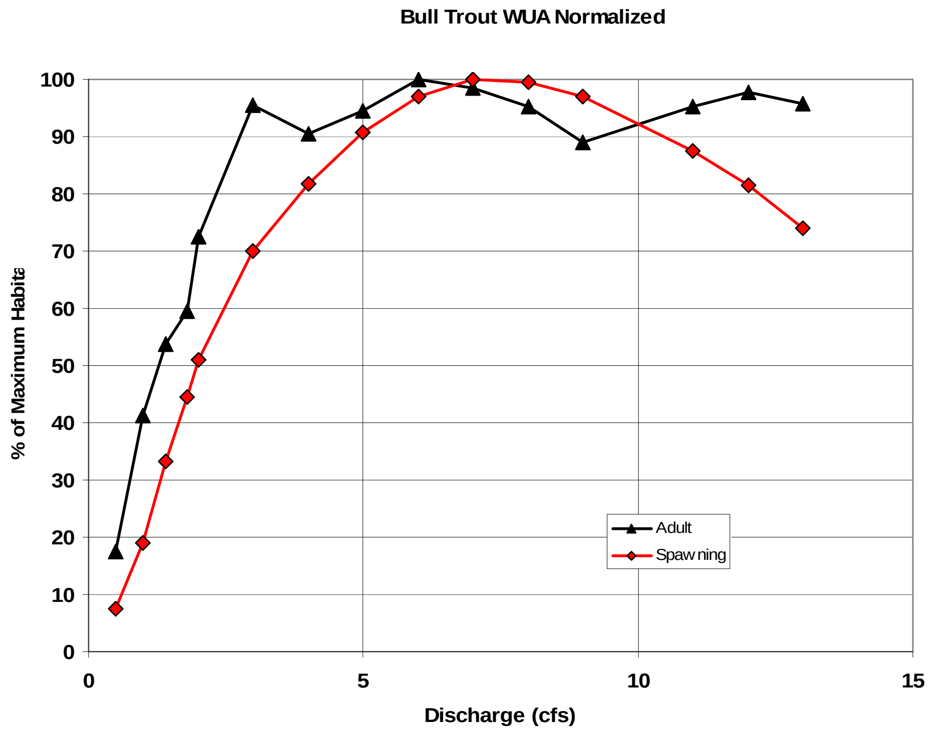


Figure 42 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Eighteenmile Creek, Study Site 2.

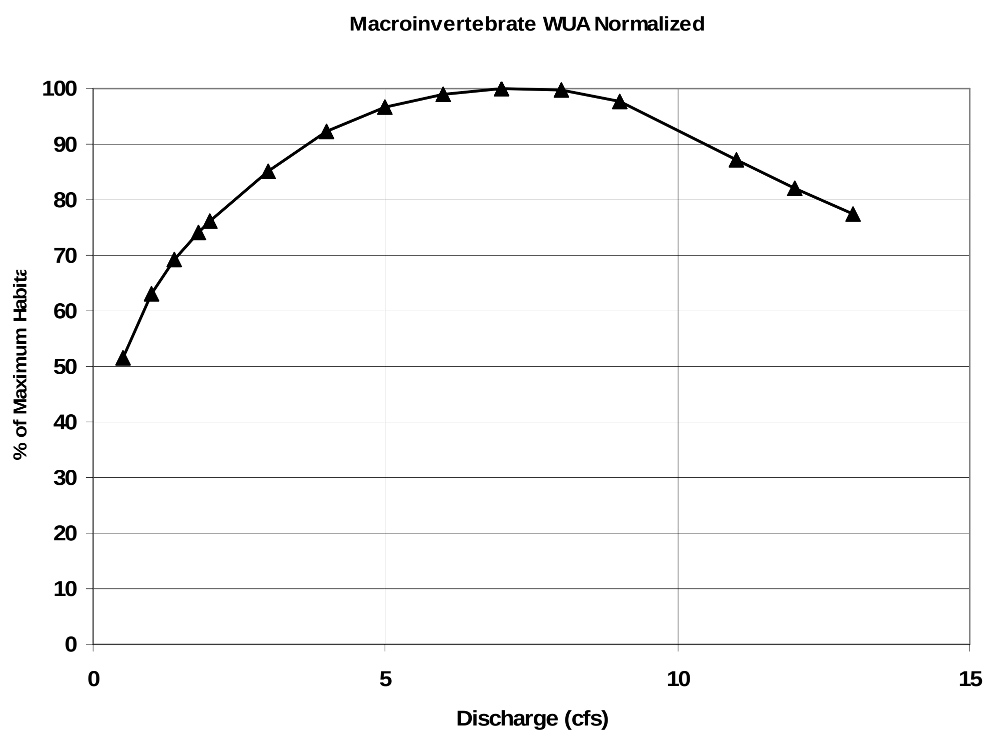


Figure 43 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Eighteenmile Creek, Study Site 2.

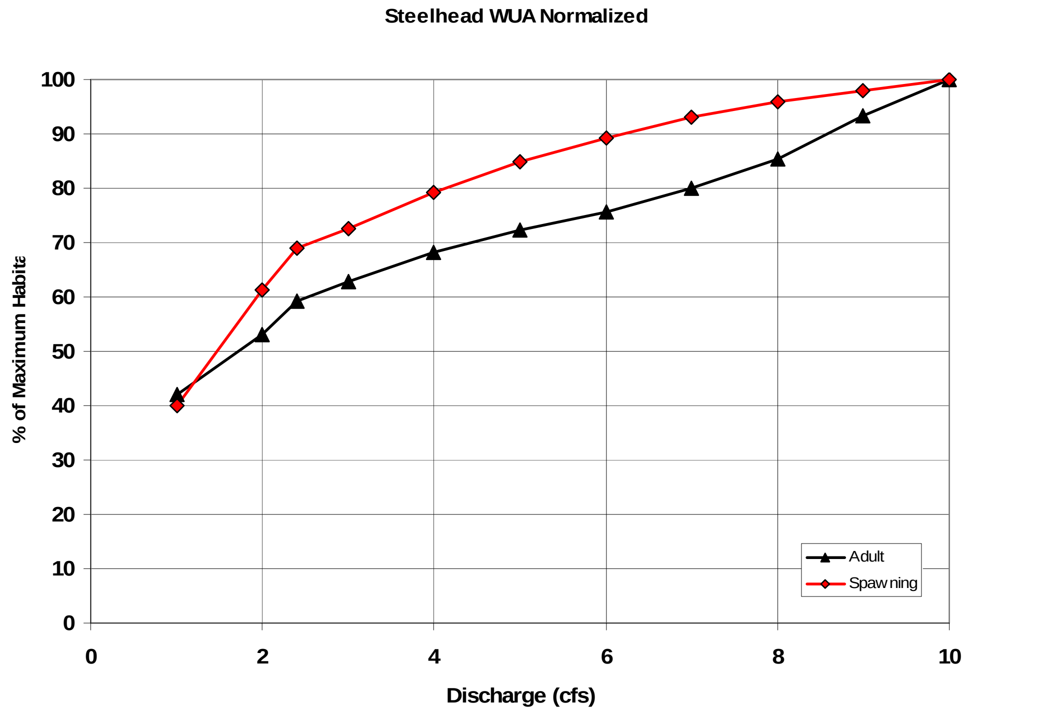


Figure 44 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Eighteenmile Creek, Study Site 3.

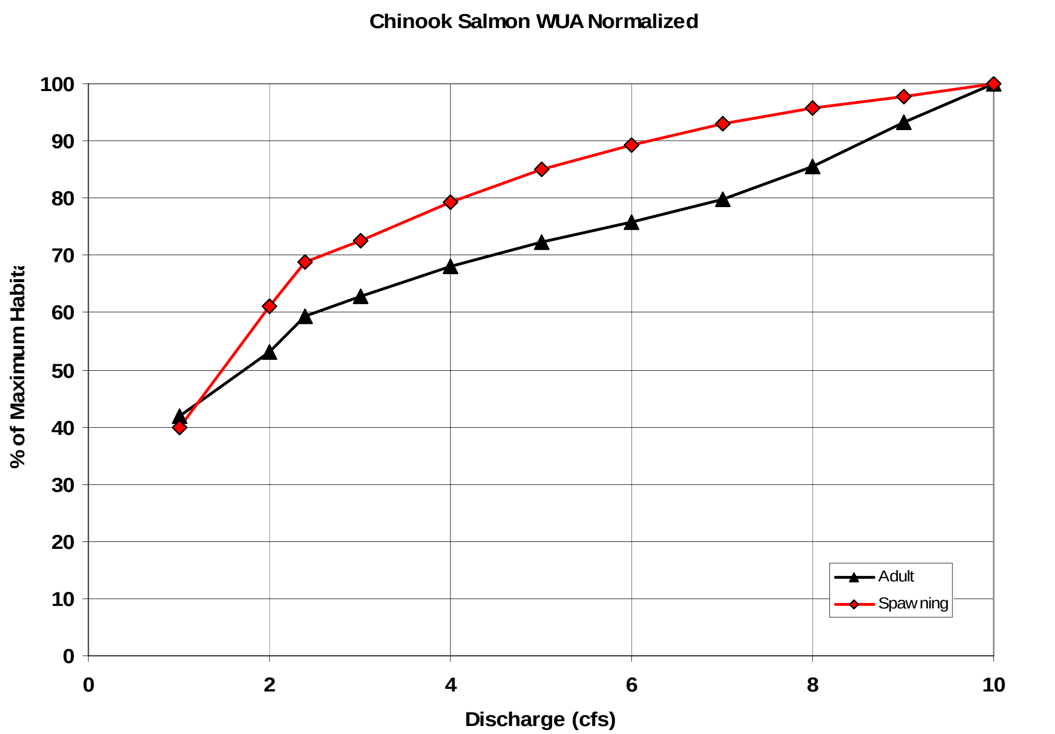


Figure 45 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Eighteenmile Creek, Study Site 3.

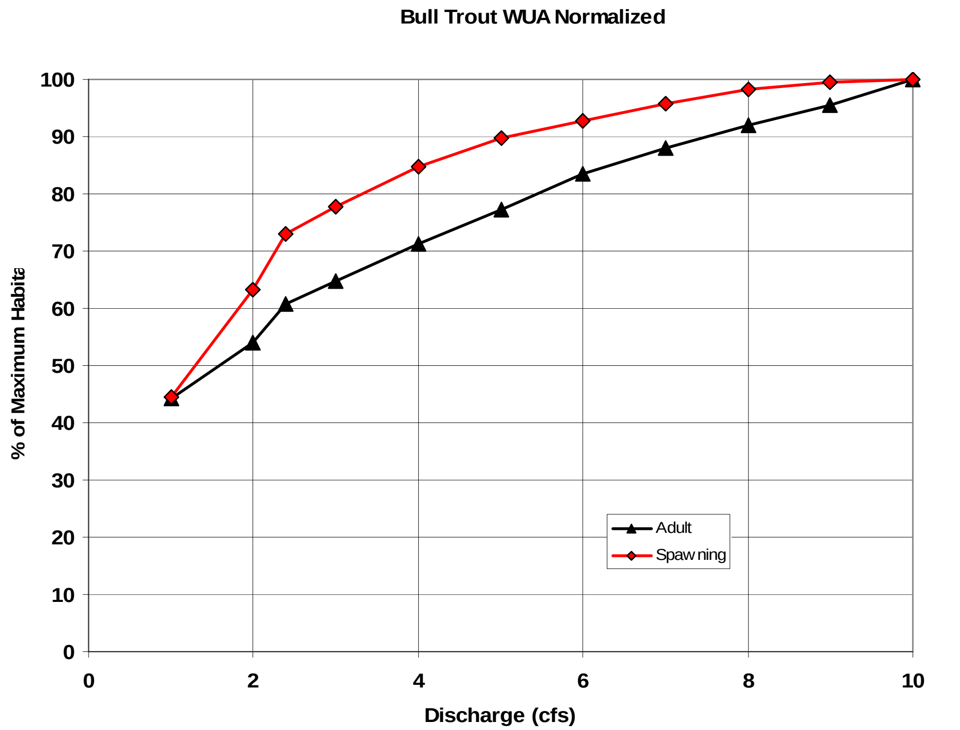


Figure 46 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Eighteenmile Creek, Study Site 3.

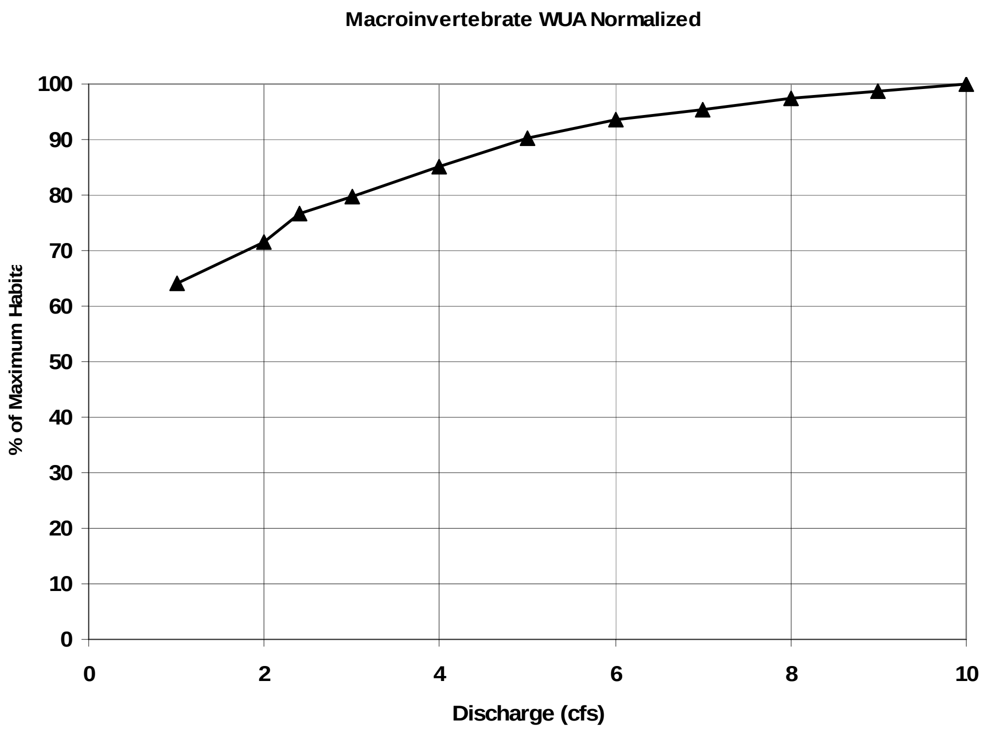


Figure 47 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Eighteenmile Creek, Study Site 3.

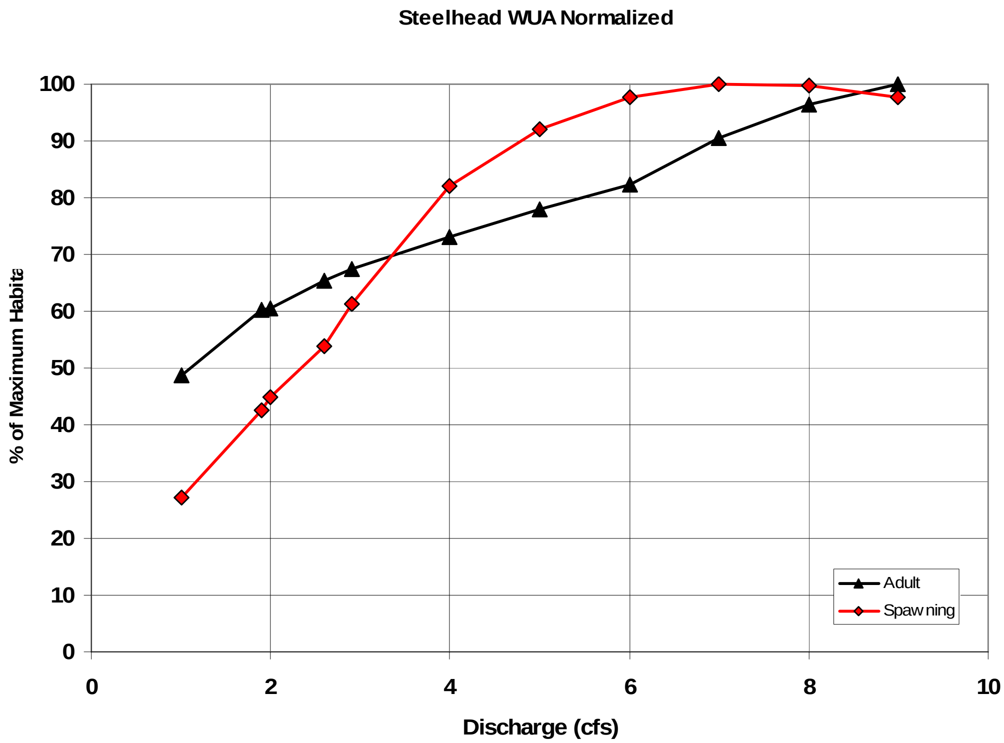


Figure 48 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Eighteenmile Creek, Study Site 4.

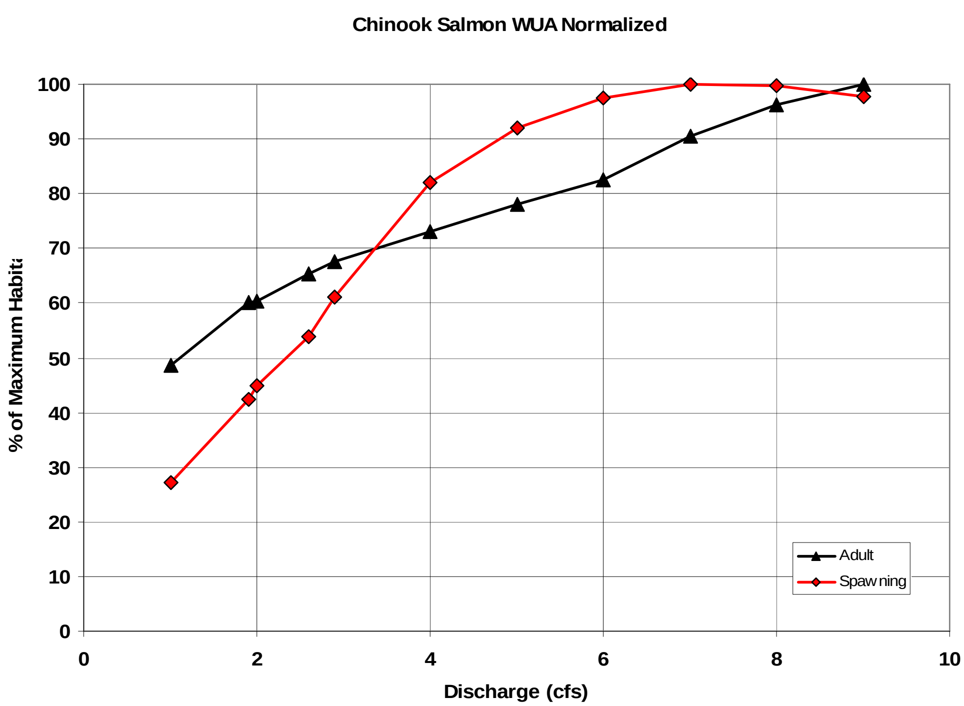


Figure 49 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Eighteenmile Creek, Study Site 4.

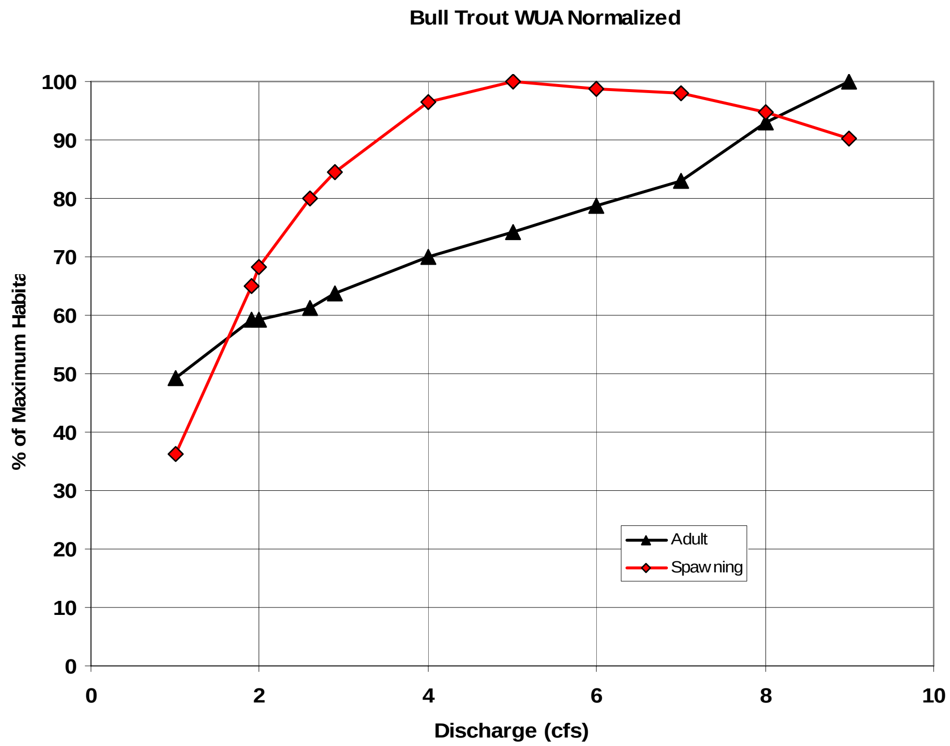


Figure 50 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Eighteenmile Creek, Study Site 4.

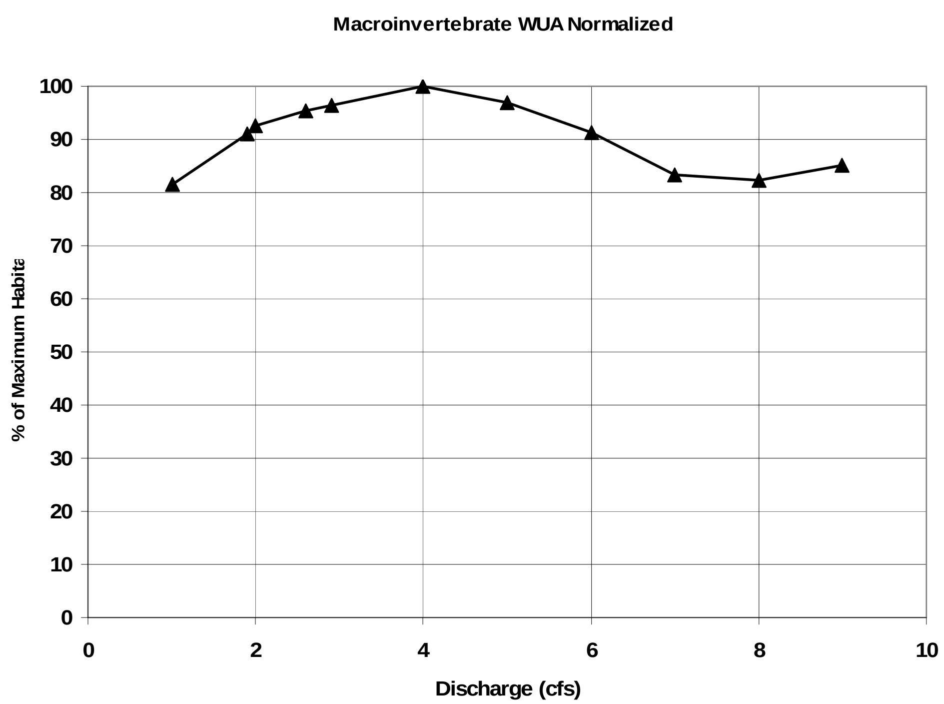


Figure 51 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Eighteenmile Creek, Study Site 4.

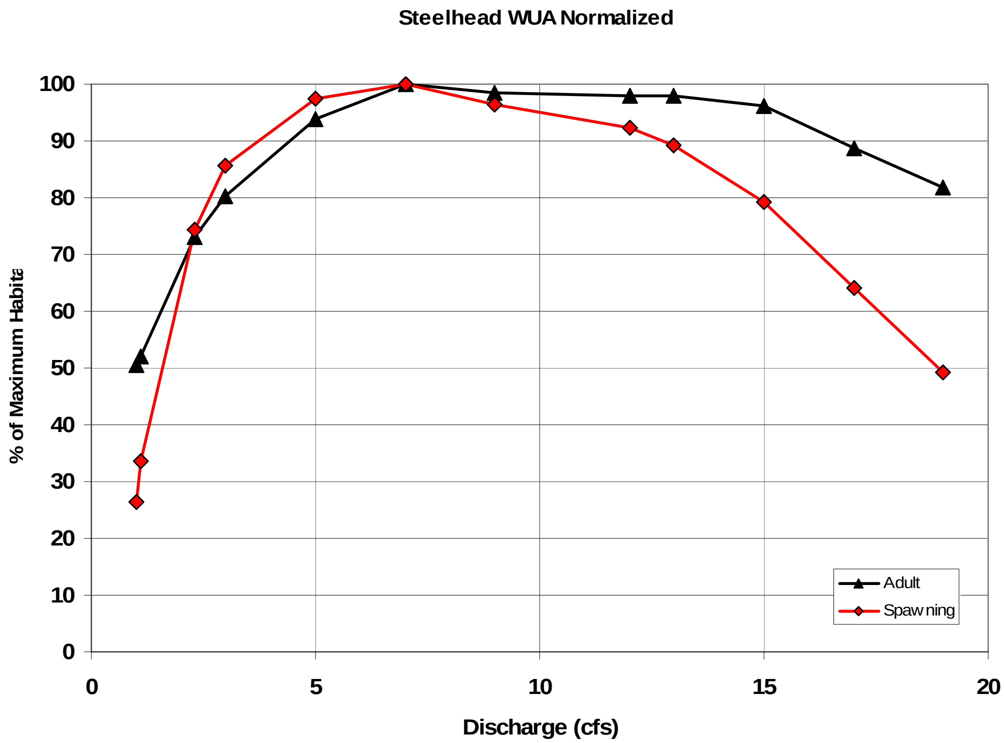


Figure 52 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Eighteenmile Creek, Study Site 5.

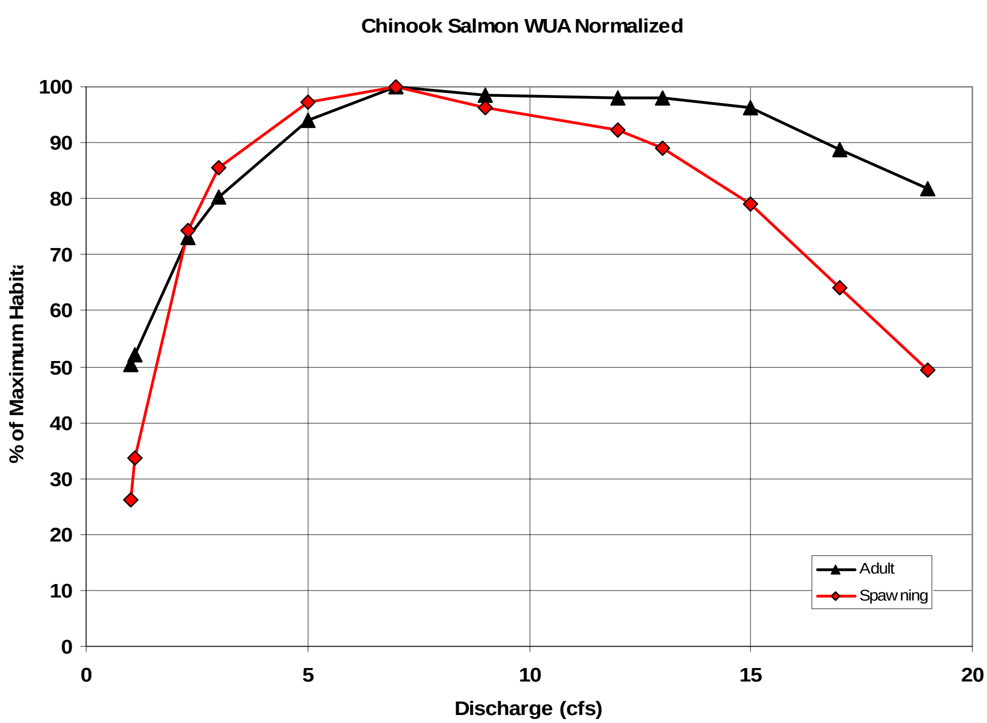


Figure 53 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Eighteenmile Creek, Study Site 5.

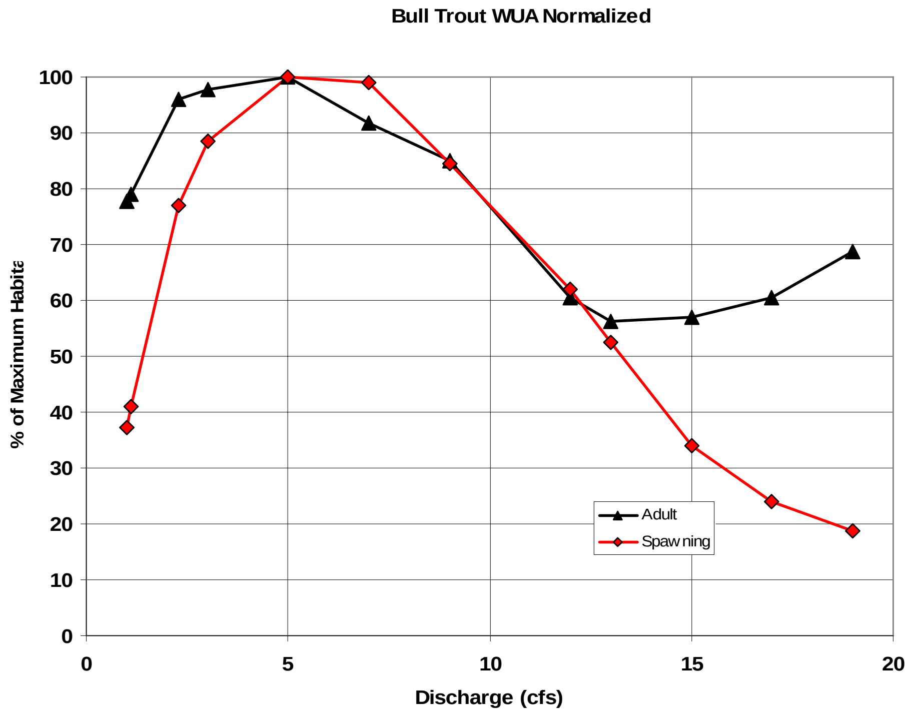


Figure 54 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Eighteenmile Creek, Study Site 5.

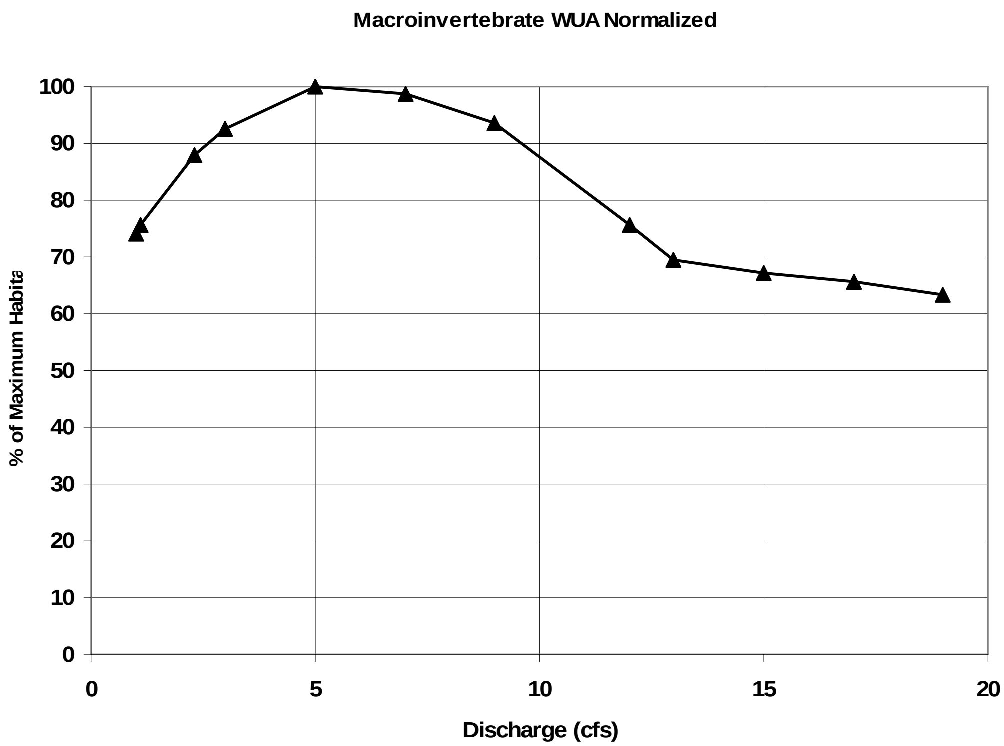


Figure 55 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Eighteenmile Creek, Study Site 5.

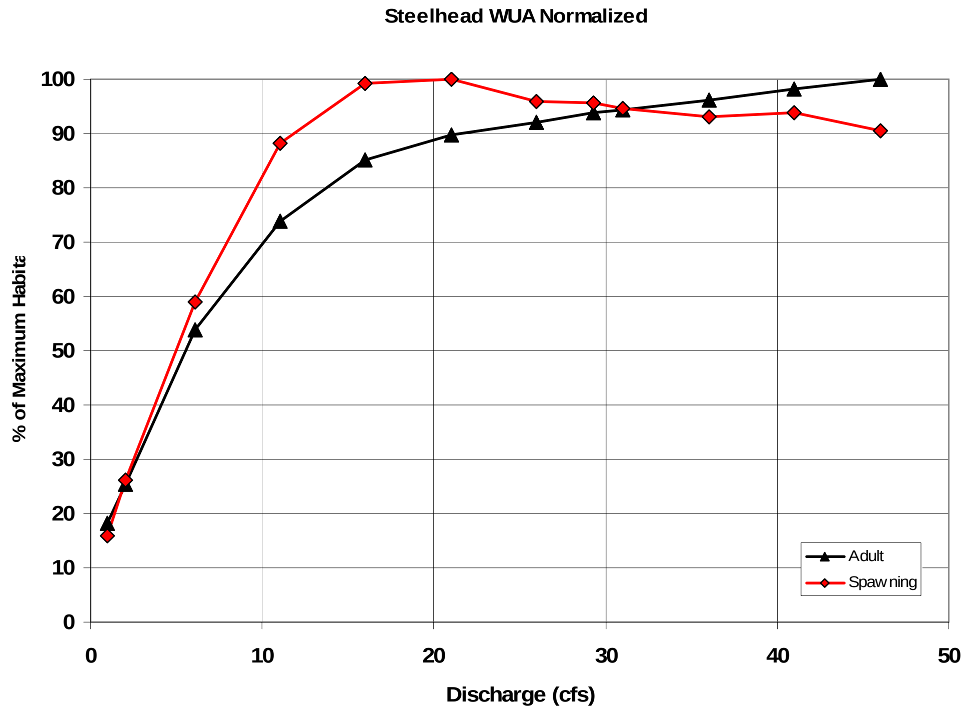


Figure 56 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead in Eighteenmile Creek, Study Site 6 (Reference).

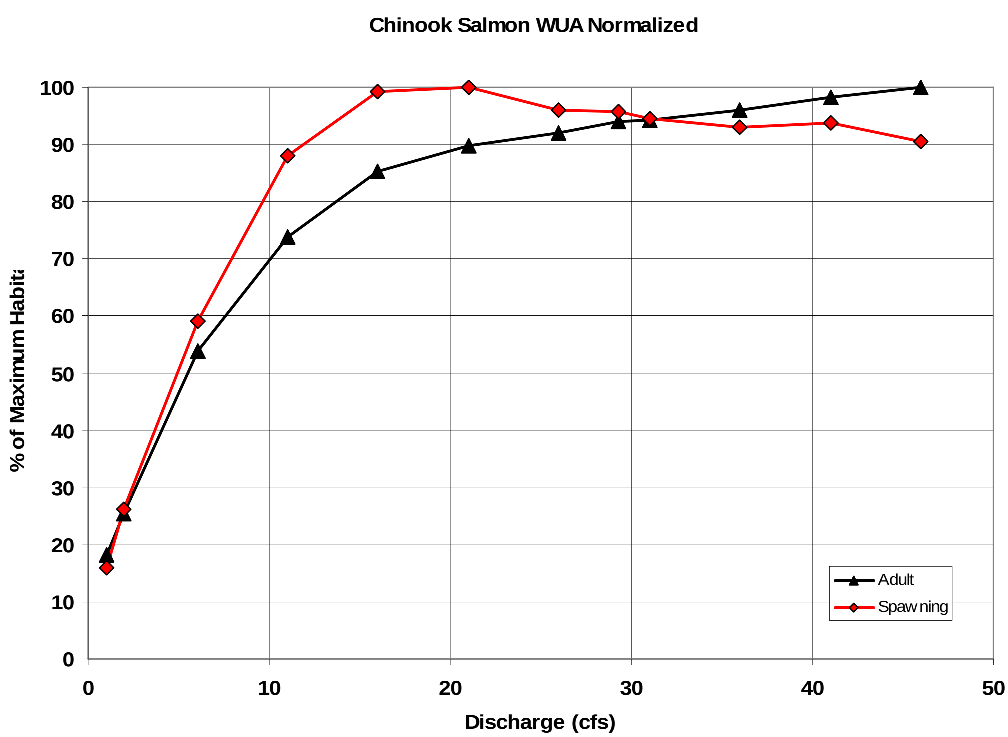


Figure 57 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon in Eighteenmile Creek, Study Site 6 (Reference).

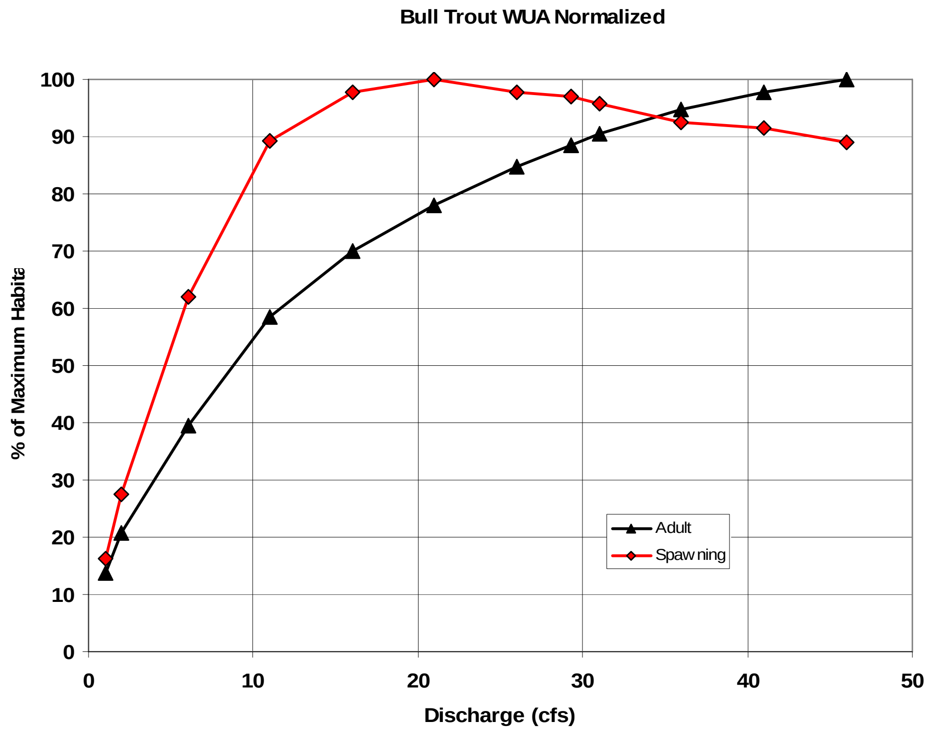


Figure 58 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout in Eighteenmile Creek, Study Site 6 (Reference).

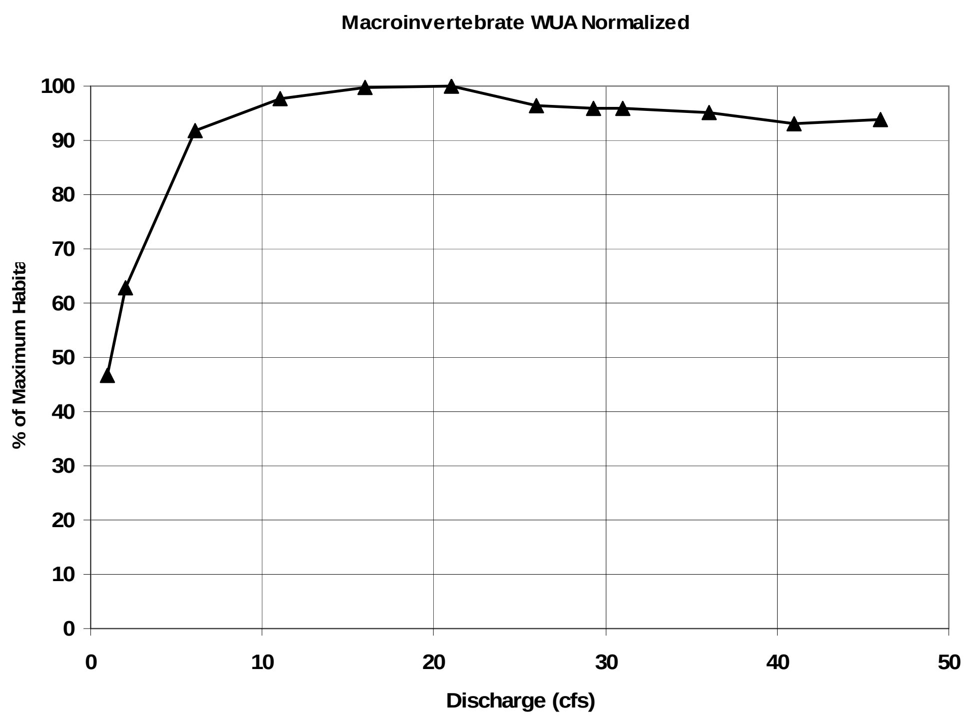


Figure 59 Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for macroinvertebrates in Eighteenmile Creek, Study Site 6 (Reference).

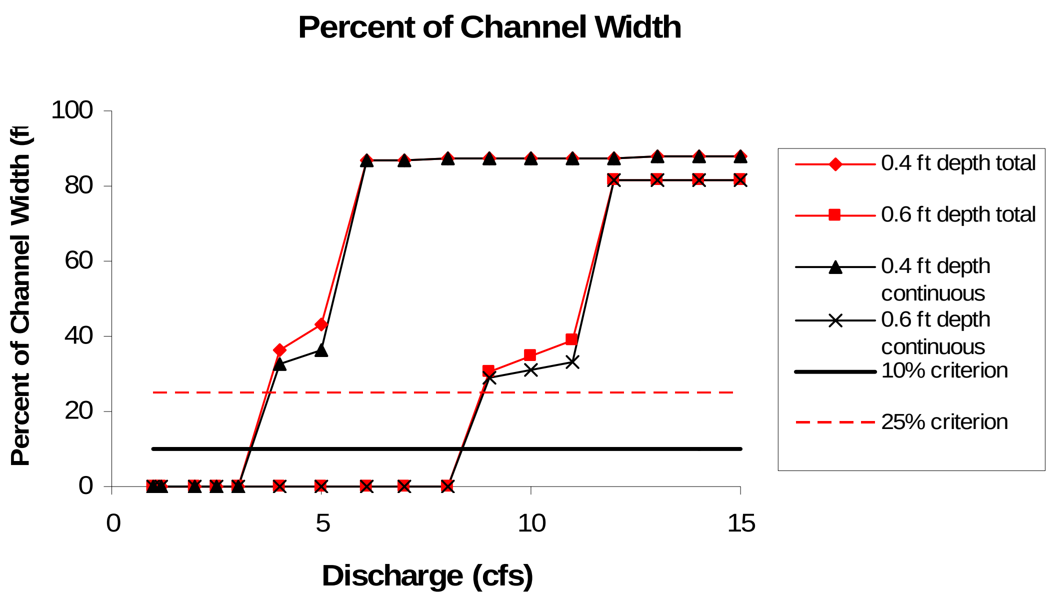


Figure 60 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Eighteenmile Creek, Study Site 1.

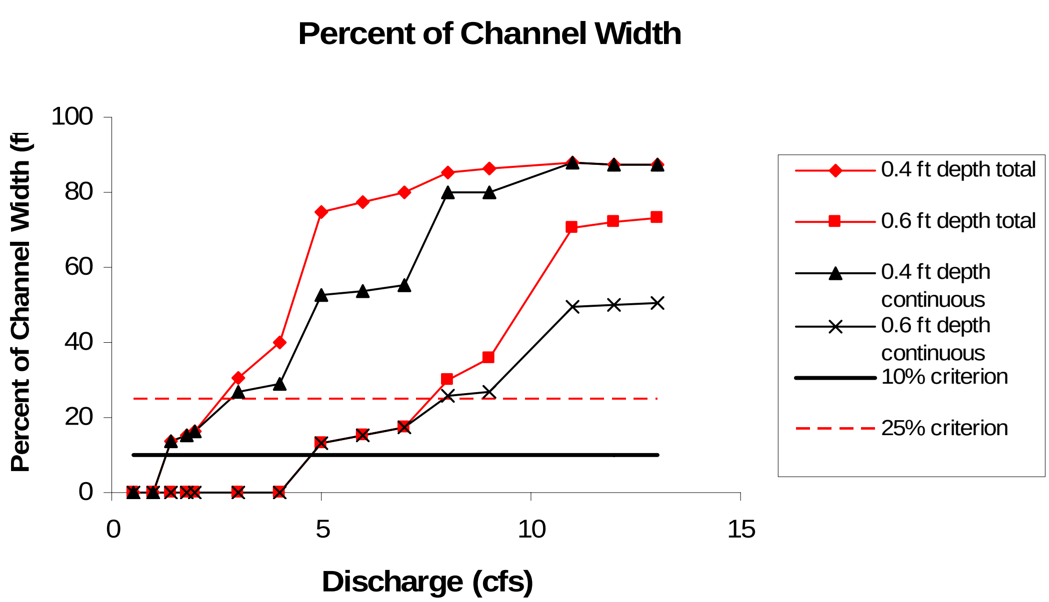


Figure 61 Total and contiguous widths at depths greater than passage criteria at a shallow transect on Eighteenmile Creek, Study Site 2.

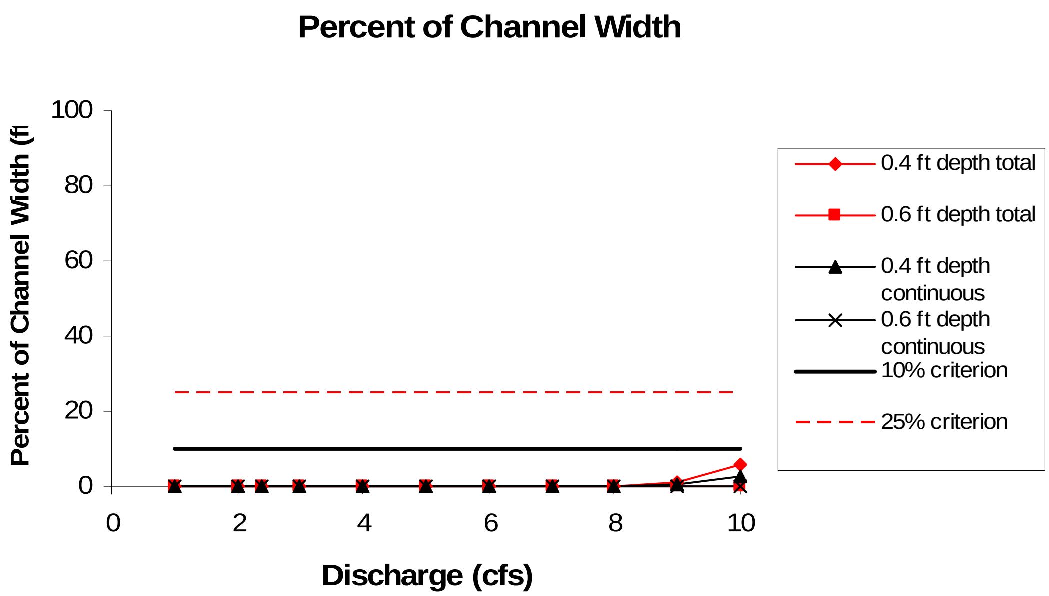


Figure 62 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Eighteenmile Creek, Study Site 3.

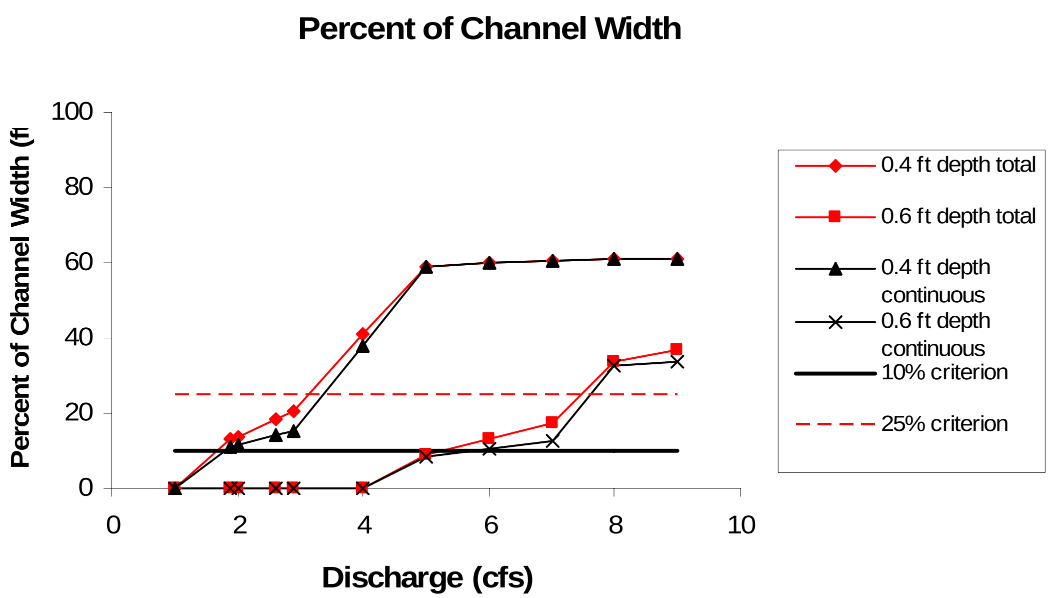


Figure 63 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Eighteenmile Creek, Study Site 4.

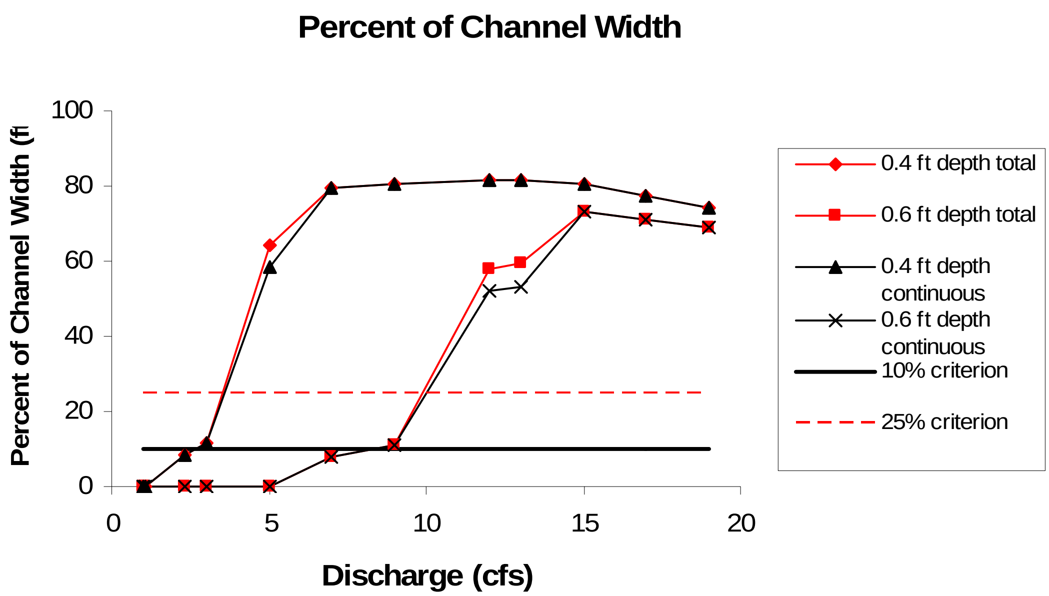


Figure 64 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Eighteenmile Creek, Study Site 5.

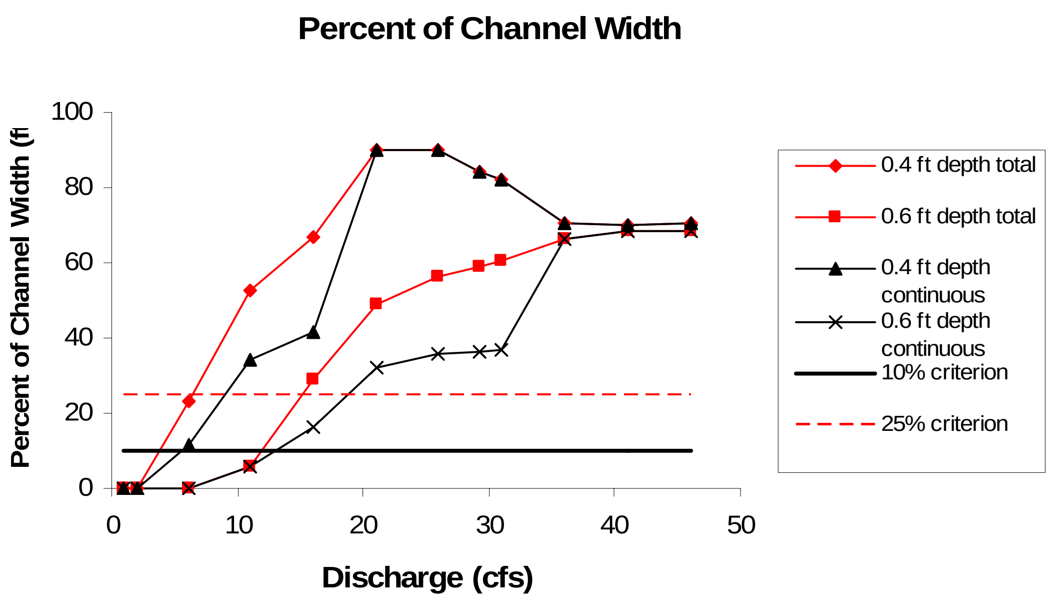


Figure 65 Total and contiguous widths at depths greater than passage criteria at a riffle transect on Eighteenmile Creek, Study Site 6 (Reference).

Table 17 Habitat modeling summary on Eighteenmile Creek.

Life Stage	Discharge (cfs) required for optimum weighted usable area (WUA)				Discharge (cfs) required for adult salmonid passage using 0.6 foot depth criterion[1]	
	Steelhead	Chinook salmon	Bull trout	Macroinvert	>25% of total channel width	>10% of contiguous channel width
Study Site 1				11		
Spawning	>15	>15	8		9	9
Adult	>15	>15	>15			
Study Site 2				7		
Spawning	12	12	7		8	5
Adult	12	12	6			
Study Site 3				>10		
Spawning	>10	>10	>10		>10	>10
Adult	>10	>10	>10			
Study Site 4				4		
Spawning	7	7	5		8	6
Adult	>9	>9	>9			
Study Site 5				5		
Spawning	7	7	5		12	9
Adult	7	7	5			
Study Site 6 (Reference)				21		
Spawning	21	21	21		16	16
Adult	>46	>46	>46			

[1] Passage criteria taken from Thompson (1972) and Scott et al. (1981); both width criteria must be met to insure passage.

5.3 Guidelines for Using Study Results

The results presented in this report summarize the hydrology, habitat, and temperature characteristics of Hawley Creek and Eighteenmile Creek during summer, 2006. PHABSIM analysis of the data collected and compiled for this study resulted in a series of graphs that illustrate relations between a dimensionless value (expressed as percent of maximum) called weighted usable area (WUA) and discharge (Figures 11-26, 31-35 and 36-59). The highest point on each curve represents the discharge at which habitat is optimized for adult or spawning life stages for the fish species analyzed in this study (salmon, steelhead, and bull trout). These optimized values, summarized in Tables 15 and 17, rarely coincide among life stages for any one species. Furthermore, adult and spawning life stages for salmon, steelhead, and bull trout occur at different times of the year. These results imply that the optimum amount of water needed for adult and spawning life stages is not constant, but varies during the year. It is suggested to consider these implications during development of flow targets.

Also, WUA-discharge curves can be used to estimate how much habitat is gained or lost with incremental flow changes. In some cases, small flow changes can result in major habitat changes. WUA is an instantaneous representation of how much water it takes to create a certain amount of habitat. In general, it simply says that if there is “X” amount of flow present, that equates to “Y” amount of habitat. It is without reference to time or period of the year. WUA says nothing about how much water may or may not be present, and thus habitat, at any particular season of the year. Seasonal, monthly, daily flow regimes have to be applied to the instantaneous WUA curves to get an indication of how much habitat is actually present. The way to use that information is, if there is ”X” flow without flow restoration, that equates to “A” habitat, but “Y” amount of flow is added through restoration, that equates to “B” amount of habitat. Depending on the shape of the curve, that change in habitat from “A” to “B” may be an increase or a decrease.

Discharge estimates providing optimal WUA for juvenile salmonid lifestages are usually less than summer base flows, suggesting a disconnect between the models used and actual juvenile salmonid needs. Reasons for this may include: inability to accurately measure and/or quantify habitat parameters such as, flow velocity, cover, and substrate, at a scale that is meaningful for small fishes; inability to accurately quantify side channels, bank indentations, riparian wetlands, or other lateral habitats that are important for rearing juvenile salmonids; and inability to adequately incorporate temperature, or other water quality parameters, into the model. Thus, until juvenile habitat characterization can be improved, juvenile life stage will not be included in this study.

The selection of target flows should be based on a hierarchical system of highest priority life stage and species present for the month or period of concern, using the assumption that the priority life stage and species would require higher streamflows than other life stages and species. Table 13 provides some general guidelines for which life stage to assess. For small tributary streams of the Lemhi River sub-basin, one possible priority life stage ranking would be (from high to low): passage > spawning > adult > juvenile. Once the priority life stage and species are ranked, then each study site should be examined to determine streamflow and passage conditions for the time period of concern.

The mechanisms by which the various components are integrated and the relative importance they are assigned within the water management decision process is a matter of professional judgment and beyond the scope of this study. However, it seems reasonable that providing and protecting connectivity to Hawley and Eighteenmile Creek to the Lemhi River by providing enough water for adult fish passage would be a management priority (Table 13). Water depths are an additional consideration for times of the year when the adult life stage is present. Choice of target flows should not be reduced to the point that stream depth is reduced below the level needed for fish passage (Tables 15 and 17), depending on available water supply. In addition, providing streamflow for optimum protection of riffle habitat will ensure healthy invertebrate communities, which are a major food source for fish.

The actual habitat experienced by fish in any river depends on the flow regime of the river. The development of habitat conditions over a period of time is an integral part of the comparison of flow regimes and developing flow recommendations. Habitat time series analysis involves interfacing a time series of streamflow data with the functional relationship between streamflow and habitat (WUA) (Bovee et al. 1998). This computational process is done for each flow regime alternative and life stage. Flow and habitat duration statistics are developed that allow a direct comparison of the changes that occur in both flow and habitat under a range of conditions. The decision point in PHABSIM is a comparison of flow regimes. In streams with more than one species of interest, the results should be reviewed to ensure recommended flows balance the needs of all species.

The natural hydrograph also needs to be considered when developing flow targets. In drought years, summer flows that provide maximum possible habitat may not be attainable because of the hydrologic limits on the stream. Also, PHABSIM does not estimate flow or habitat needs of downstream migrants or spring runoff conditions necessary for maintenance of channel morphology or riparian zone functions. Arthaud et al. (2001) have shown that downstream migrant survival can significantly increase with discharge. Thus, high spring flows that mimic the natural hydrograph should be a consideration in managing streamflows outside PHABSIM analysis.

Finally, it should be noted that PHABSIM was designed as a tool to provide science-based linkage between biology and river hydraulics with results to be used in negotiations or mediated settlements (Arthaud et al. 2001).

6.0 ACKNOWLEDGMENTS

We thank the numerous representatives from various organizations and private landowners who contributed to the success of this project. Al Simpson and Joe Spinazola of Reclamation assisted in obtaining landowner permission on private land and reviewed a draft version of this report. We also thank landowners who allowed access to their property. Joe Spinazola of Reclamation contributed to the planning and funding arrangements for the study. Jack Doyle, Joseph Bunt, and Alvin Sablan of USGS assisted with obtaining valuable hydrology data. Representatives on the Interagency Technical Workgroup organized by Reclamation also provided guidance, including Cynthia Robertson (IDFG), Jim Morrow (NMFS), and Jude Trapani (BLM).

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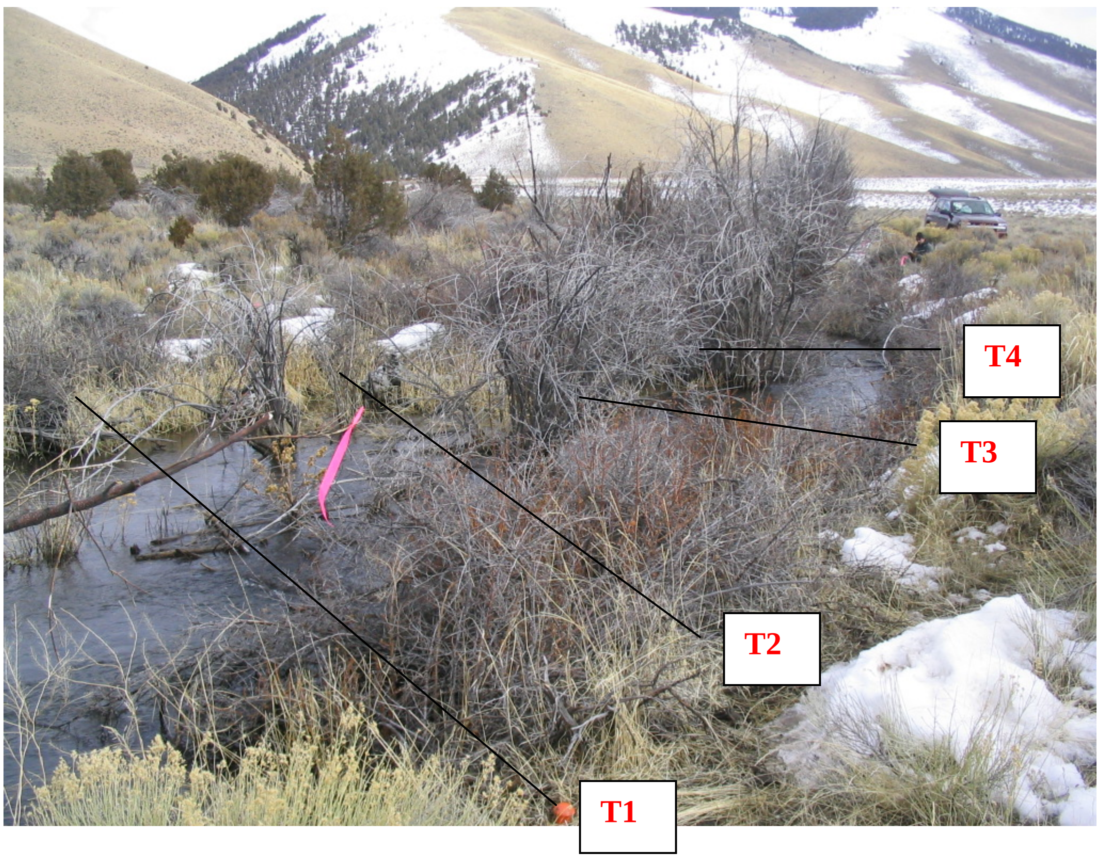
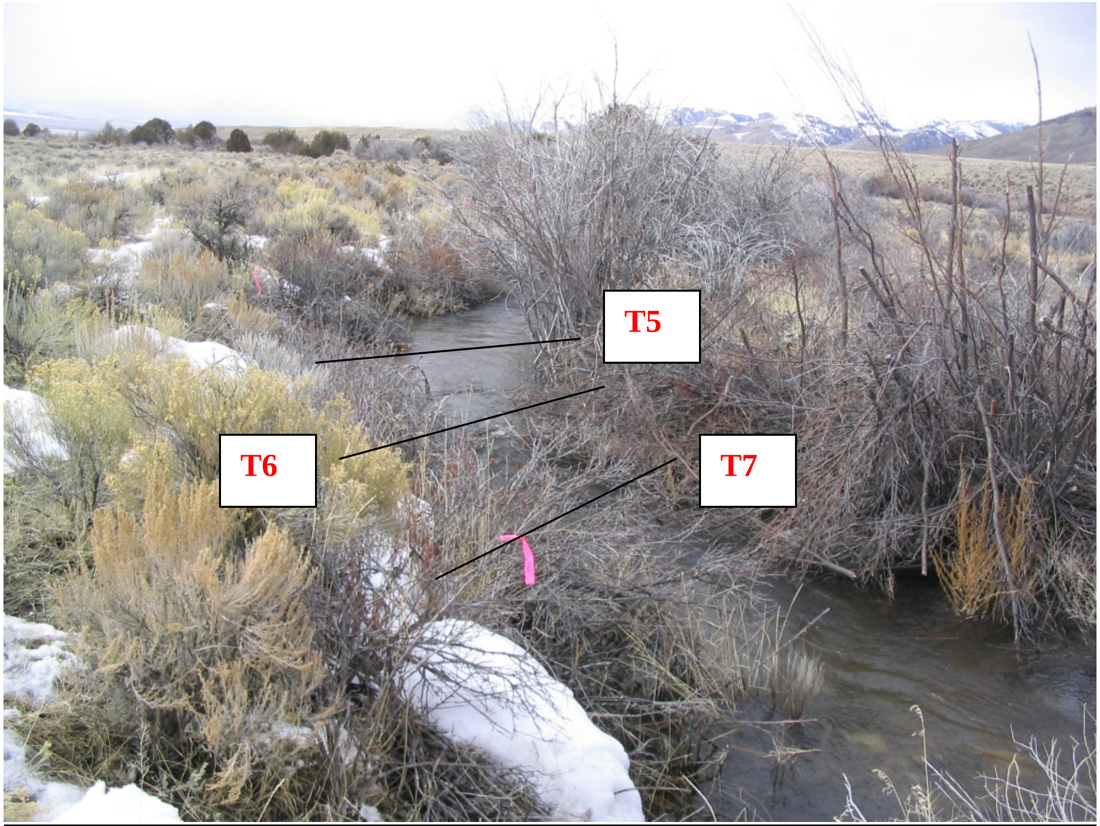
APPENDIX A – REACH AND STUDY SITE DESCRIPTIONS AND PHOTOS

Hawley Creek, Reach 1: This reach was the most downstream segment in Hawley Creek. It was characterized mainly by lowgradient riffles glides and pools.

<u>Study Site 1 – Most downstream study site (N44°39.477’ W113°13.337’)</u>

Transect 1 – glide (downstream transect)
Transect 2 – glide
Transect 3 – riffle
Transect 4 – riffle
Transect 5 – hydraulic control
Transect 6 – pool
Transect 7 – pool (upstream transect)




T5
T6
T7

**Hawley Creek was diverted for irrigation purposes on March 22, 2006. Pictured below, Transect 3, Study Site 1, on March 21 at 14.1 cfs (top) and March 22 at 0.5 cfs (bottom). .

Hawley Creek, Reach 2: This reach primarily consisted of glides, riffles and pools in a moderately vegetated area.

<u>Study Site 2 – (N 44°39.621’ W 113°12.266’)</u>

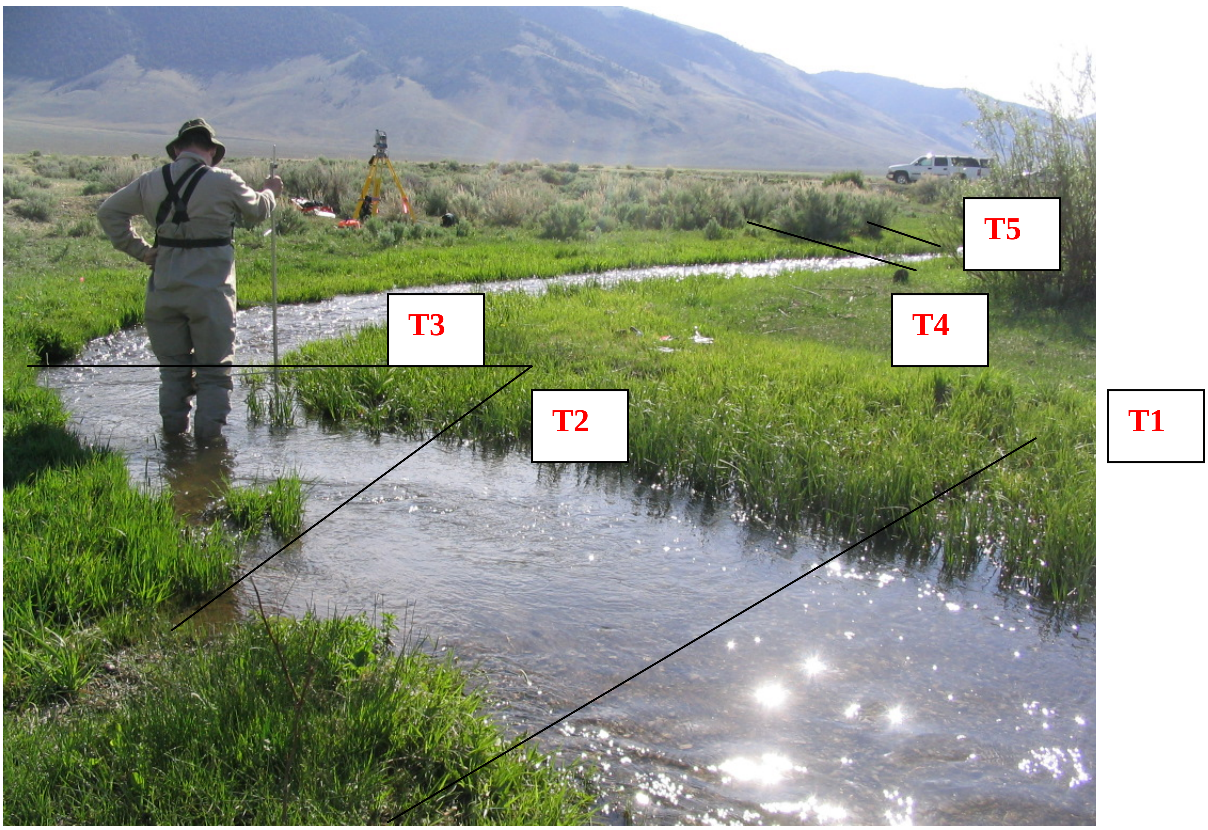
Transect 1 – hydraulic control
Transect 2 – pool
Transect 3 – pool
Transect 4 – glide
Transect 5 – riffle
Transect 6 – riffle
Transect 7 - glide


T6
T7

Hawley Creek, Diversion Reach: This reach was located on private land, and was diverted waters of Hawley Creek. The study site was a mixture of riffle, glide and pool habitat types.

<u>Study Site 3 (Diversion) – (N44°40.678' W113°12.266')</u>

Transect 1 – hydraulic control
Transect 2 – pool
Transect 3 – riffle
Transect 4 – hydraulic control/glide
Transect 5 – pool

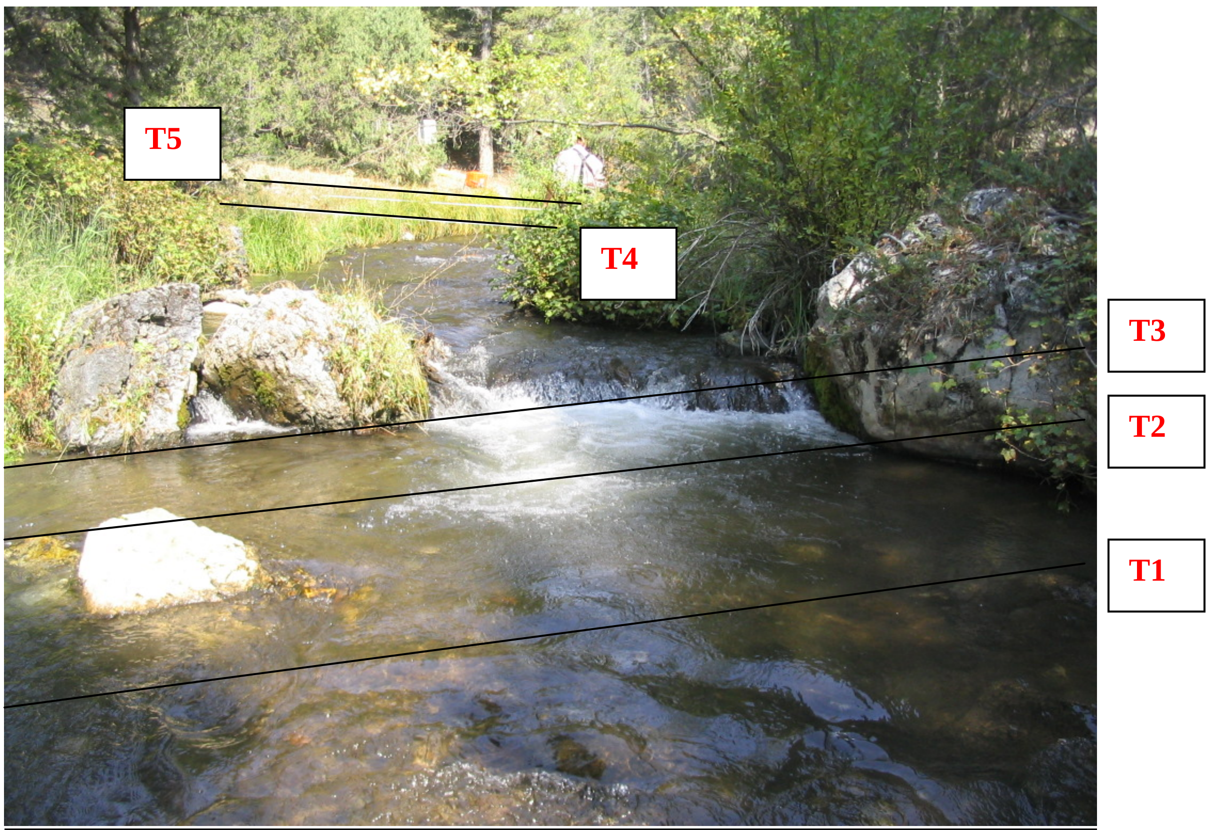



T4
T5

Hawley Creek, Reach 4 (Reference): This study site for this reach was located on USFS property. The stream channel consisted of glides, riffles and pools with natural heavy vegetation. A USGS gage was placed at this site to monitor flows during the study.

<u>Study Site 4 – Most upstream site (N44°40.253’ W°11.170’)</u>

Transect 1 – hydraulic control
Transect 2 – pool
Transect 3 – pool
Transect 4 – riffle
Transect 5 – riffle
Transect 6 – glide
Transect 7 – glide

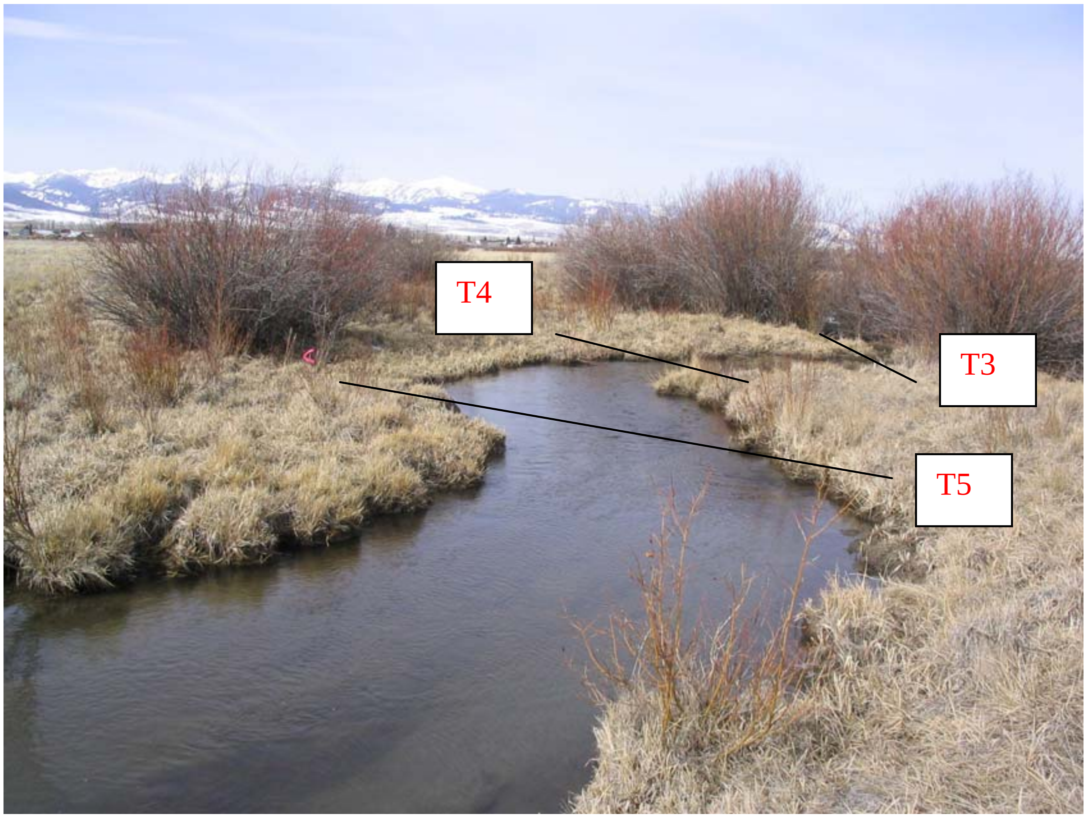



T5
T6
T7

Eighteenmile Creek, Reach 1: This reach extended from the upper confluence with Whitefish Ditch upstream to the first major diversion. The stream channel consisted primarily of riffles and glides and was located on private property.

Study Site 1 – Most downstream site (N44°40.934' W113°20.930)

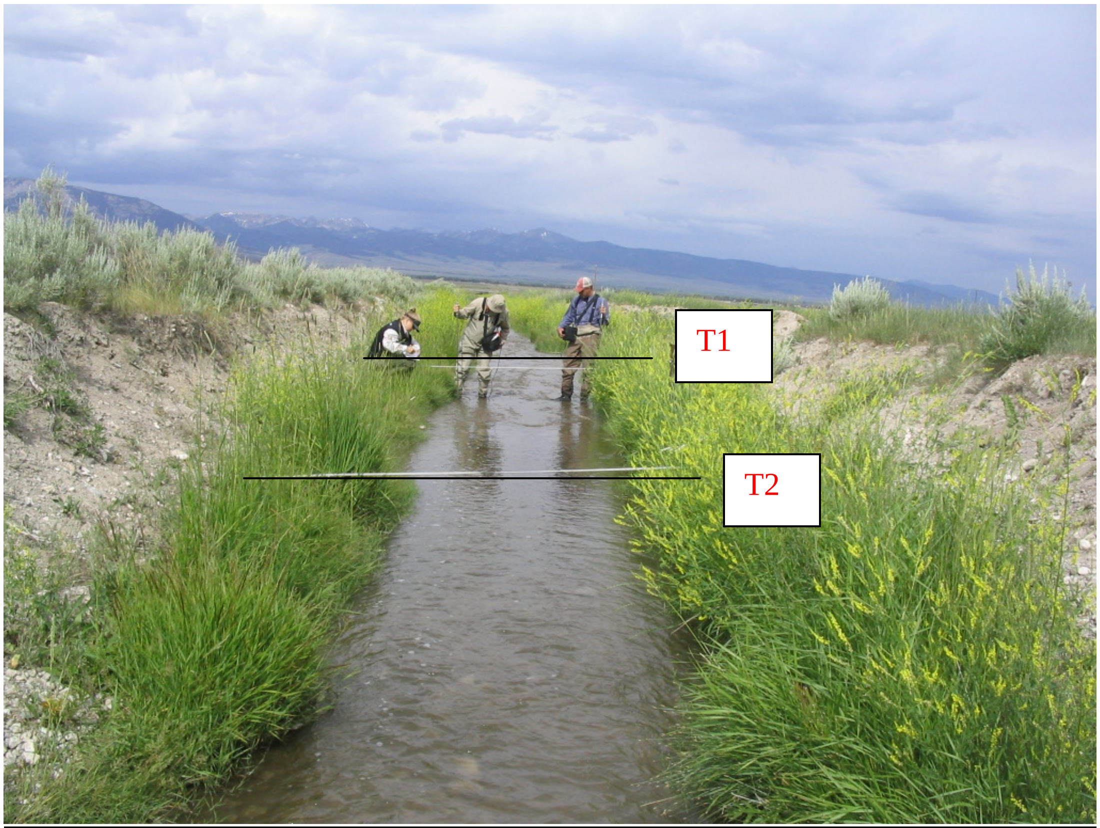
Transect 1 – riffle
Transect 2 – riffle
Transect 3 – riffle
Transect 4 – glide
Transect 5 – glide


T4
T3
T5

Eighteenmile Creek, Reach 2: This reach was located on private property; it was bracketed by two major diversions. It primarily consisted of riffles and glides.

Study Site 2 – (N 44°40.934' W 113°20.930')

Transect 1 – riffle
Transect 2 – glide



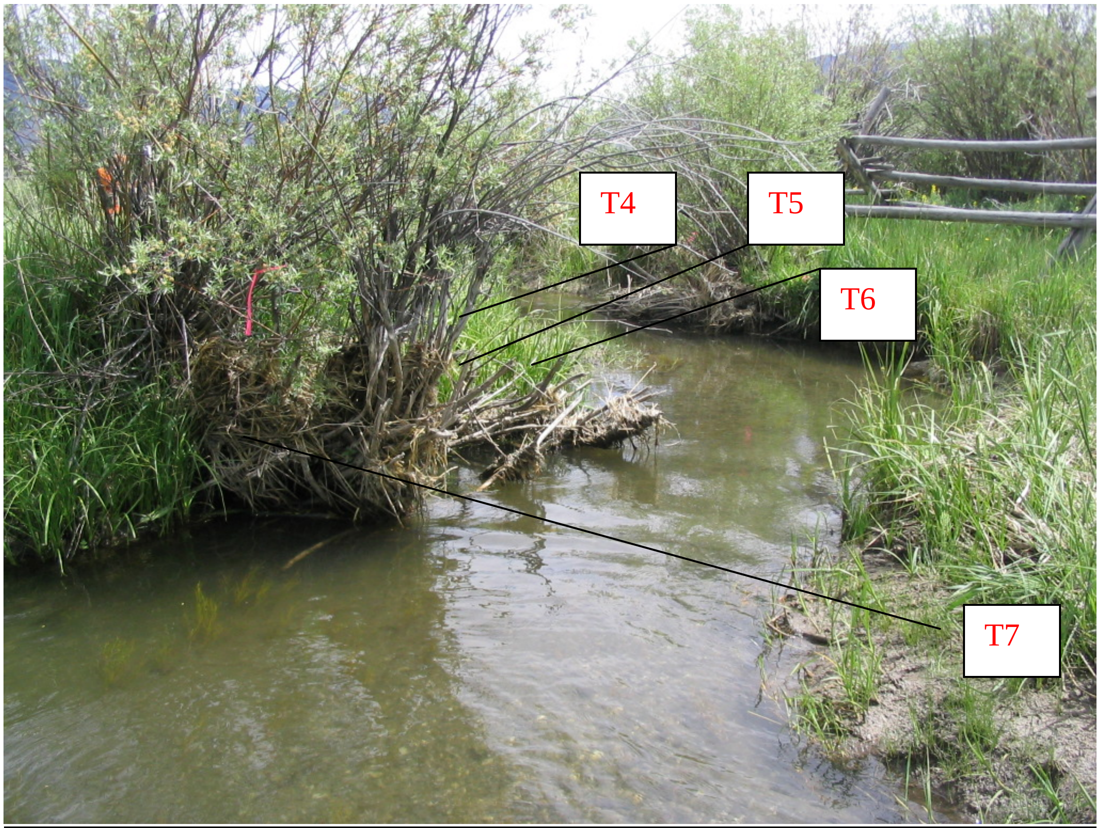
Eighteenmile Creek, Reach 3: This reach was located on private property and between two major diversions that defined the upstream and downstream boundaries of 2 and 4, respectively. The study site was a mixture of pool, riffle and glide habitat types.

Study Site 3 – (N 44°38.379' W 113°17.590)
Transect 1 – riffle/passage
Transect 2 – glide
Transect 3 – riffle
Transect 4 – riffle
Transect 5 – HC
Transect 6 – pool
Transect 7 – pool
Transect 8 – glide


T4
T5
T6
T7
T8

Eighteenmile Creek, Reach 4: This study site for this reach was located on private property and represented a mixture of riffle and run habitat types. The upper and lower boundaries of this reach were two diversions, separating reaches 3 and 5, respectively.

Study Site 4 – (N 44°36.901' W 113°16.342')
Transece 1 – glide
Transect 2 – glide
Transect 3 – riffle
Transect 4 – HC/passage
Transect 5 – pool
Transect 6 – pool
Transect 7 – glide


T4
T5
T6
T7

Eighteenmile Creek, Reach 5: This reach was located on BLM land. The upper and lower boundaries of this reach were two diversions. The study site was a mixture of riffle, pool and glide habitats.

Study Site 5 – (N 44°30.252 W 113°11.570)

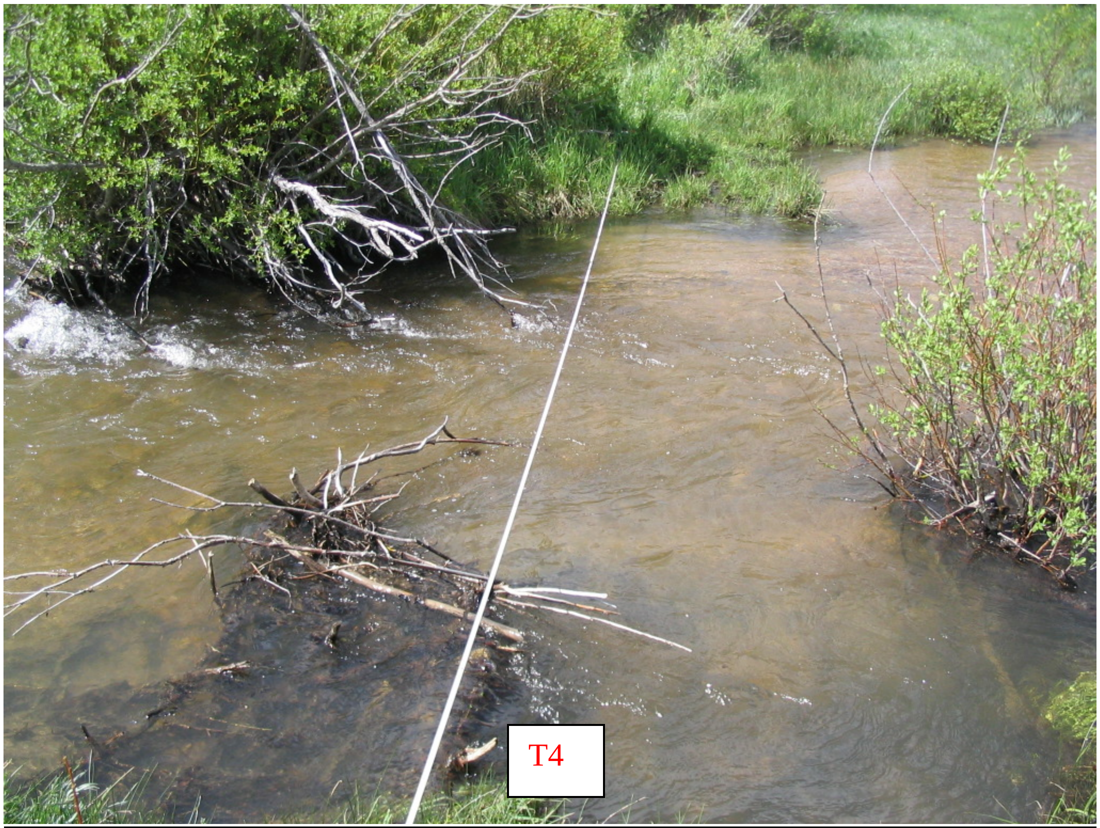
Transcect 1 – riffle
Transect 2 – glide
Transect 3 – HC
Transect 4 – pool
Transect 5 – riffle
Transect 6 – glide
Transect 7 – glide

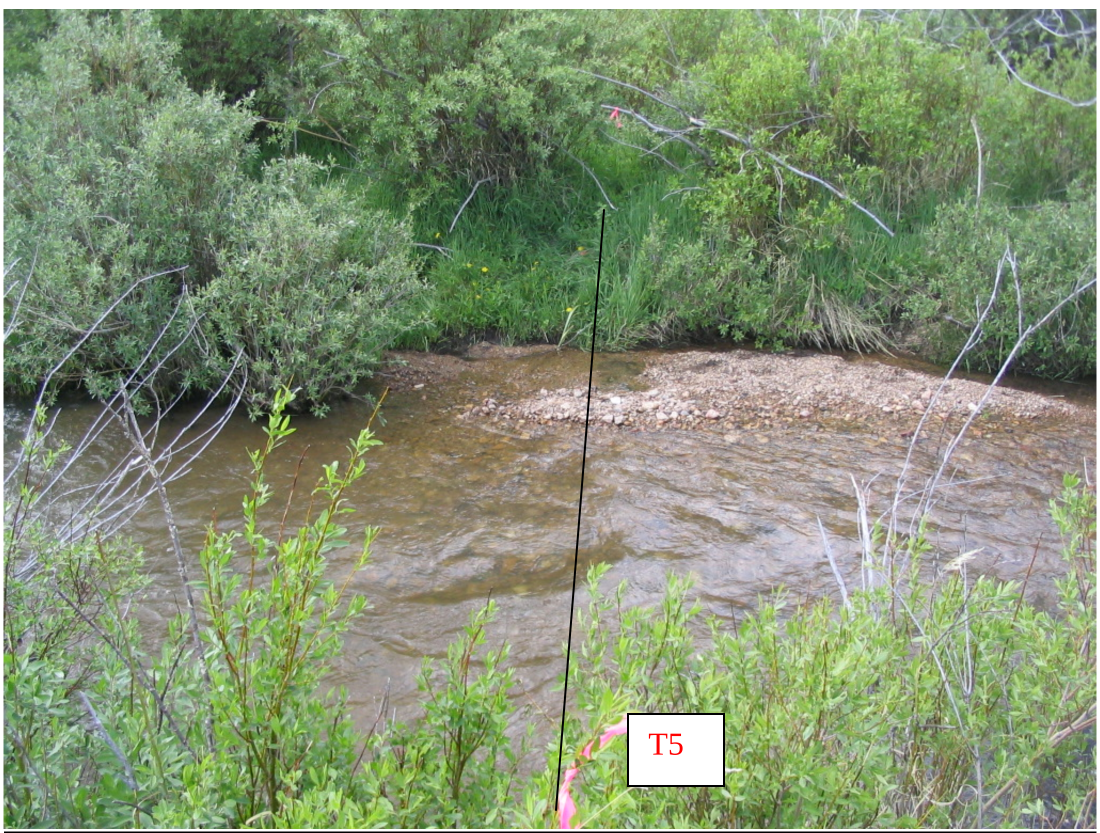

T5
T6
T7

Eighteenmile Creek, Reach 6: This reach was located on BLM land, upstream of a major diversion. This study site was representative of Eighteenmile Creek undisturbed by diversion structures. The study site represented natural flow conditions immediately upstream from the major diversions on Eighteenmile Creek.

Study Site 6 – (N 44°29.111' W 113°04.736)

Transect 1 – HC
Transect 2 – pool
Transect 3 – riffle/passage
Transect 4 – glide
Transect 5 – glide
Transect 6 – riffle


T4


T5


T6

APPENDIX B – HABITAT MAPPING PROPORTIONS

Hawley Creek

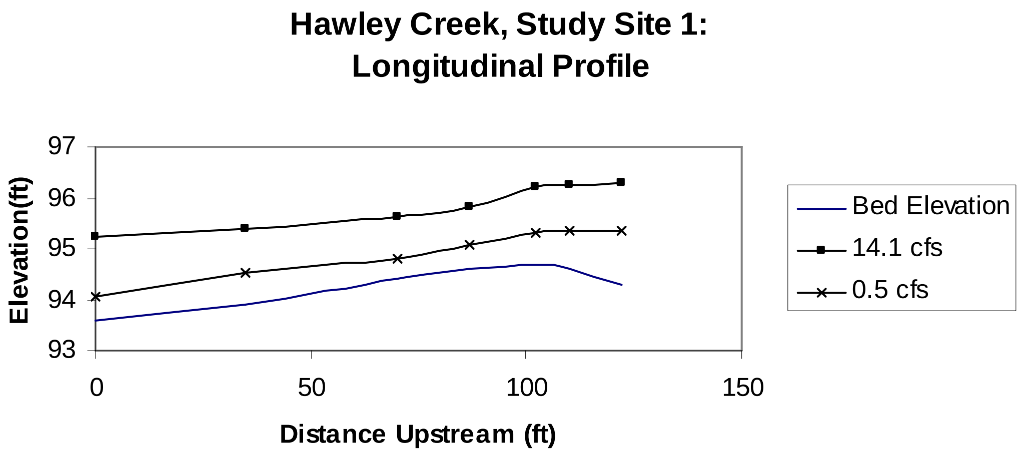
	Distance Mapped (feet)	Proportions (%)
Study Site 1		
Riffle	1217	42.7
Glide	1512	53.1
Pool	120	4.20
Total	2849	100
Study Site 2		
Riffle	2006	61.5
Glide	1124	34.5
Pool	131	4.00
Total	3261	100
Study Site 3 (Diversion)		
Riffle	853	69.2
Glide	257	20.8
Pool	123	10.0
Total	1233	100
Study Site 4		
Riffle	648	65.7
Glide	232	23.5
Pool	106	10.8
Total	986	100

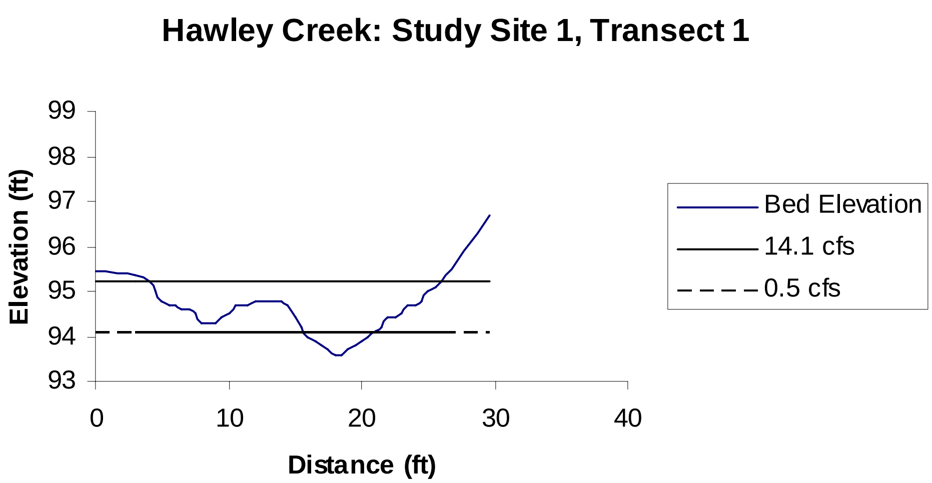
Eighteenmile Creek

	Distance Mapped (feet)	Proportions (%)
Study Site 1		
Riffle	794	22.0
Glide	2732	75.8
Pool	80	2.20
Total	3606	100
Study Site 2		
Riffle	528	92.3
Glide	44	7.70
Pool	0	0.00
Total	572	100
Study Site 3		
Riffle	683	49.3
Glide	517	37.4
Pool	184	13.3
Total	1384	100
Study Site 4		
Riffle	175	12.1
Glide	1143	79.0
Pool	129	8.90
Total	1447	100
Study Site 5		
Riffle	122	26.0
Glide	333	70.8
Pool	15	3.20
Total	470	100
Study Site 6		
Riffle	235	32.6
Glide	426	59.1
Pool	60	8.30
Total	721	100

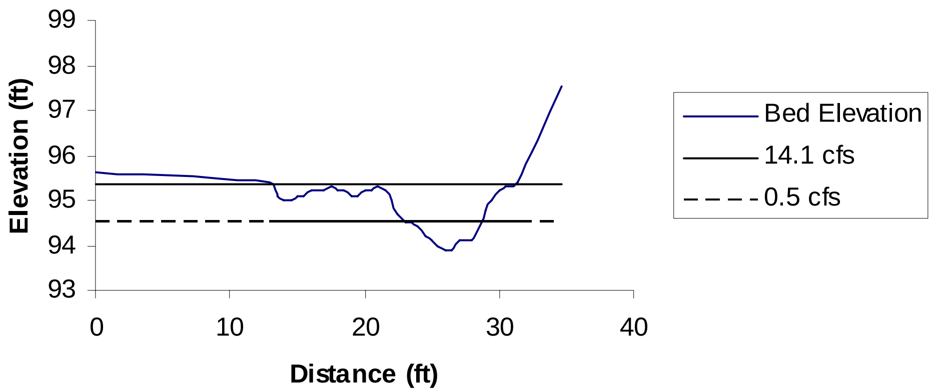
APPENDIX C – CROSS-SECTIONAL PROFILES AND MEASURED WATER SURFACE ELEVATIONS

Hawley Creek, Site 1

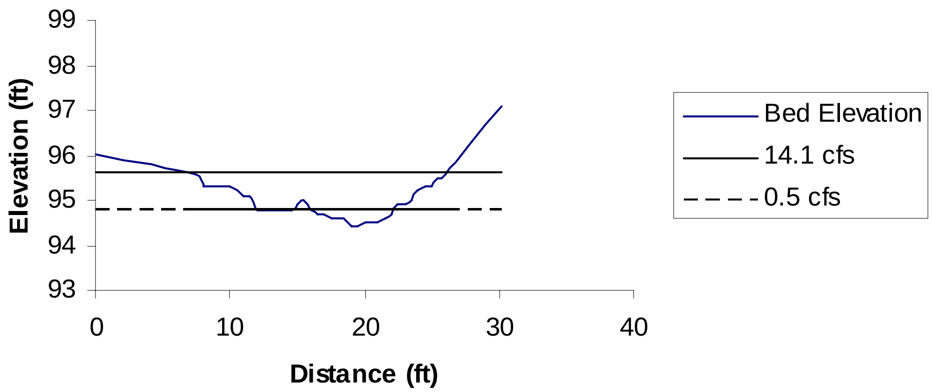




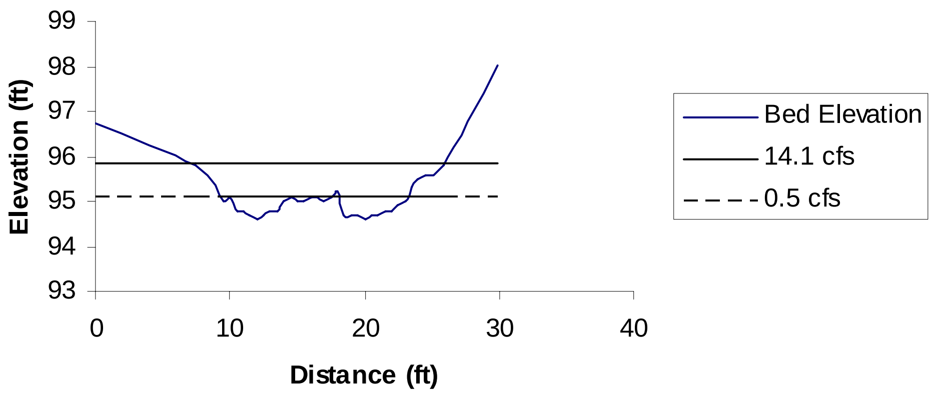
Hawley Creek: Study Site 1, Transect 2

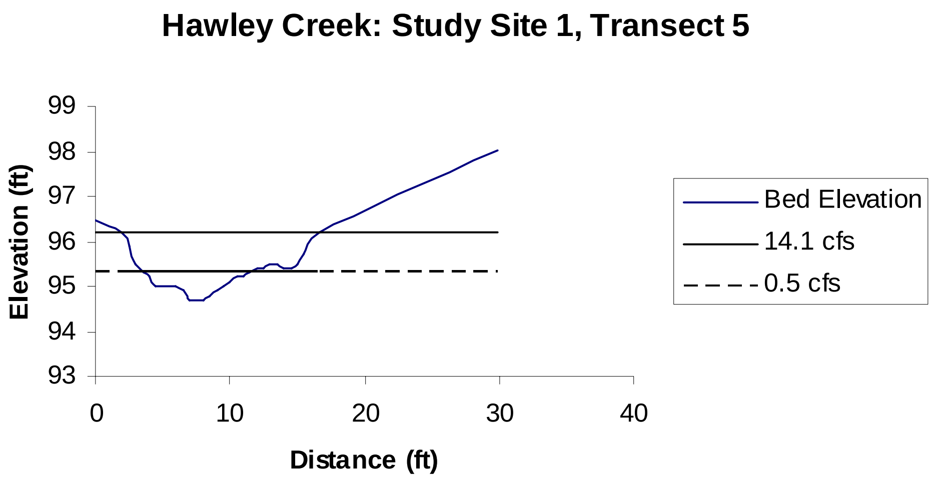


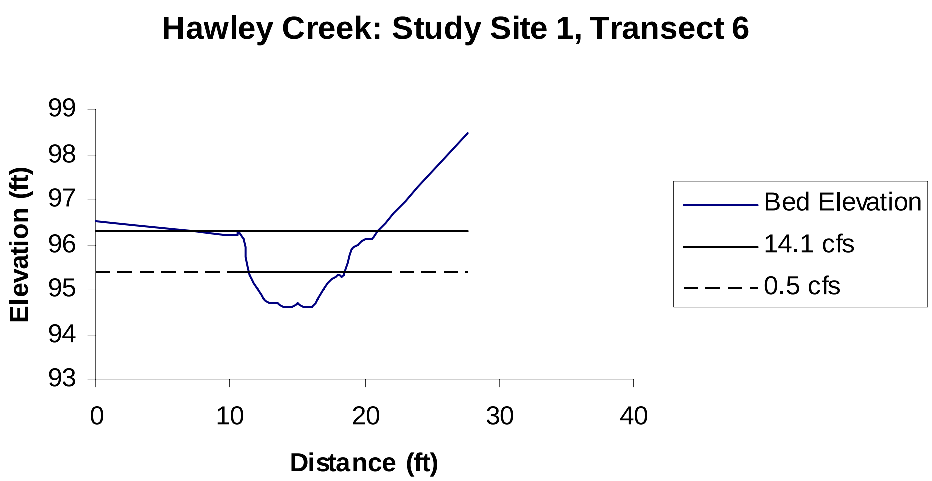
Hawley Creek: Study Site 1, Transect 3

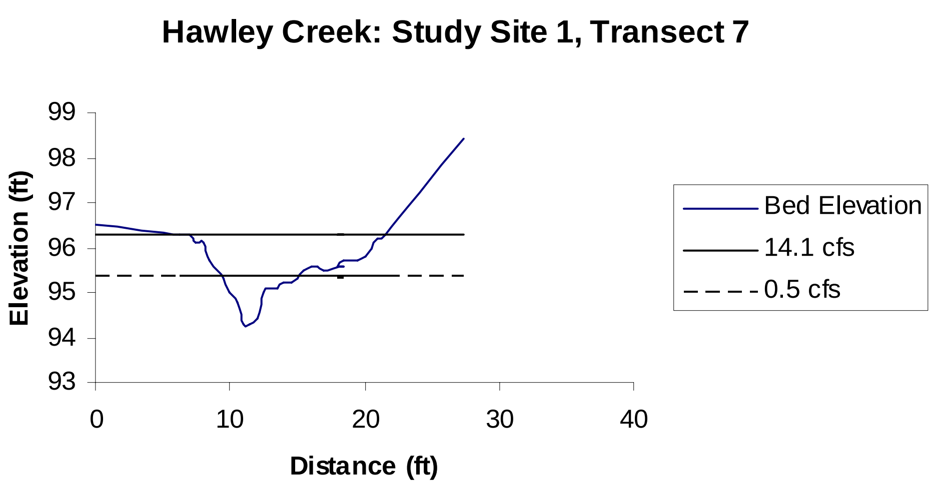


Hawley Creek: Study Site 1, Transect 4

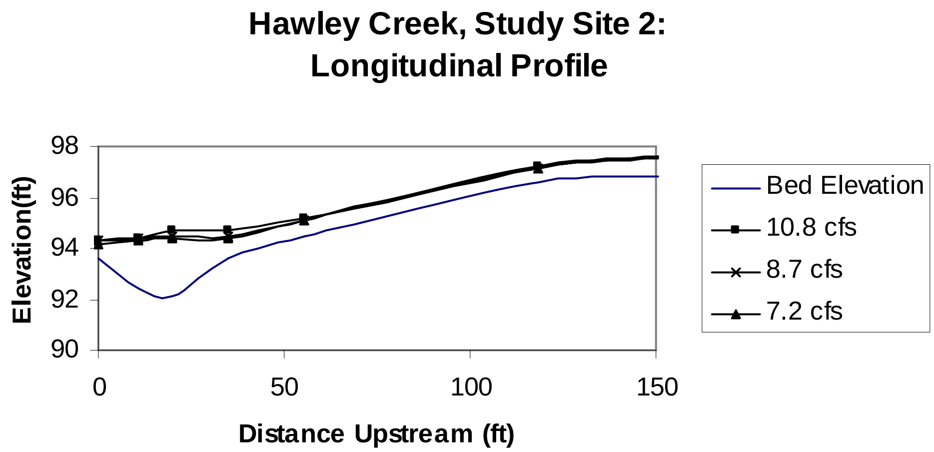


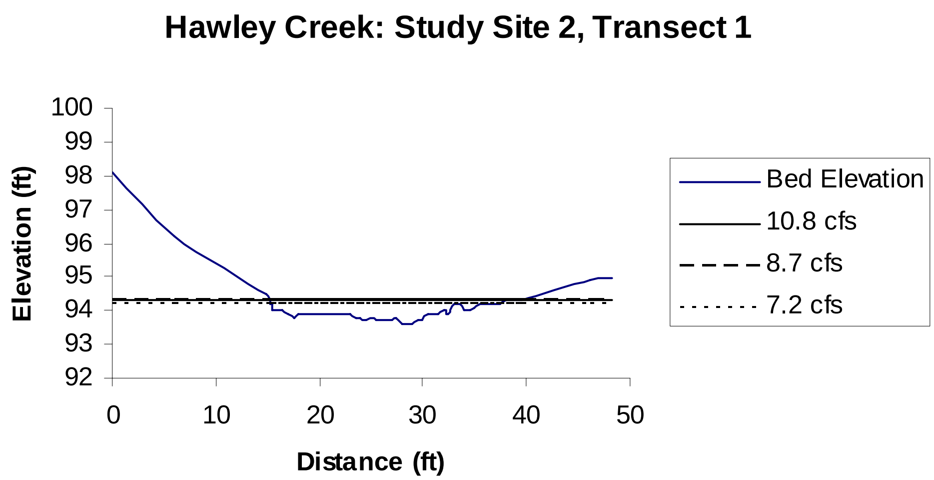

Hawley Creek: Study Site 1, Transect 5
Elevation (ft)
99
98
97
96
95
94
93
0
10
20
30
40
Distance (ft)
Bed Elevation
14.1 cfs
0.5 cfs

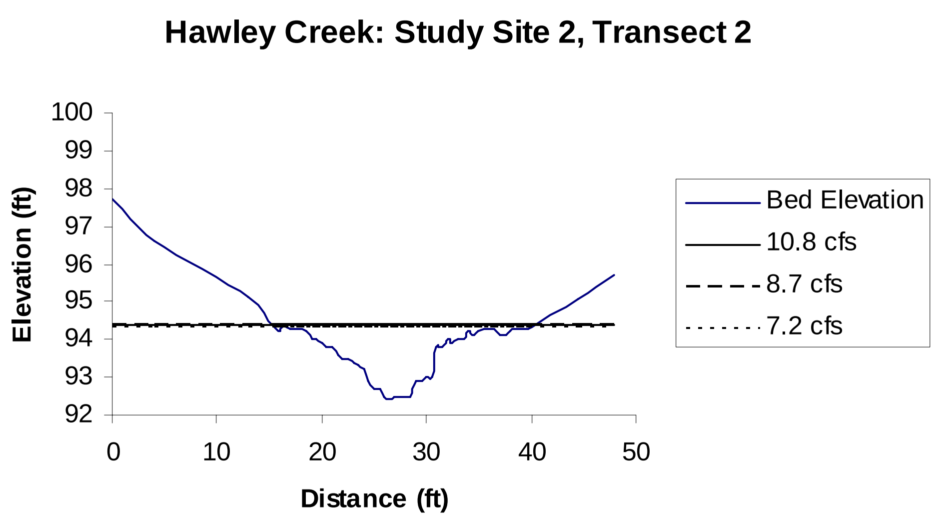

Hawley Creek: Study Site 1, Transect 6
Elevation (ft)
99
98
97
96
95
94
93
0
10
20
30
40
Distance (ft)
Bed Elevation
14.1 cfs
0.5 cfs


Hawley Creek: Study Site 1, Transect 7
Elevation (ft)
99
98
97
96
95
94
93
0
10
20
30
40
Distance (ft)
Bed Elevation
14.1 cfs
0.5 cfs

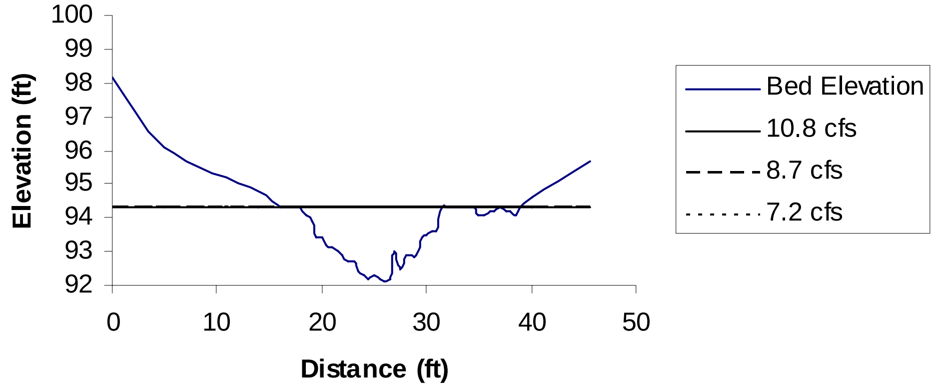
Hawley Creek, Site 2



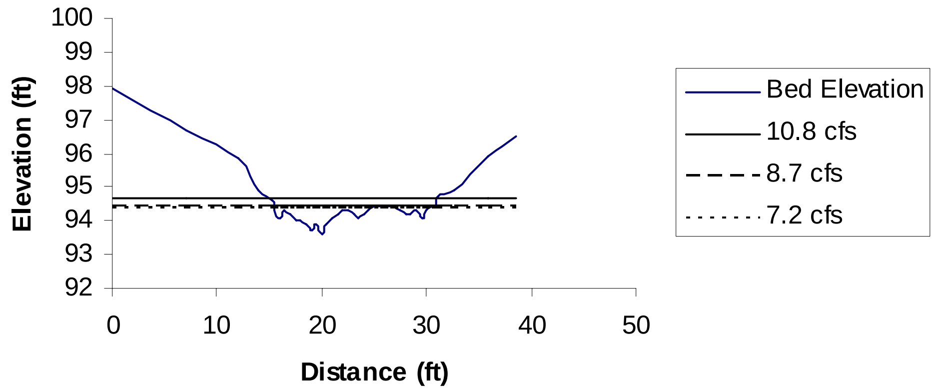




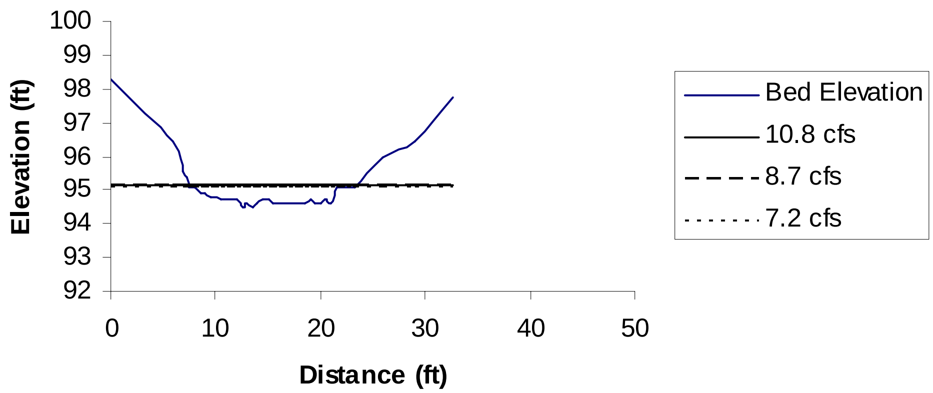
Hawley Creek: Study Site 2, Transect 3

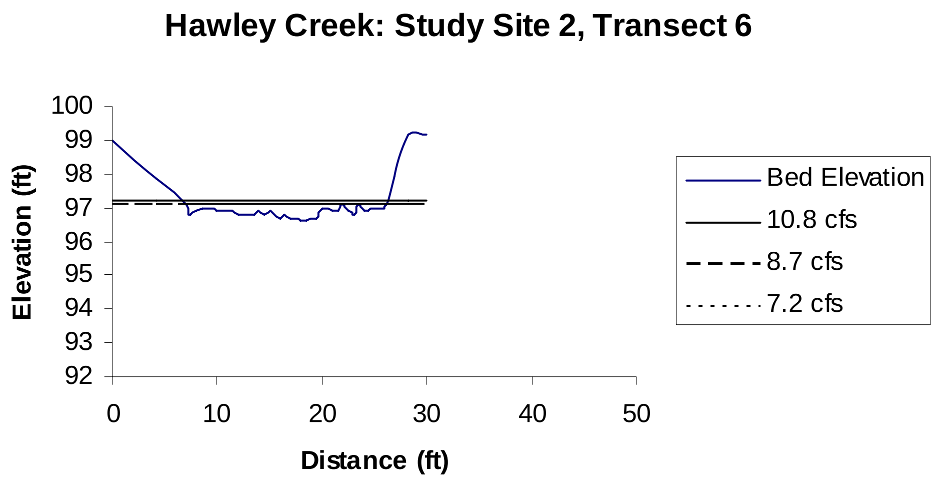


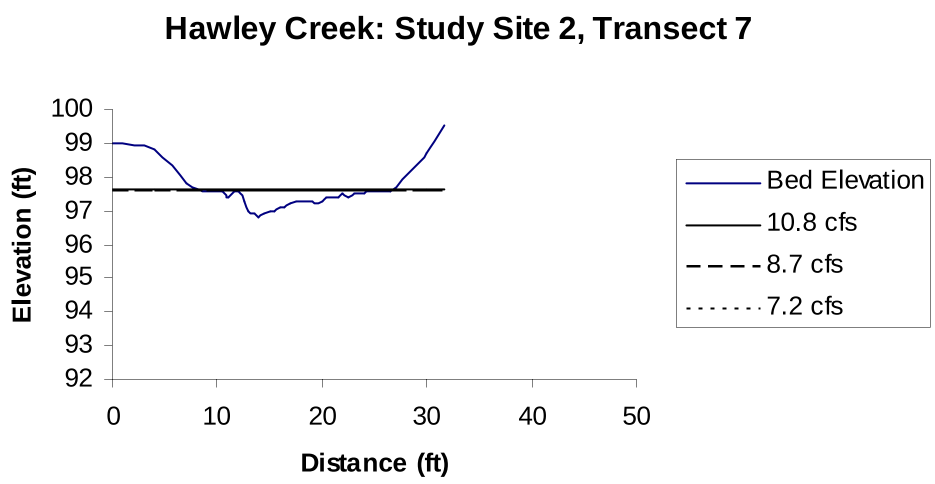
Hawley Creek: Study Site 2, Transect 4



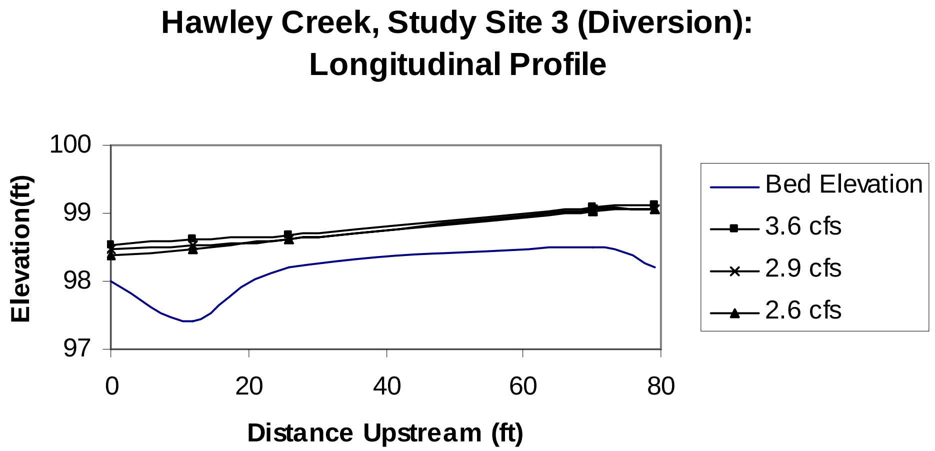
Hawley Creek: Study Site 2, Transect 5



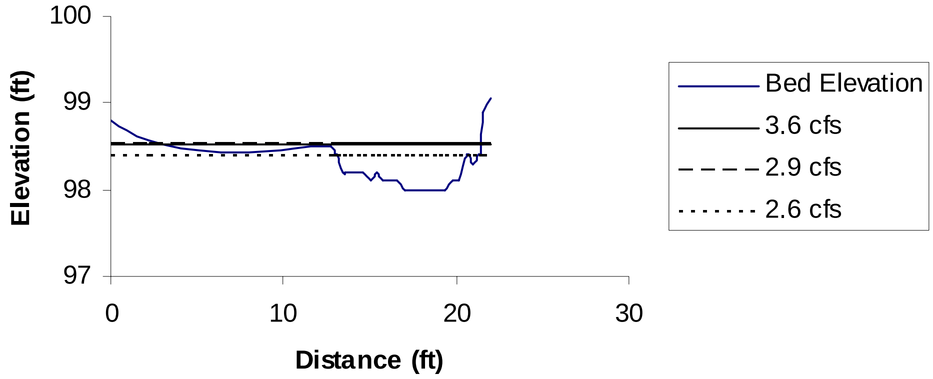




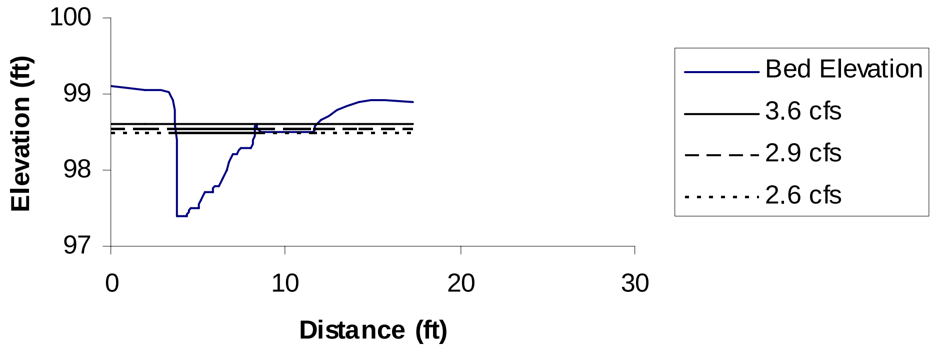
Hawley Creek, Site 3 (Diversion)



Hawley Creek: Study Site 3 (Diversion), Transect 1



Hawley Creek: Study Site 3 (Diversion), Transect 2



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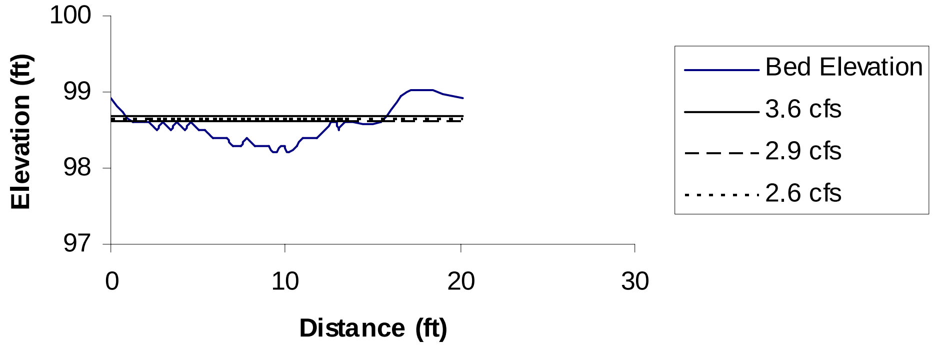
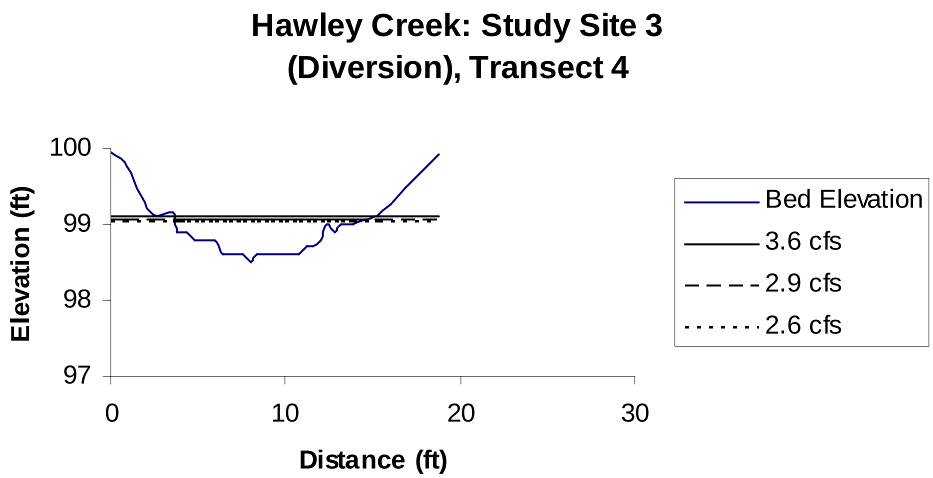
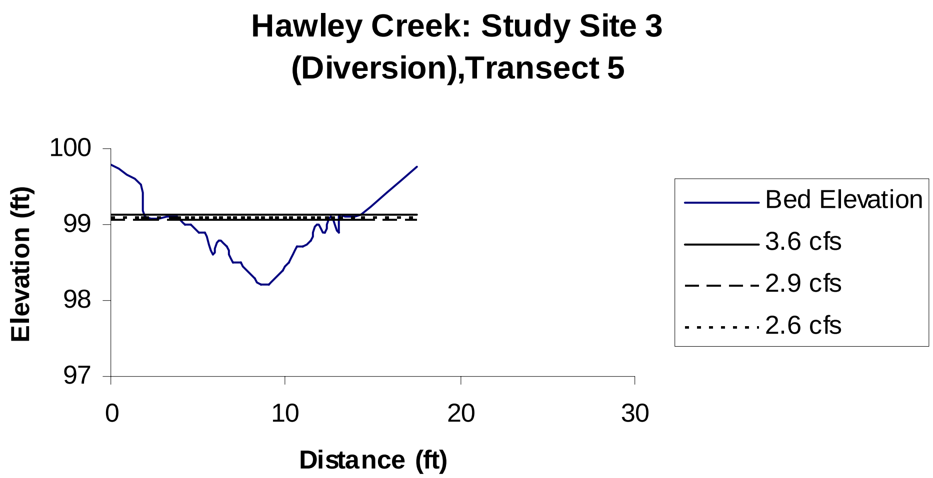
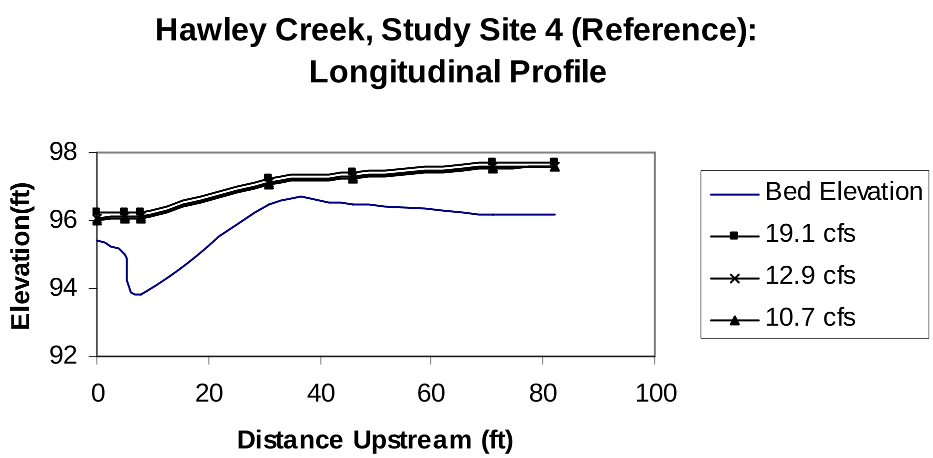
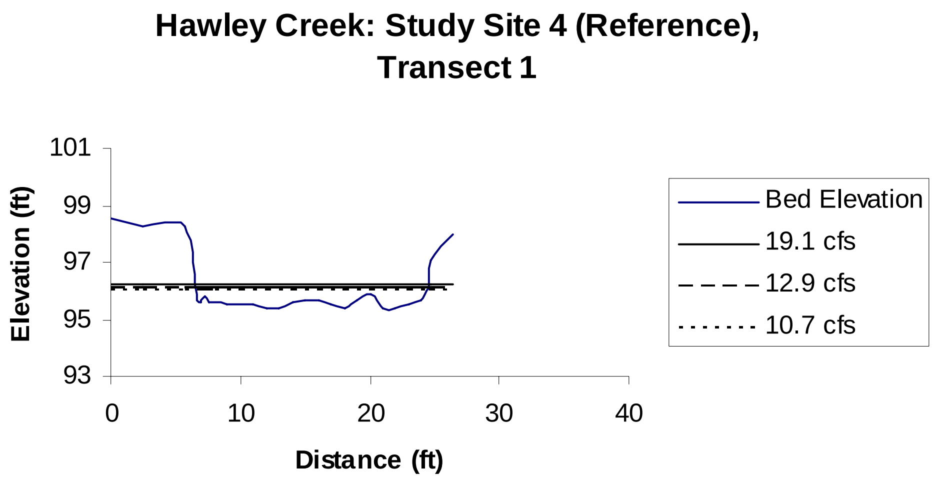


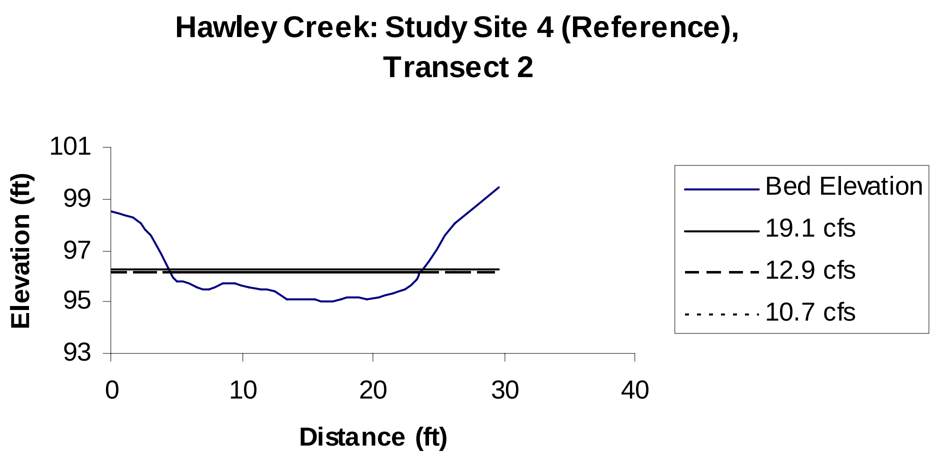


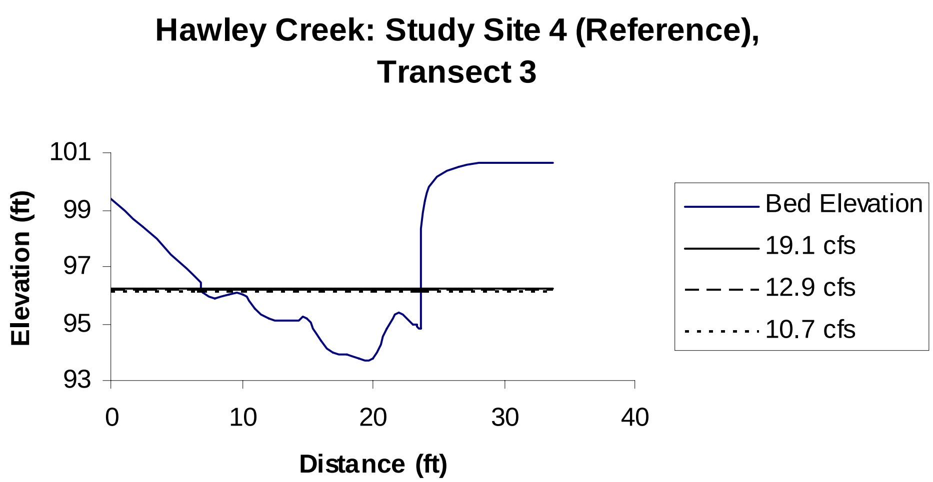


Hawley Creek, Site 4 (Reference)

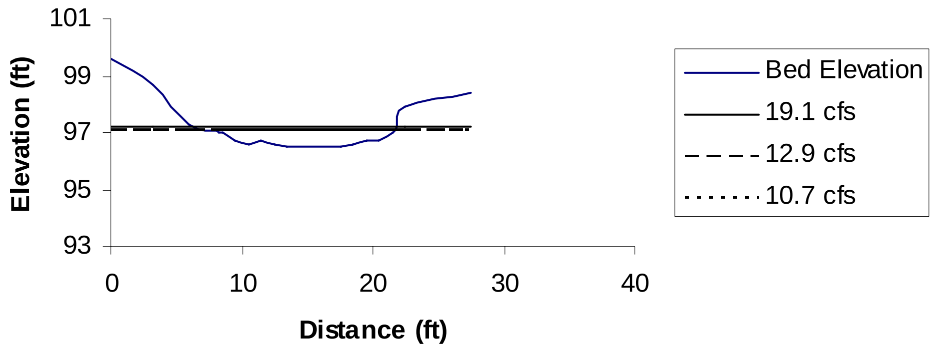



Hawley Creek: Study Site 4 (Reference), Transect 1
Elevation (ft)
101
99
97
95
93
0
10
20
30
40
Distance (ft)
Bed Elevation
19.1 cfs
12.9 cfs
10.7 cfs

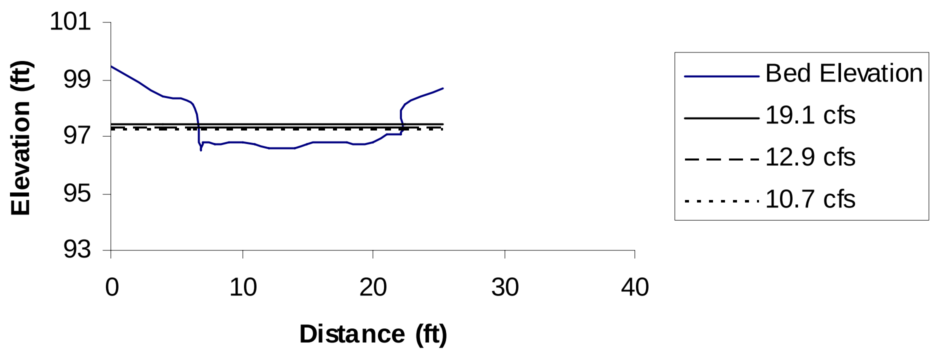

Hawley Creek: Study Site 4 (Reference), Transect 2
Elevation (ft)
101
99
97
95
93
0
10
20
30
40
Distance (ft)
Bed Elevation
19.1 cfs
12.9 cfs
10.7 cfs


Hawley Creek: Study Site 4 (Reference), Transect 3
Elevation (ft)
101
99
97
95
93
0
10
20
30
40
Distance (ft)
Bed Elevation
19.1 cfs
12.9 cfs
10.7 cfs

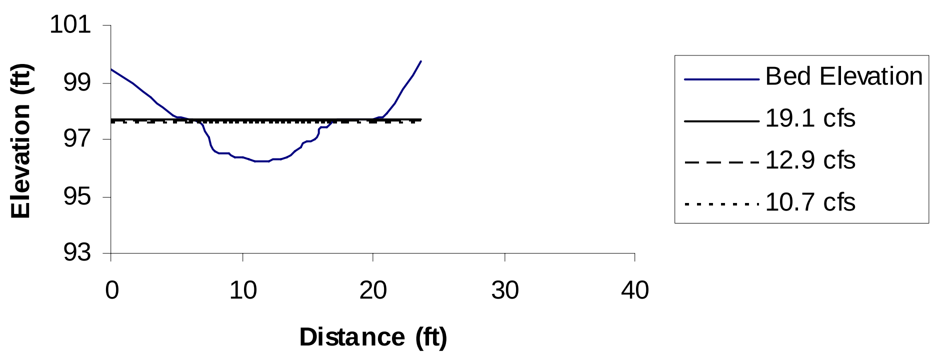
Hawley Creek: Study Site 4 (Reference), Transect 4

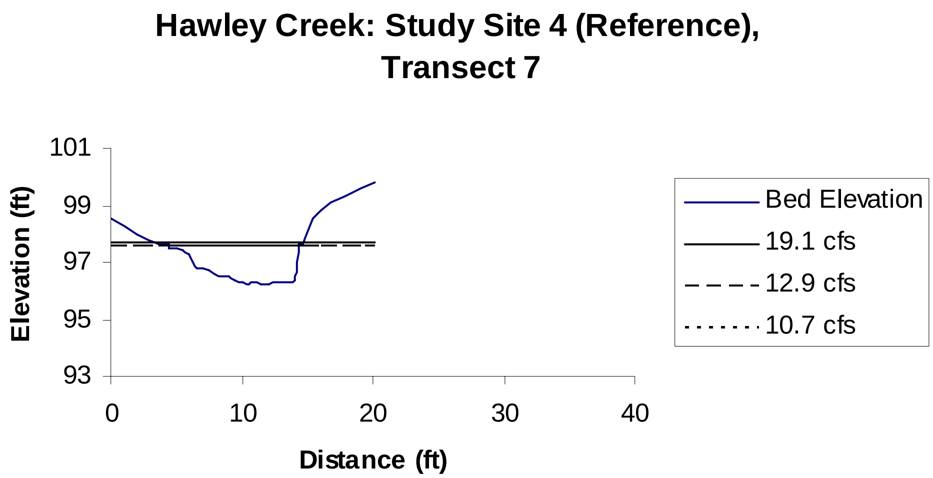


Hawley Creek: Study Site 4 (Reference), Transect 5

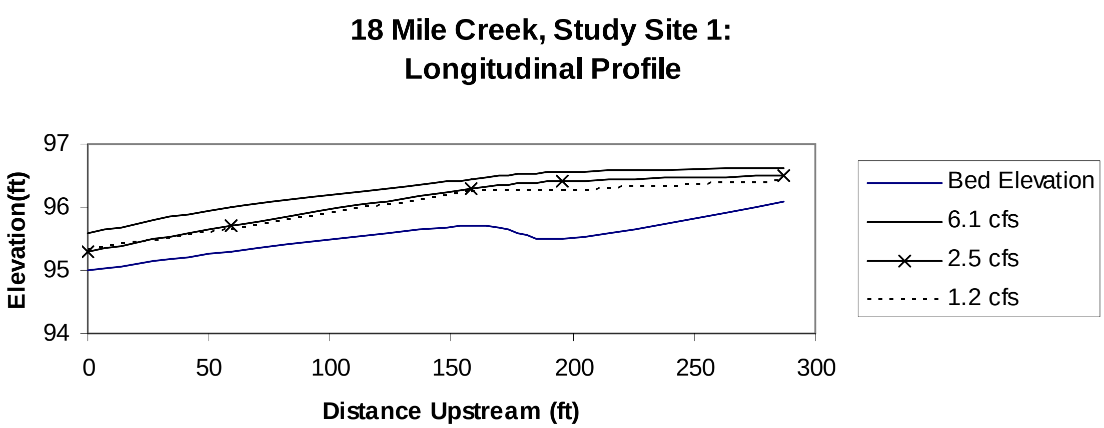


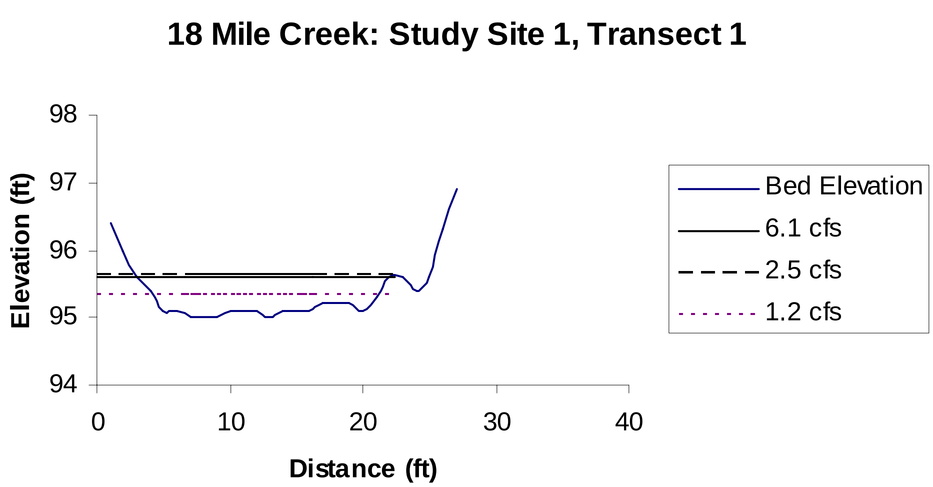
Hawley Creek: Study Site 4 (Reference), Transect 6



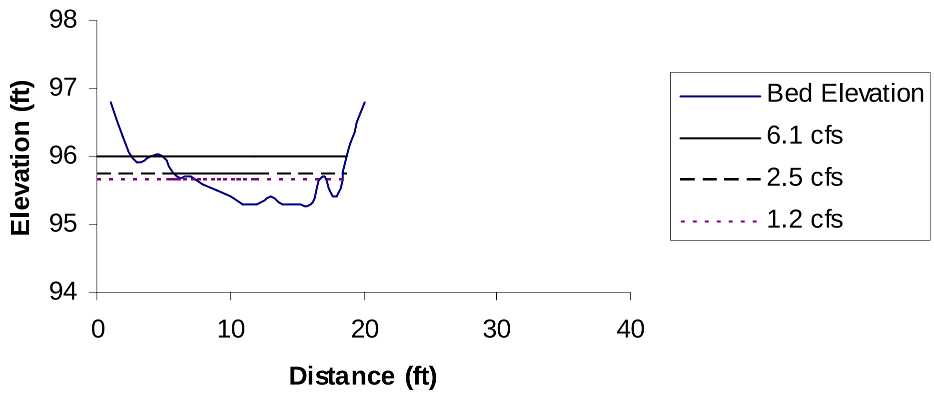


Eighteenmile Creek, Site 1

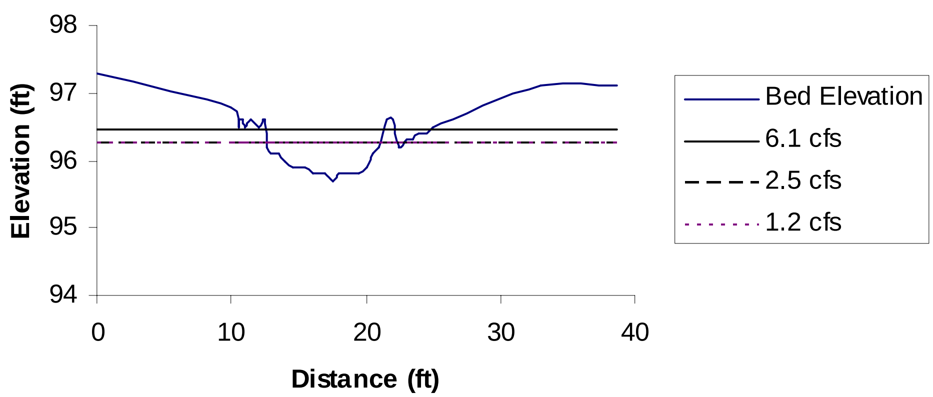




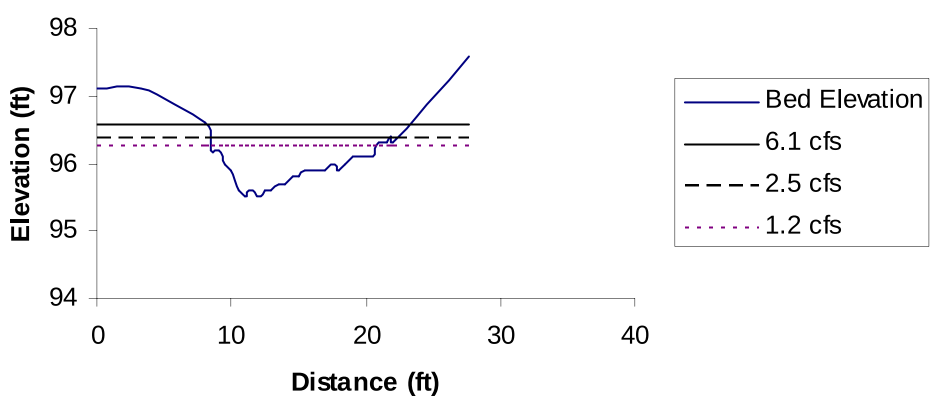
18 Mile Creek: Study Site 1, Transect 2

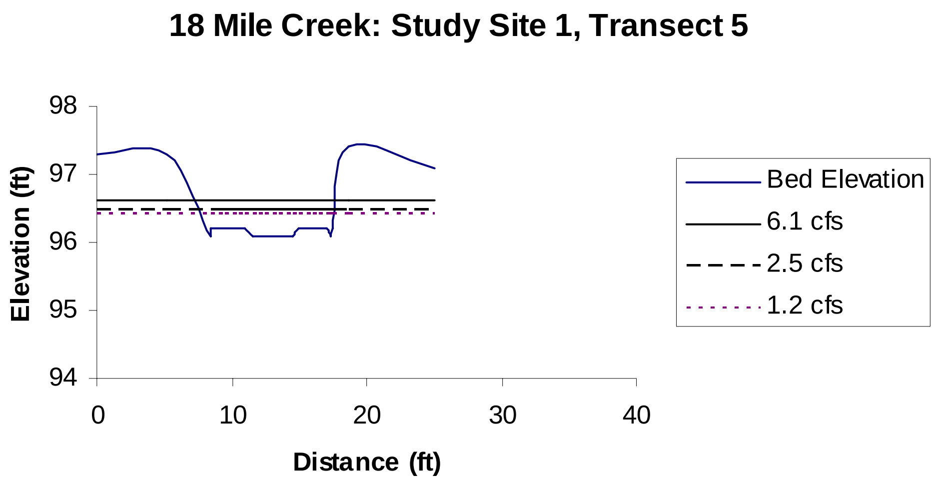


18 Mile Creek: Study Site 1, Transect 3

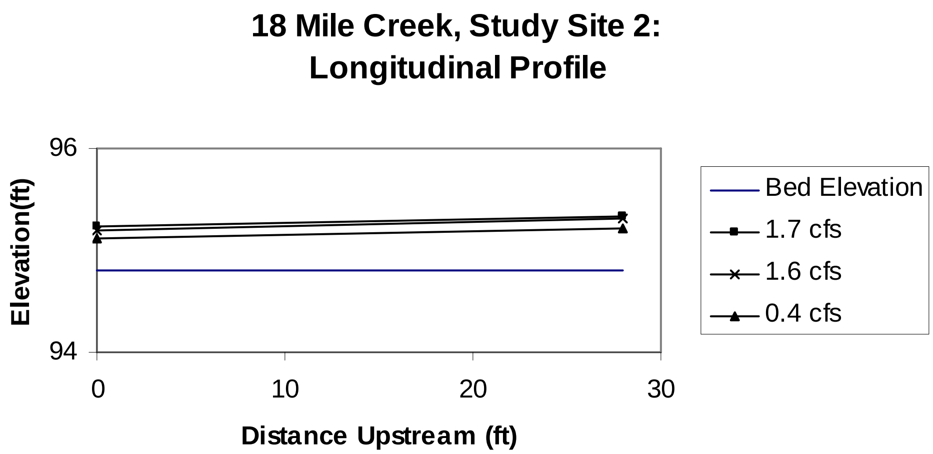


18 Mile Creek: Study Site 1, Transect 4

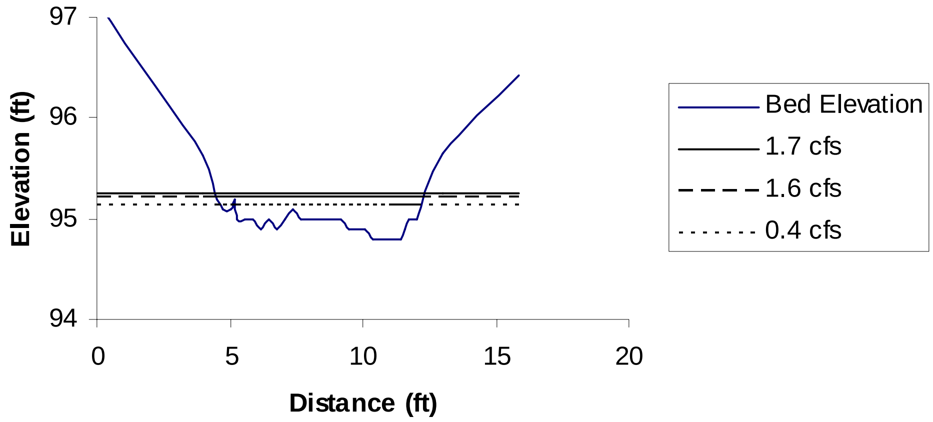




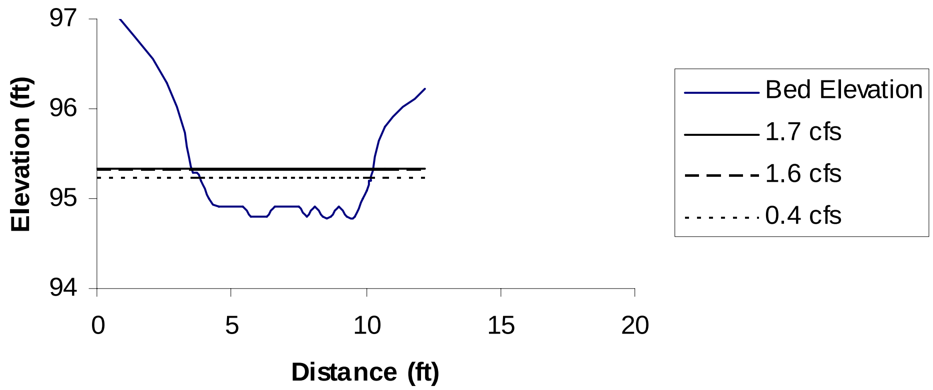
Eighteenmile Creek, Site 2



18 Mile Creek: Study Site 2, Transect 1

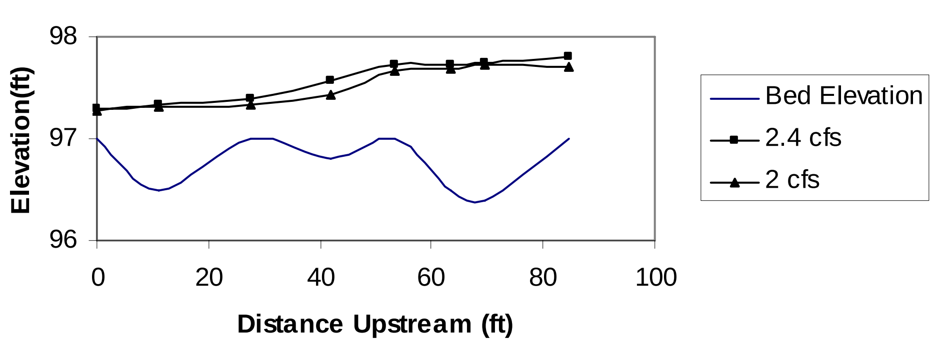


18 Mile Creek: Study Site 2, Transect 2

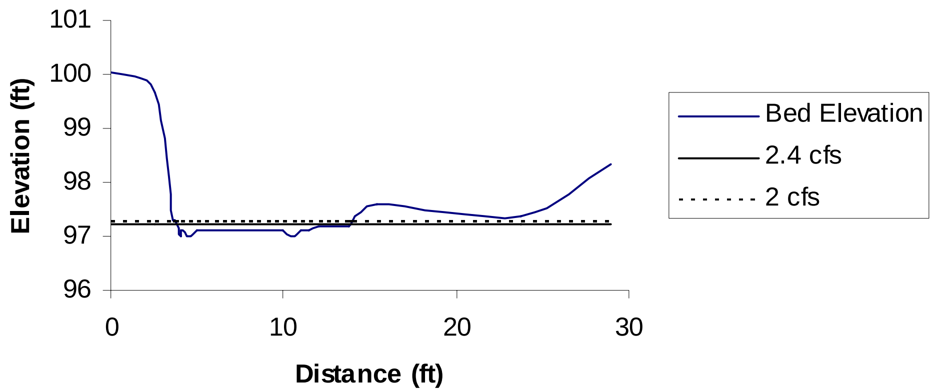


Eighteenmile Creek, Site 3

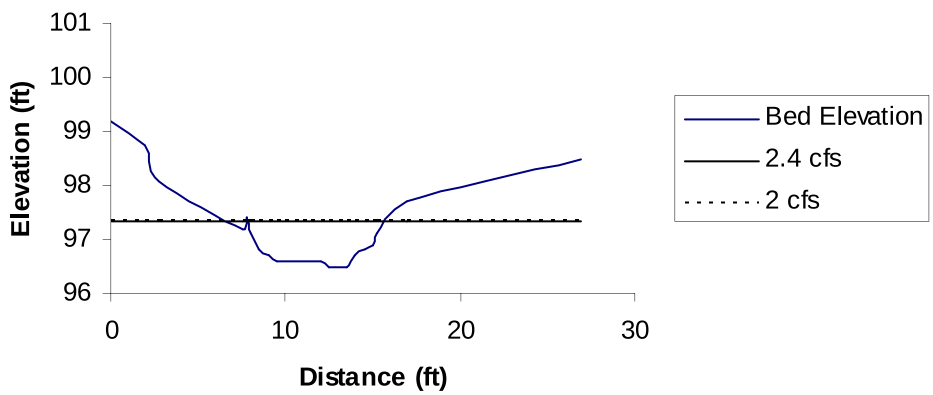
18 Mile Creek, Study Site 3: Longitudinal Profile



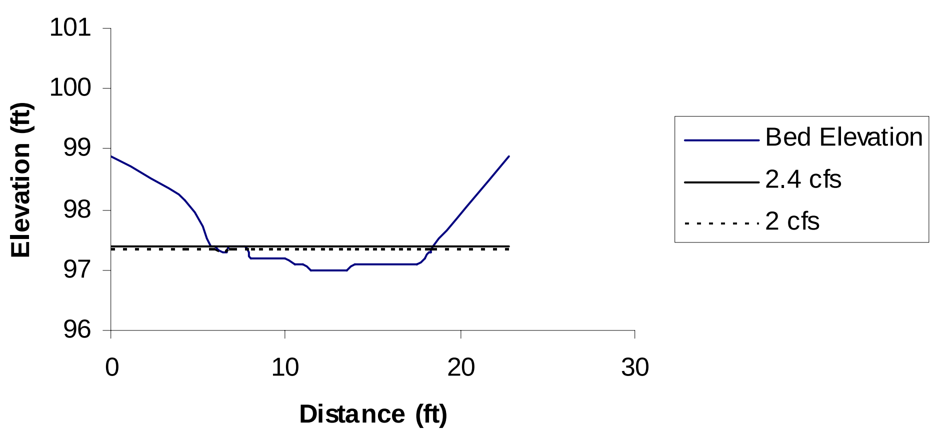
18 Mile Creek: Study Site 3, Transect 1



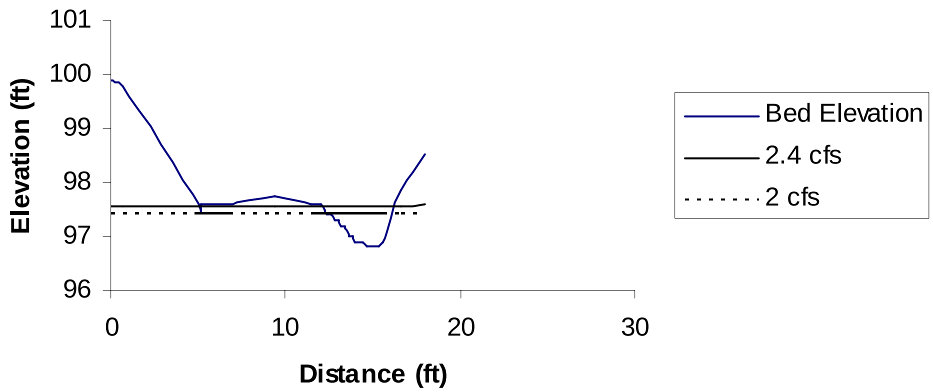
18 Mile Creek: Study Site 3, Transect 2



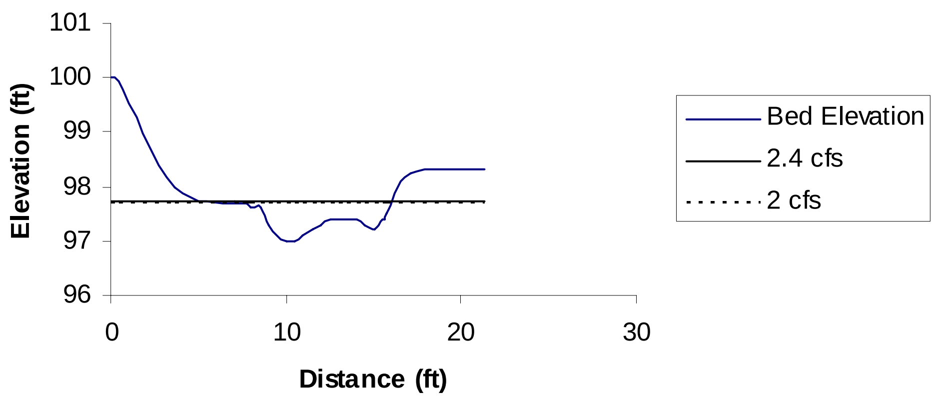
18 Mile Creek: Study Site 3, Transect 3



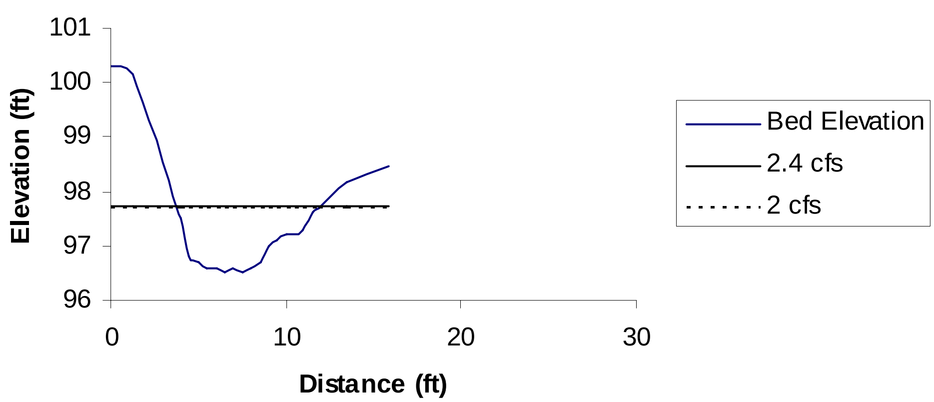
18 Mile Creek: Study Site 3, Transect 4

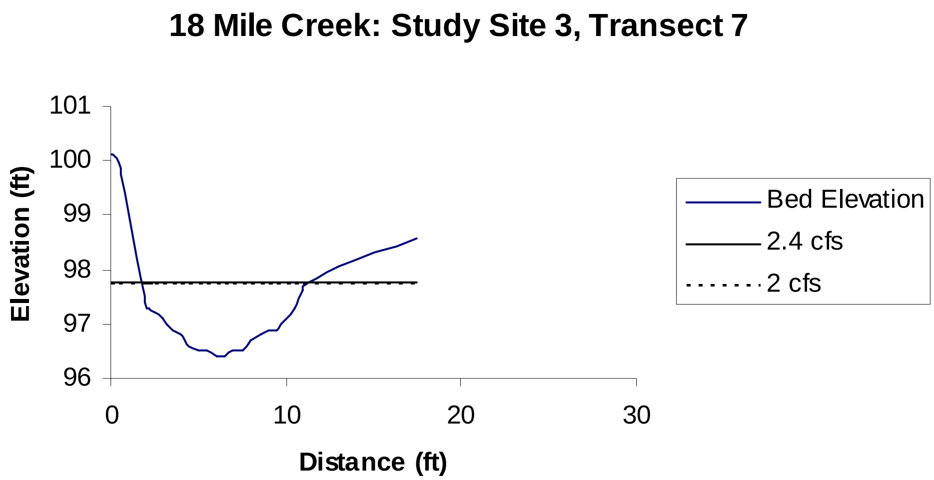


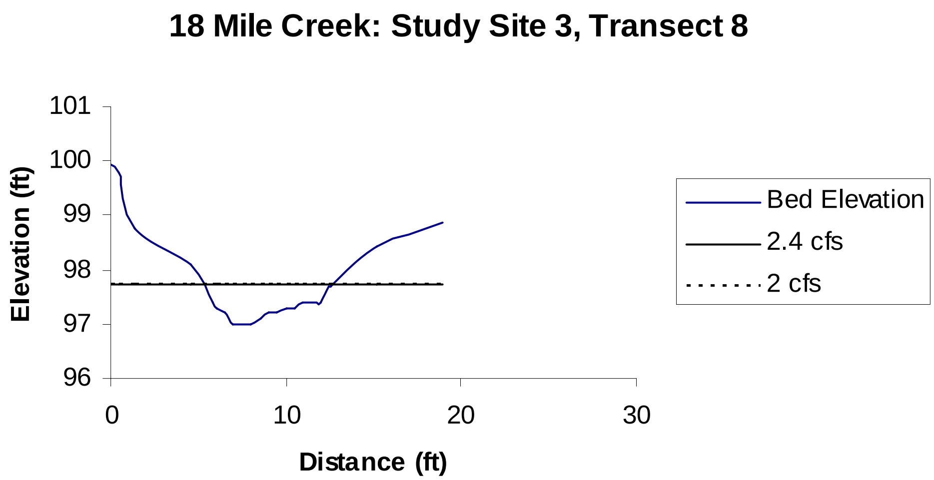
18 Mile Creek: Study Site 3, Transect 5



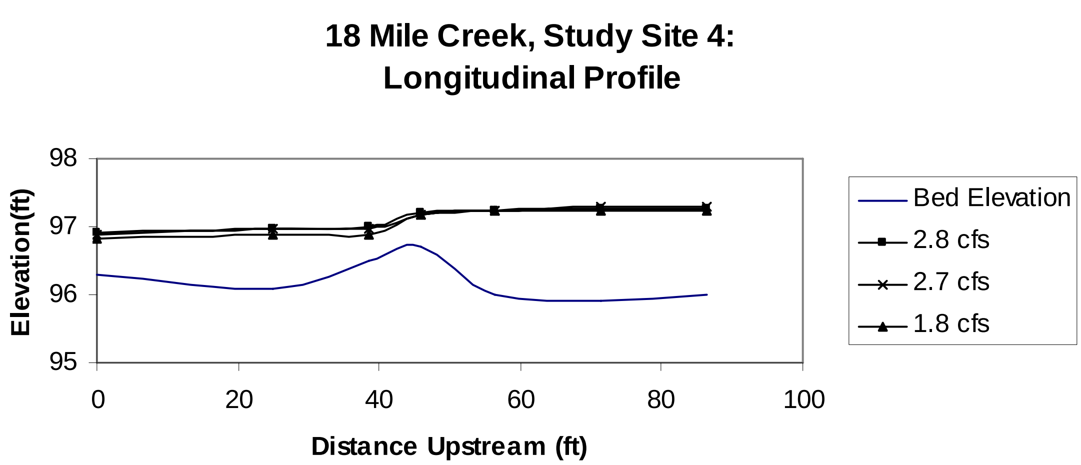
18 Mile Creek: Study Site 3, Transect 6



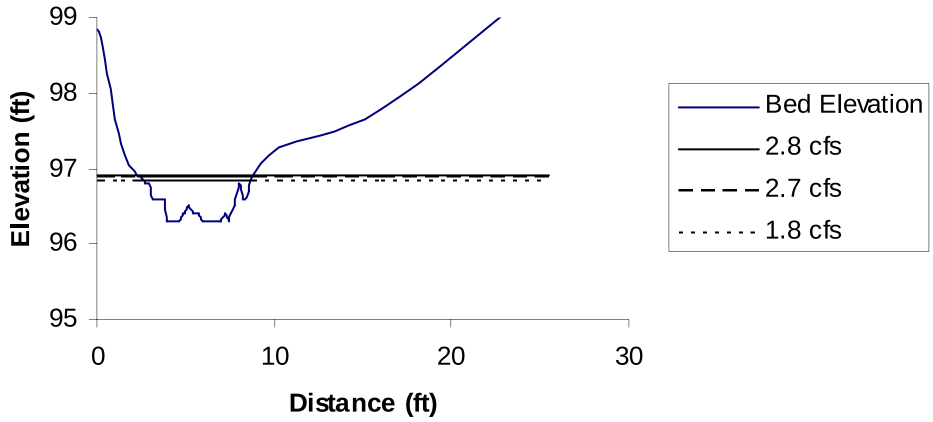




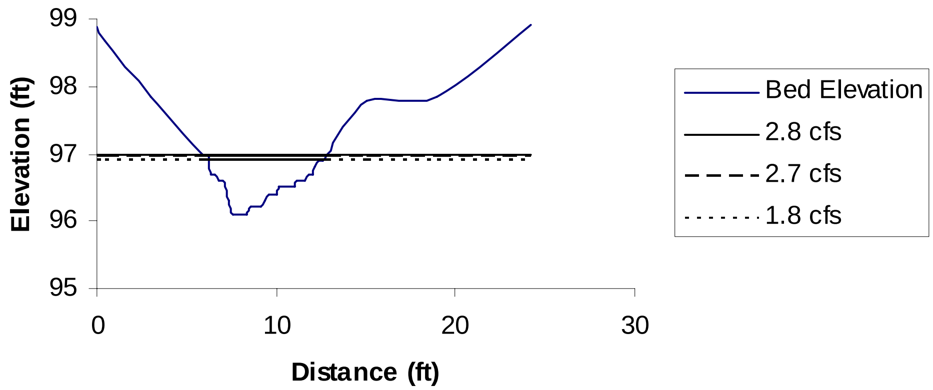
Eighteenmile Creek, Site 4



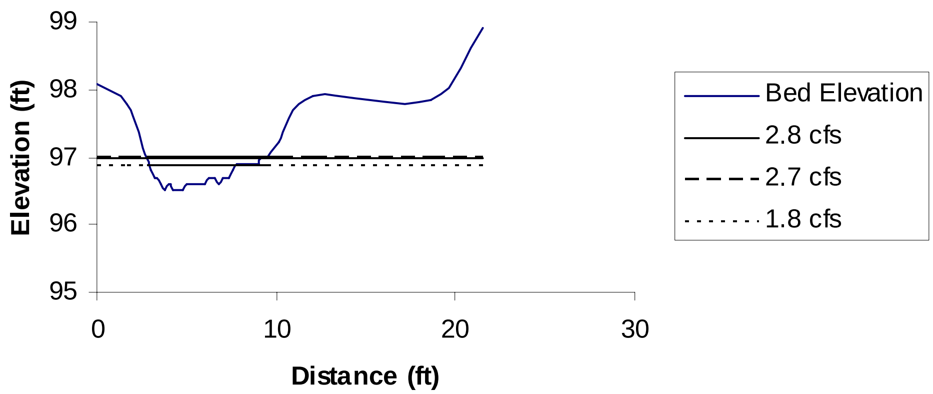
18 Mile Creek: Study Site 4, Transect 1



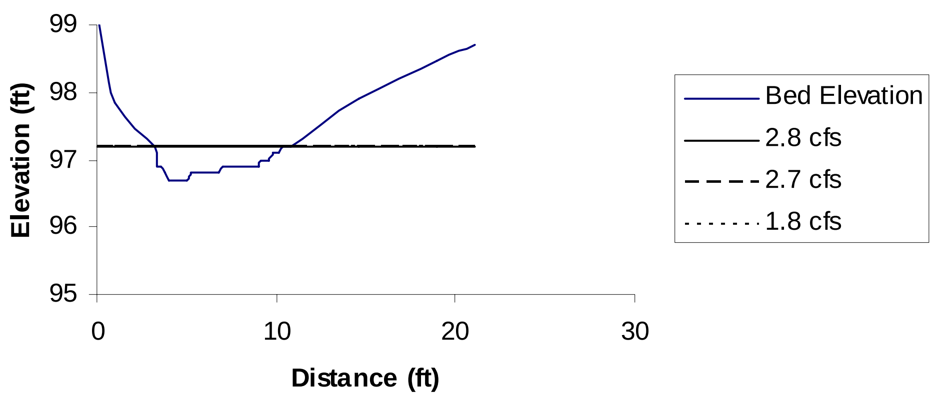
18 Mile Creek: Study Site 4, Transect 2



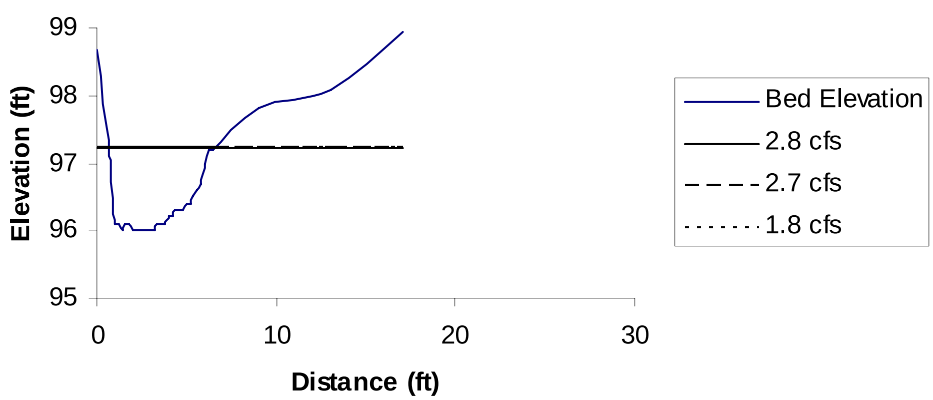
18 Mile Creek: Study Site 4, Transect 3



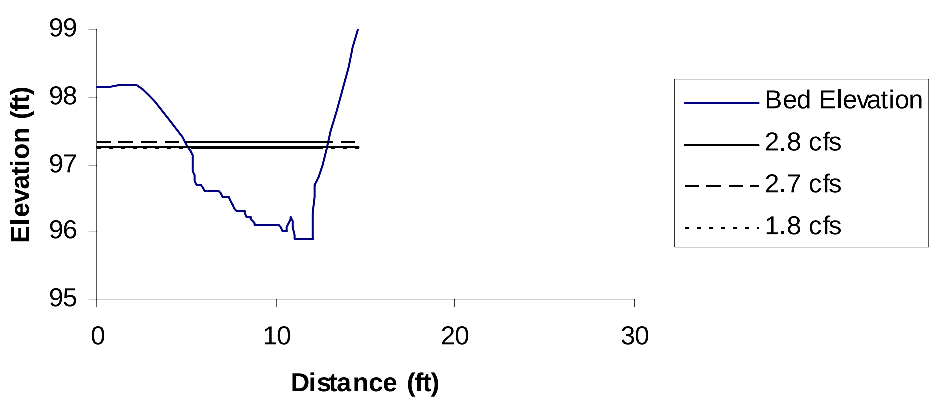
18 Mile Creek: Study Site 4, Transect 4



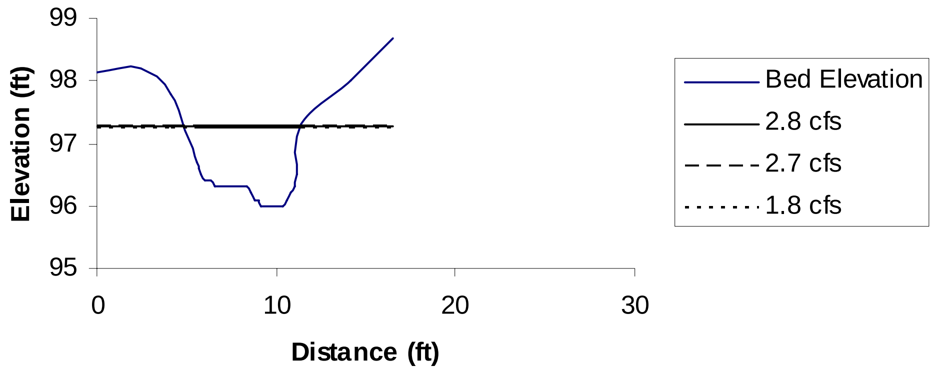
18 Mile Creek: Study Site 4, Transect 5



18 Mile Creek: Study Site 4, Transect 6

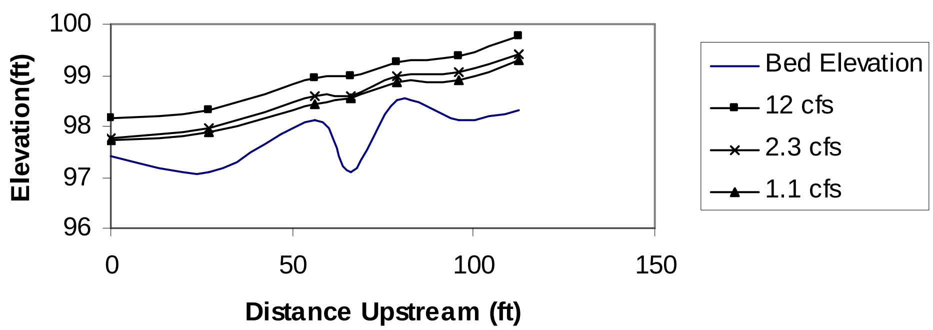


18 Mile Creek: Study Site 4, Transect 7

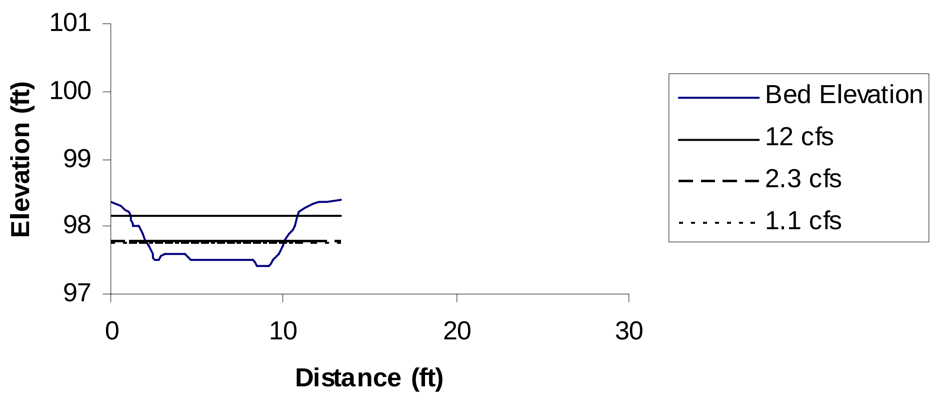


Eighteenmile Creek, Site 5

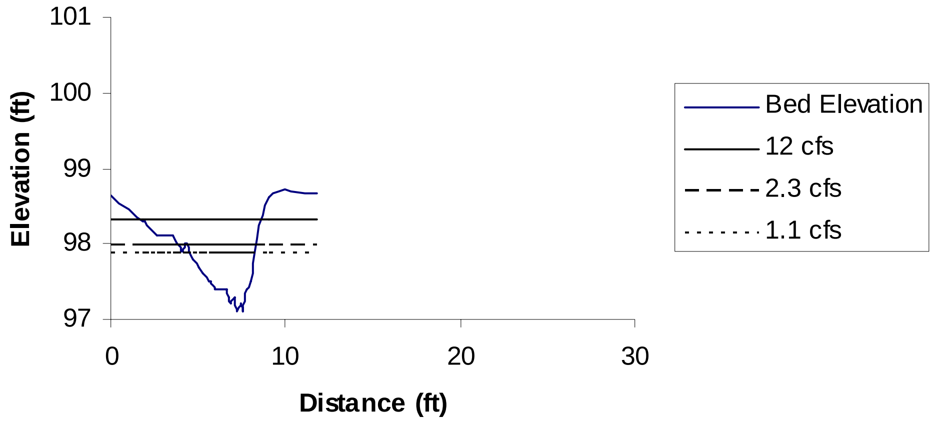
18 Mile Creek, Study Site 5: Longitudinal Profile



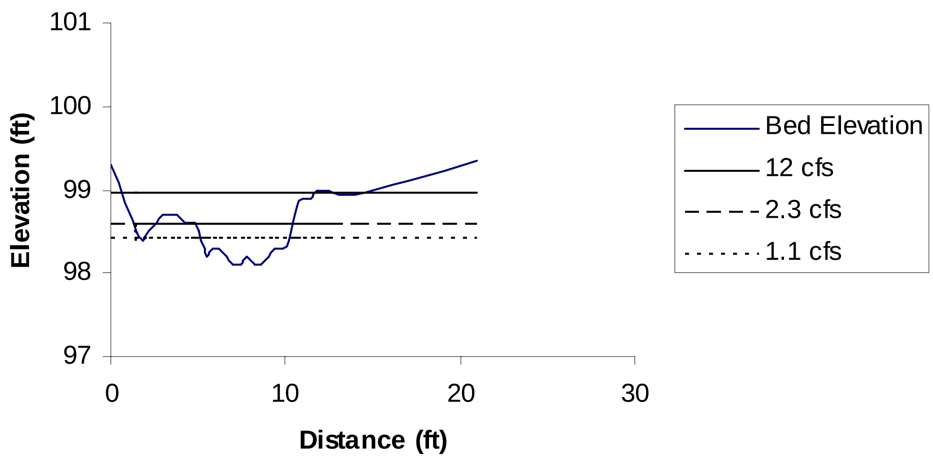
18 Mile Creek: Study Site 5, Transect 1



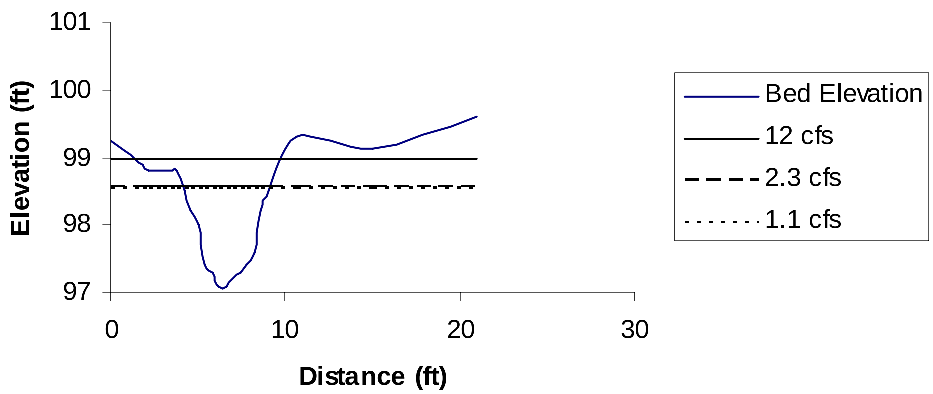
18 Mile Creek: Study Site 5, Transect 2



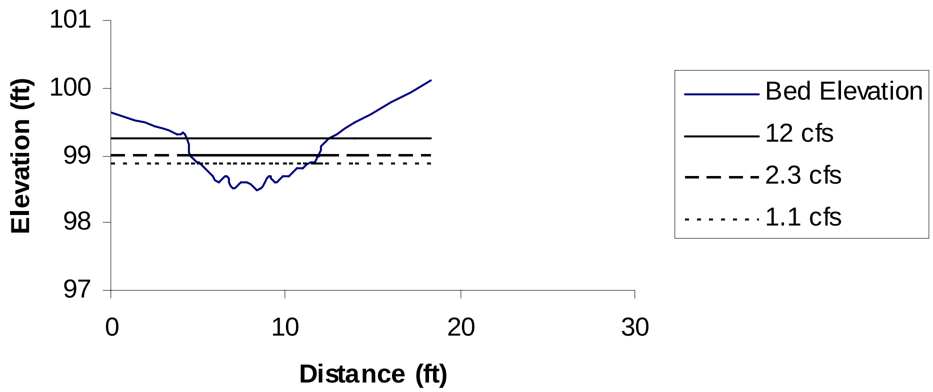
18 Mile Creek: Study Site 5, Transect 3



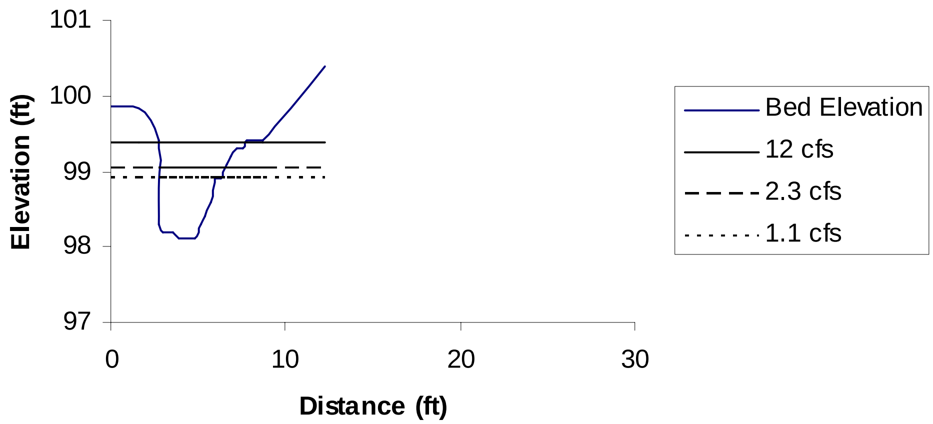
18 Mile Creek: Study Site 5, Transect 4



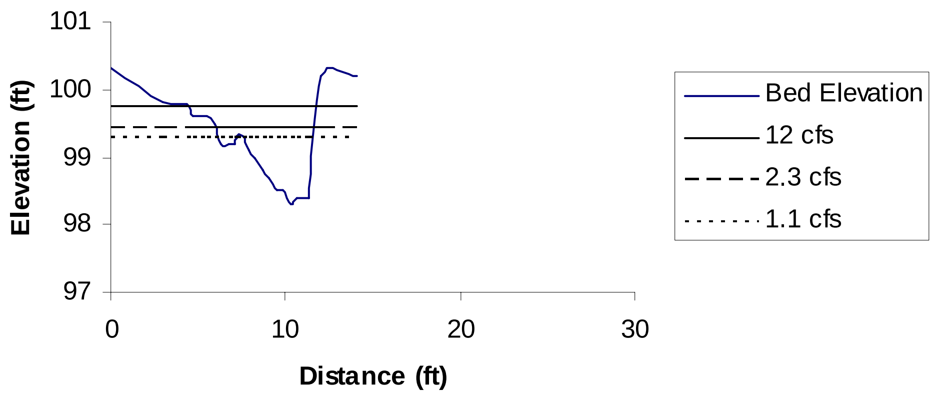
18 MIle Creek: Study Site 5, Transect 5



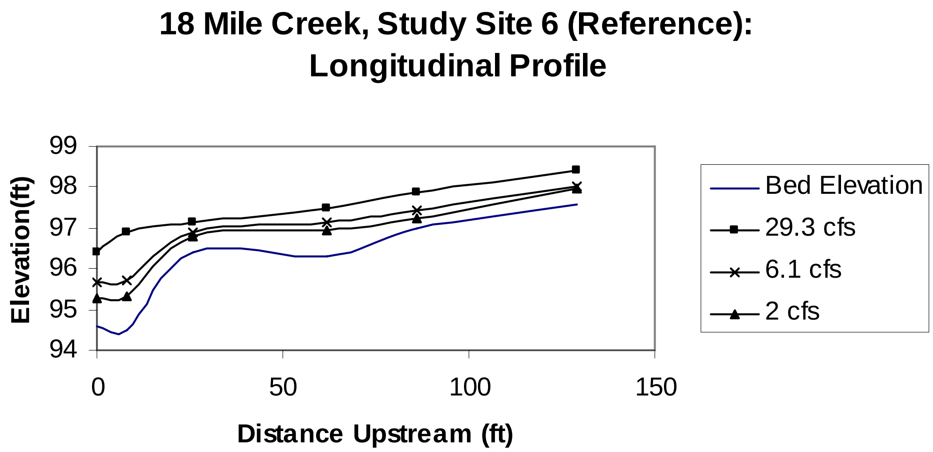
18 Mile Creek: Study Site 5, Transect 6

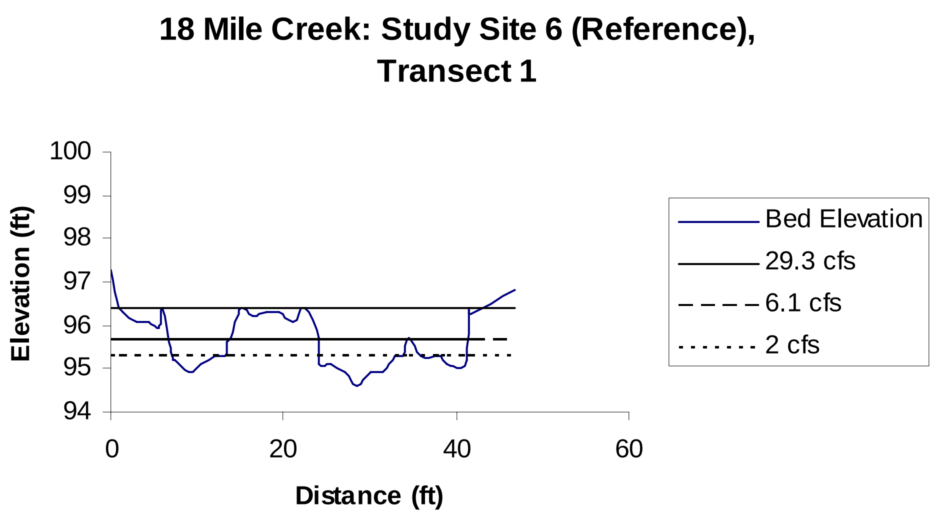


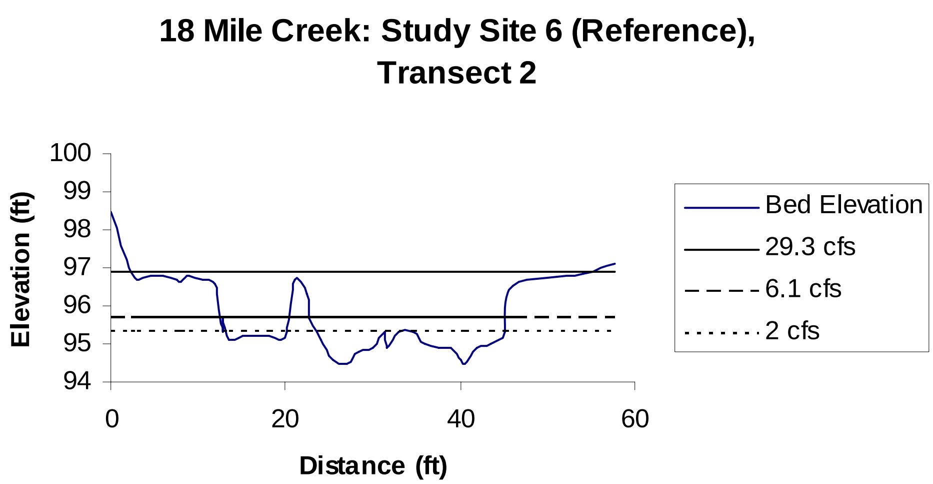
18 Mile Creek: Study Site 5, Transect 7



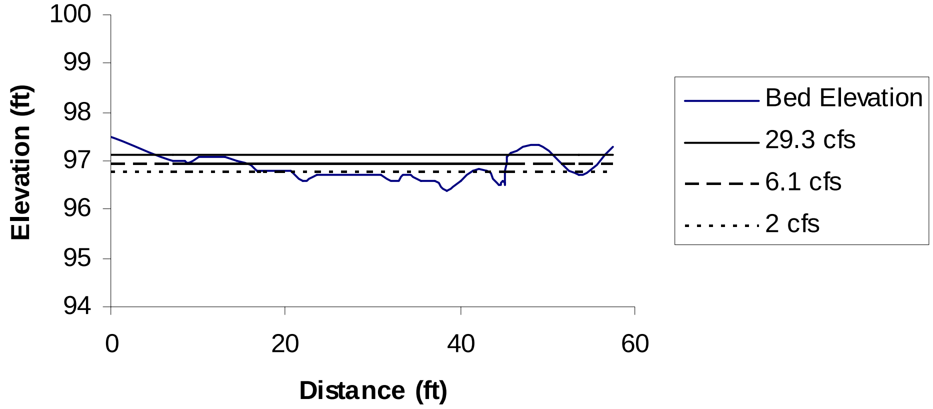
Eighteenmile Creek, Site 6



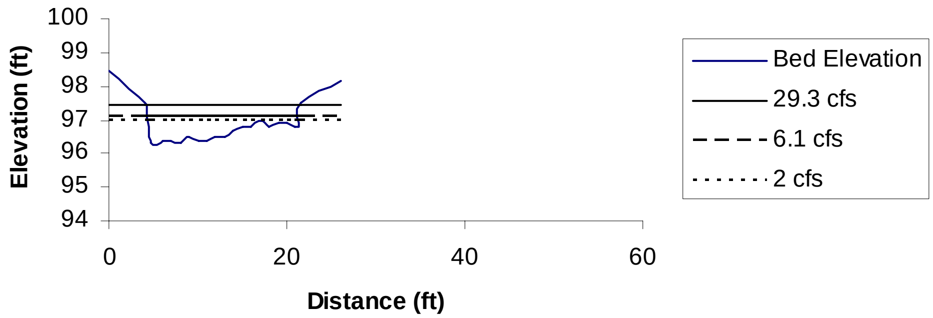




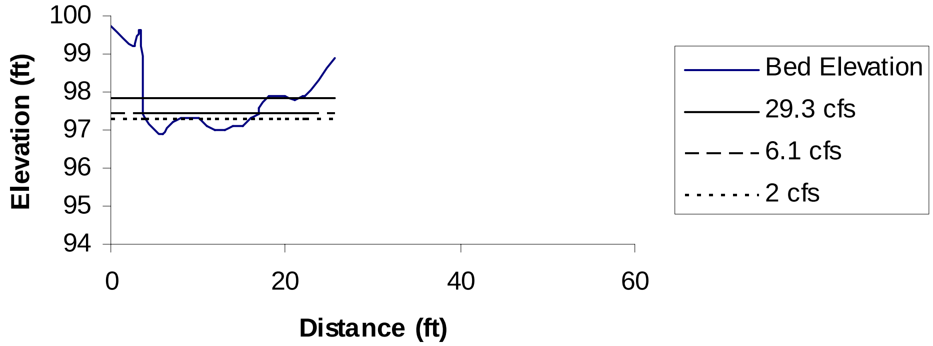
18 Mile Creek: Study Site 6 (Reference), Transect 3



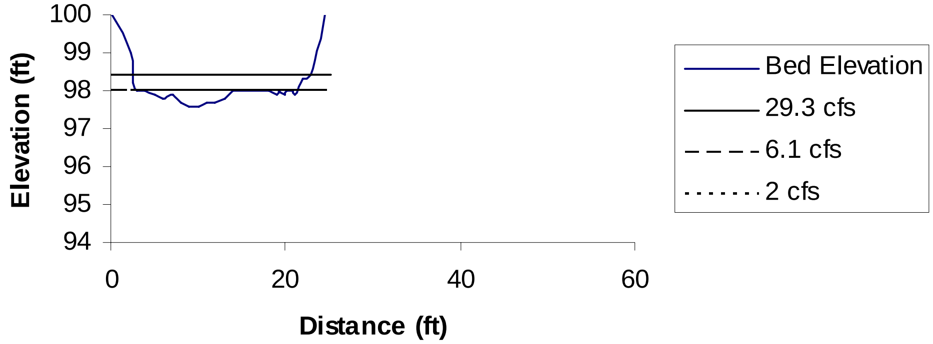
18 Mile Creek: Study Site 6 (Reference), Transect 4



18 Mile Creek: Study Site 6 (Reference), Transect 5



18 Mile Creek: Study Site 6 (Reference), Transect 6



APPENDIX D – HYDRAULIC CALIBRATION RESULTS

Table D-1 Water surface elevation calibration results (ft) for Hawley Creek, Site 1 using MANSQ for transects 1-4 and WSP for transects 5-7.

Transect	Distance from next downstream transect (ft)	0.5 cfs			14.1 cfs			N/A		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	94.070	94.120	0.050	95.230	95.230	0.000	N/A	N/A	N/A
2	35	94.510	94.489	-0.021	95.380	95.375	-0.005	N/A	N/A	N/A
3	35	94.790	94.796	0.006	95.610	95.610	0.000	N/A	N/A	N/A
4	17	95.090	95.094	0.004	95.830	95.825	-0.005	N/A	N/A	N/A
5	15	95.320	95.320	0.000	96.200	96.200	0.000	N/A	N/A	N/A
6	8	95.340	95.320	-0.020	96.250	96.200	-0.050	N/A	N/A	N/A
7	12	95.330	95.321	-0.009	96.270	96.220	-0.046	N/A	N/A	N/A

Table D-2 Water surface elevation calibration results (ft) for Hawley Creek, Site 2 using the WSP model for transects 1-3 and the STGQ model for transects 4-7.

Transect	Distance from next downstream transect (ft)	7.2 cfs			8.7 cfs			10.8 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	94.200	94.200	0.000	94.280	94.280	0.000	94.290	94.290	0.000
2	10.5	94.300	94.249	-0.051	94.320	94.331	0.011	94.330	94.364	0.034
3	9.5	94.300	94.262	-0.038	94.320	94.346	0.026	94.330	94.385	0.055
4	15	94.460	94.512	0.052	94.570	94.549	-0.021	94.590	94.595	0.005
5	20.5	95.050	95.056	0.006	95.120	95.089	-0.031	95.150	95.150	-0.000
6	63	97.100	97.134	0.034	97.120	97.157	0.037	97.180	97.185	0.005
7	32	97.540	97.528	-0.012	97.580	97.554	-0.026	97.640	97.615	-0.025

Table D-3 Water surface elevation calibration results (ft) for Hawley Creek Site 3 (Diversion) using the WSP model for transects 1-2 and 4-5 and MANSQ for transect 3.

Transect	Distance from next downstream transect (ft)	2.6 cfs			2.9 cfs			3.9 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	98.380	98.380	0.000	98.500	98.500	0.000	98.560	98.560	0.000
2	12	98.440	98.474	0.034	98.520	98.550	0.030	98.610	98.613	0.003
3	14	98.600	98.652	0.052	98.630	98.664	0.034	98.670	98.690	0.020
4	44	99.030	99.030	0.000	99.050	99.050	0.000	99.100	99.100	0.000
5	9	99.070	99.042	-0.028	99.060	99.063	0.003	99.130	99.113	-0.017

Table D-4 Water surface elevation calibration results (ft) for Hawley Creek Site 4 (Reference) using the WSP model for transects 1-3 and MANSQ for transects 4-7.

Transect	Distance from next downstream transect (ft)	10.7 cfs			12.9 cfs			19.1 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	96.010	96.010	0.000	96.090	96.090	0.000	96.220	96.220	0.000
2	5	96.040	96.032	-0.008	96.110	96.111	0.001	96.230	96.249	0.019
3	3	96.070	96.032	-0.038	96.120	96.111	-0.009	96.240	96.249	0.009
4	23	97.050	97.052	0.002	97.110	96.107	-0.003	97.270	97.271	0.001
5	15	97.250	97.259	0.009	97.320	97.304	-0.016	97.420	97.428	0.008
6	25	97.550	97.547	-0.003	97.580	97.584	0.004	97.680	97.679	-0.001
7	11	97.560	97.556	-0.004	97.590	97.595	0.005	97.700	97.699	-0.001

Table D-5 Water surface elevation calibration results (ft) for Eighteenmile Creek, Site 1 using the MANSQ for all 5 transects.

Transect	Distance from next downstream transect (ft)	1.2 cfs			2.5 cfs			6.1 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	95.330	95.314	-0.016	95.360	95.409	0.049	95.590	95.590	0.000
2	59	95.650	95.647	-0.003	95.740	95.764	0.024	95.950	95.945	-0.005
3	99	96.240	96.190	-0.050	96.260	96.290	0.030	96.460	96.455	-0.005
4	38	96.250	96.225	-0.025	96.350	96.361	0.011	96.570	96.565	-0.005
5	91	96.240	96.380	-0.040	96.470	96.470	0.000	96.630	96.630	0.000

Table D-6 Water surface elevation calibration results (ft) for Eighteenmile Creek Site 2 using the MANSQ model for transects 1-2.

Transect	Distance from next downstream transect (ft)	0.4 cfs			1.6 cfs			1.7 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	95.130	95.110	-0.020	95.210	95.213	0.003	95.250	95.245	-0.005
2	28	95.220	95.179	-0.041	95.320	95.295	-0.025	95.330	95.330	0.000

Table D-7 Water surface elevation calibration results (ft) for Eighteenmile Creek Site 3 using the WSP model on transects 1-2, 3-4, 5-7 and MANSQ on transect 8.

Transect	Distance from next downstream transect (ft)	2.0 cfs			2.4 cfs			N/A cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	97.260	97.260	0.000	97.270	97.270	0.000	N/A	N/A	N/A
2	11	97.320	97.296	-0.024	97.330	97.316	-0.014	N/A	N/A	N/A
3	16.5	97.340	97.340	0.000	97.410	97.410	0.000	N/A	N/A	N/A
4	14.5	97.420	97.454	0.034	97.550	97.511	-0.039	N/A	N/A	N/A
5	11.5	97.680	97.680	0.000	97.730	97.730	0.000	N/A	N/A	N/A
6	10	97.700	97.687	-0.013	97.740	97.738	-0.002	N/A	N/A	N/A
7	6	97.730	97.689	-0.041	97.750	97.740	-0.010	N/A	N/A	N/A
8	15	97.730	97.696	-0.034	97.750	97.745	-0.005	N/A	N/A	N/A

Table D-8 Water surface elevation calibration results (ft) for Eighteenmile Creek Site 4 using the MANSQ model for transects 1-3 and the WSP model for transects 4-7.

Transect	Distance from next downstream transect (ft)	1.8 cfs			2.7 cfs			2.8 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	96.830	96.825	-0.005	96.880	96.887	0.007	96.920	96.915	-0.005
2	25	96.870	96.899	0.029	96.970	96.959	-0.011	96.980	96.980	0.000
3	13.5	96.870	96.925	0.055	96.980	96.972	-0.008	96.990	96.990	0.000
4	7.5	97.180	97.180	0.000	97.190	97.190	0.000	97.220	97.220	0.000
5	10.5	97.220	97.195	-0.025	97.230	97.216	-0.014	97.240	97.247	0.007
6	15	97.230	97.199	-0.031	97.260	97.224	-0.036	97.270	97.255	-0.015
7	15	97.240	97.205	-0.035	97.280	97.234	-0.046	97.280	97.267	-0.013

Table D-9 Water surface elevation calibration results (ft) for Eighteenmile Creek Site 5 using the MANSQ model for transects 1-2, the WSP model for transects 3-4, 5-6 and the STGQ model for transect 7.

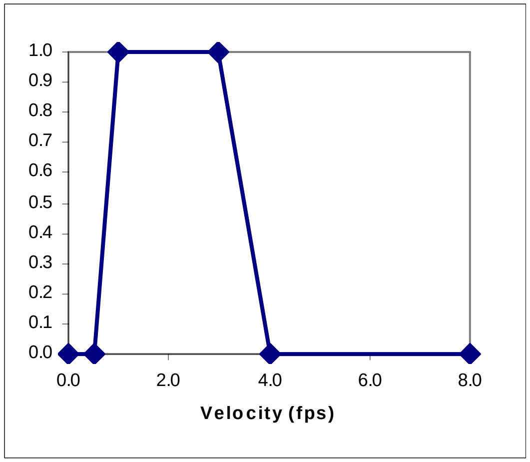
Transect	Distance from next downstream transect (ft)	1.1 cfs			2.3 cfs			12.0 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	97.720	97.732	0.012	97.780	97.817	0.037	98.130	98.150	0.020
2	27	97.870	97.848	-0.022	97.970	97.978	0.008	98.360	98.320	-0.040
3	29	98.450	98.450	0.000	98.570	98.570	0.000	98.900	98.900	0.000
4	10	98.510	98.471	-0.039	98.590	98.610	0.020	99.030	99.078	0.048
5	13	98.870	98.870	0.000	98.890	98.980	0.000	99.270	99.270	0.000
6	17	98.920	98.885	-0.035	99.010	99.003	-0.007	99.380	99.340	-0.040
7	16.5	99.300	99.301	0.001	99.430	99.428	-0.002	99.770	99.771	0.001

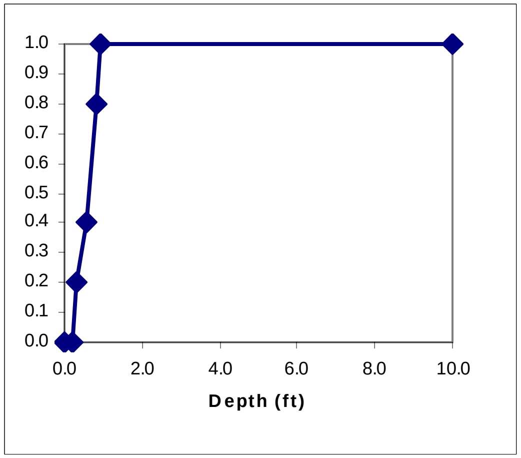
Table D-10 Water surface elevation calibration results (ft) for Eighteenmile Creek Site 6 (Reference site) using the WSP model for transects 1-2 and STGQ for transects 3-6.

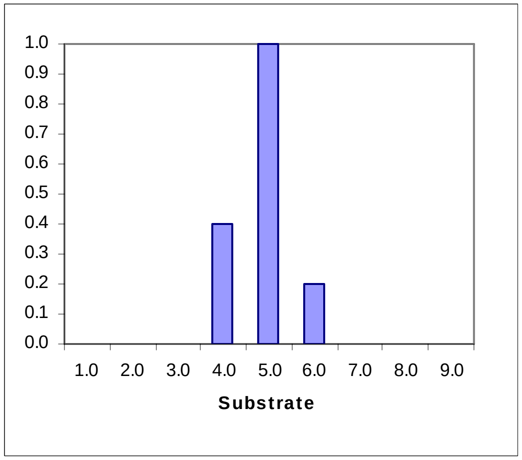
Transect	Distance from next downstream transect (ft)	2.0 cfs			6.1 cfs			29.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	95.300	95.300	0.000	95.660	95.660	0.000	96.400	96.400	0.000
2	8	95.320	95.303	-0.017	95.710	95.663	-0.047	96.420	96.407	-0.013
3	18	96.770	96.773	0.003	96.900	96.892	-0.008	97.120	97.125	0.005
4	36	96.950	96.948	-0.002	97.120	97.124	0.004	97.460	97.457	-0.003
5	24	97.260	97.258	-0.002	97.420	97.426	0.006	97.870	97.865	-0.005
6	43	97.980	97.947	-0.033	98.040	98.092	0.052	98.420	98.403	-0.017

APPENDIX E – HABITAT SUITABILITY CRITERIA

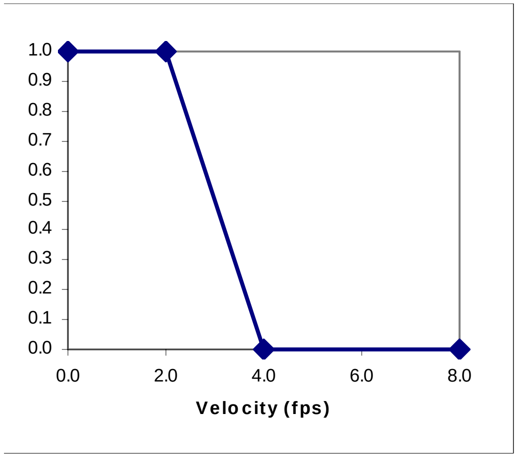
Chinook Salmon – spawning

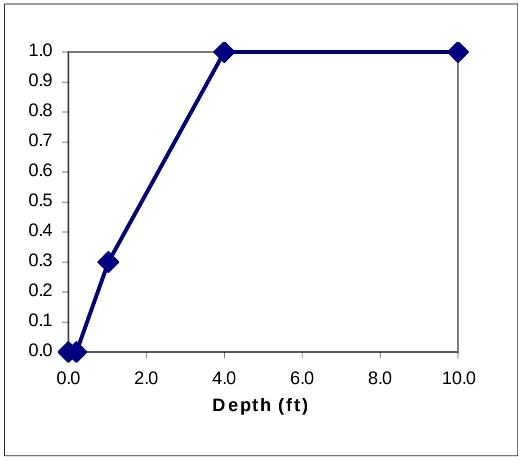


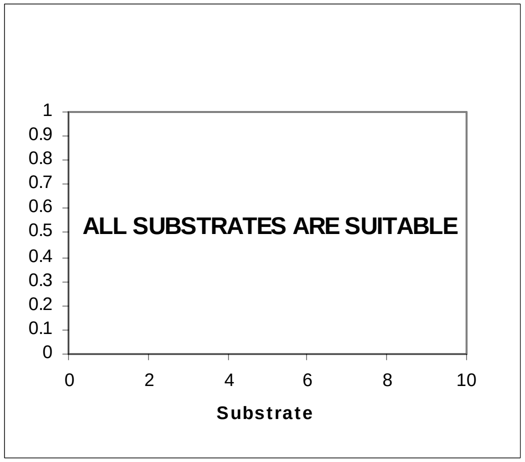




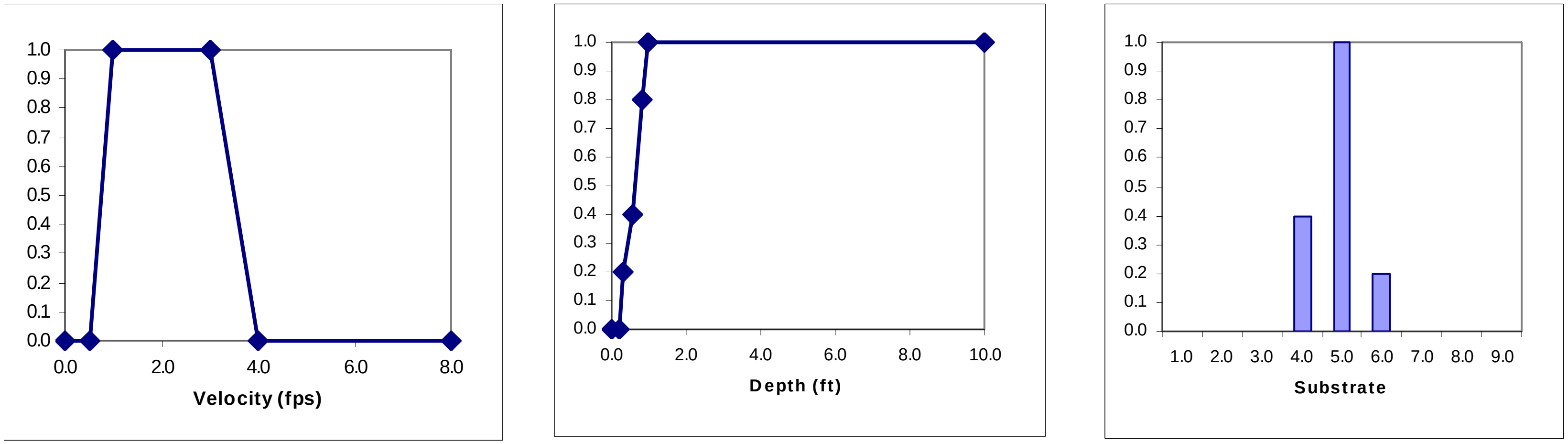
Chinook Salmon – adult holding



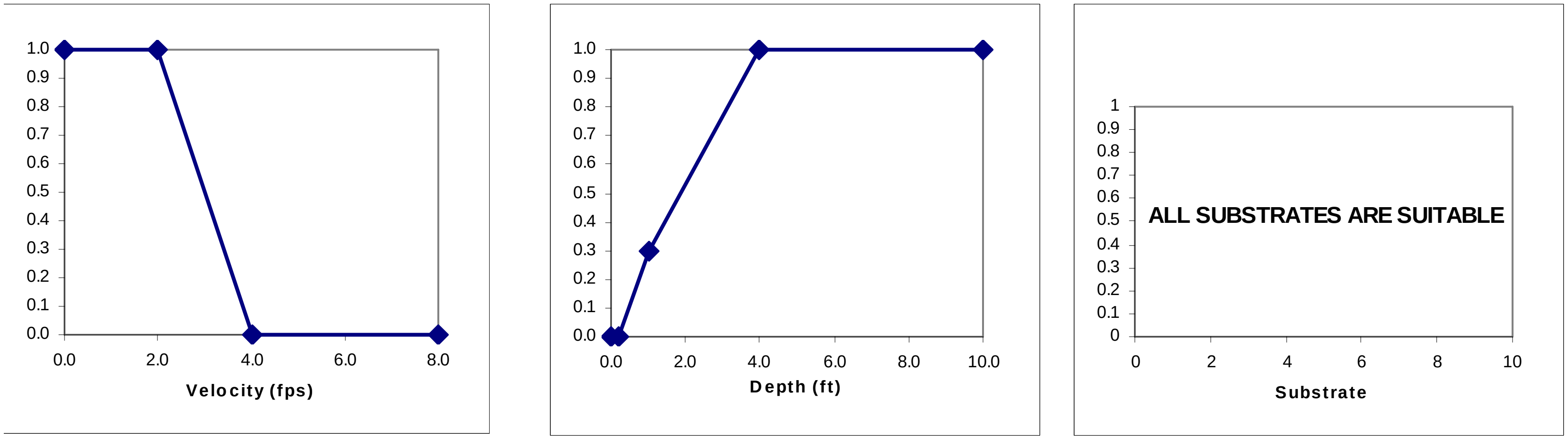




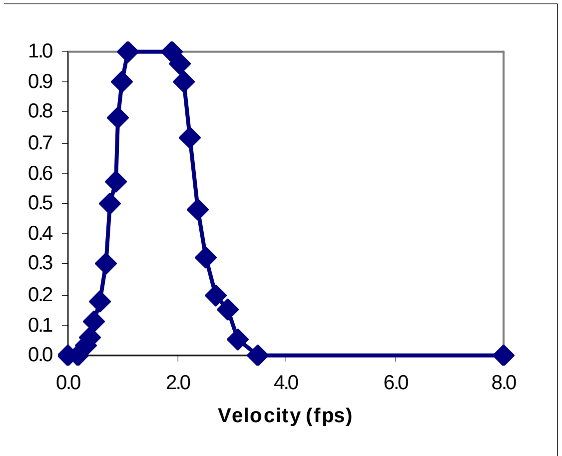
Steelhead – spawning

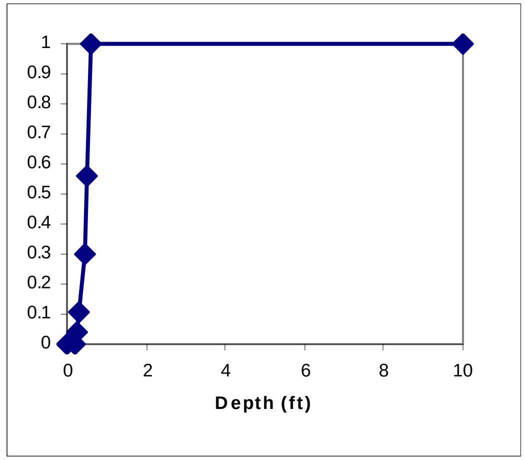


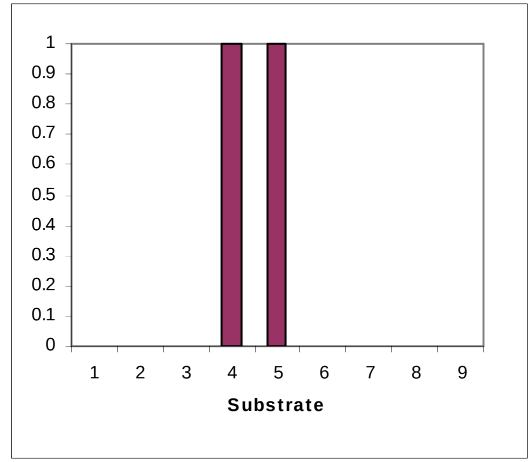
Steelhead – adult holding



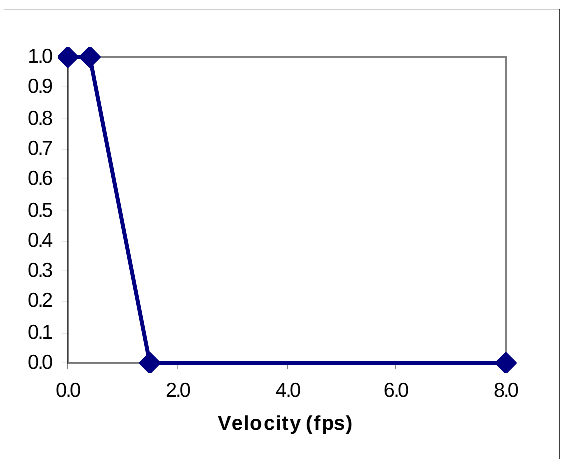
Bull trout - spawning

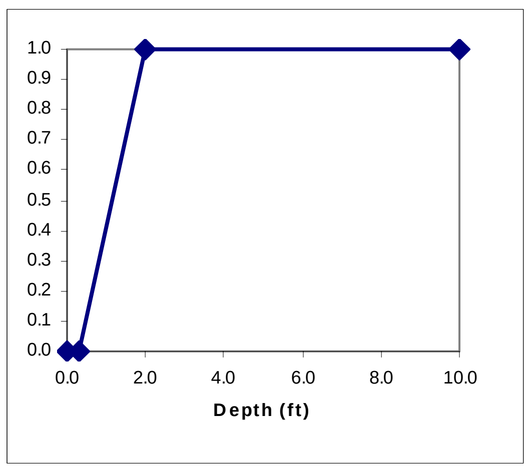


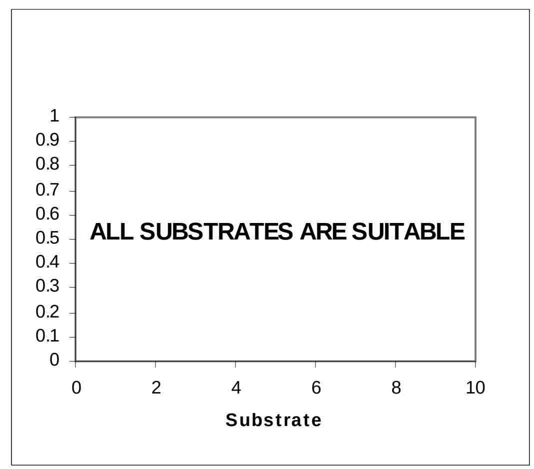




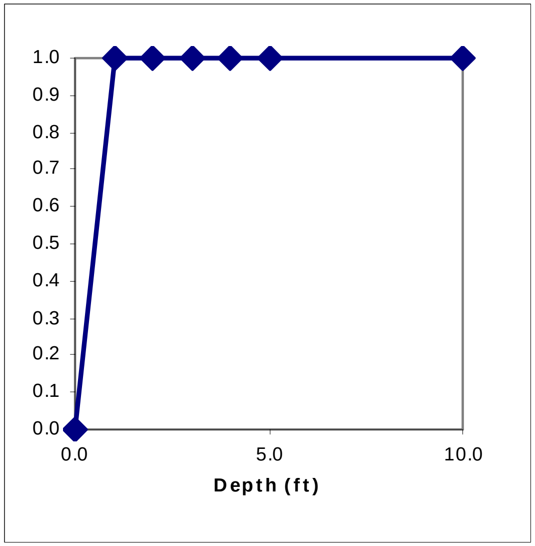
Bull trout – adult



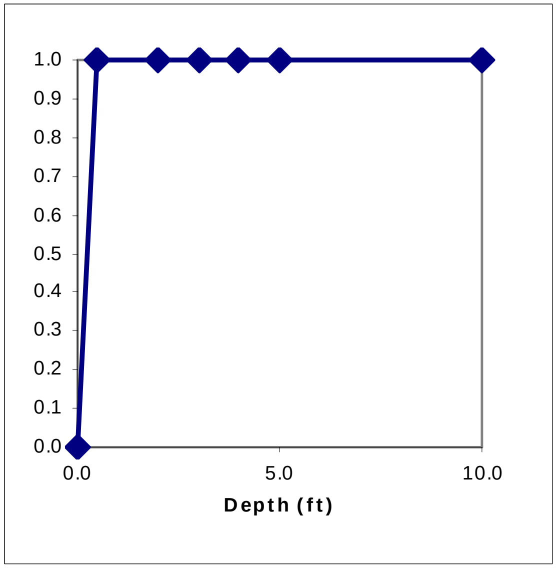




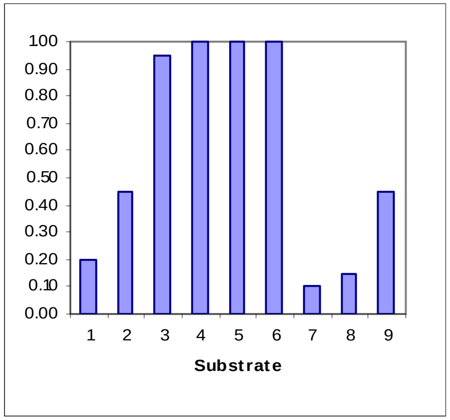
Upstream anadromous passage

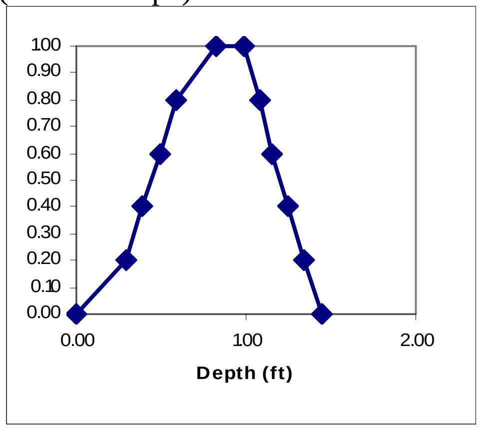


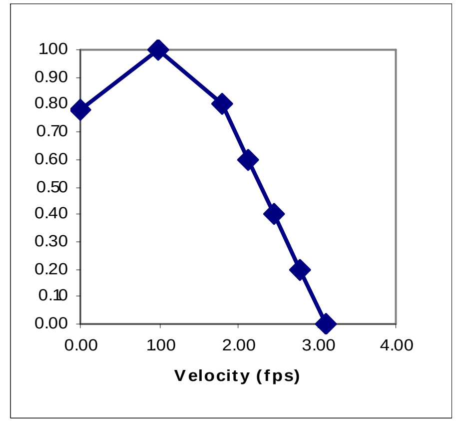
Upstream resident passage



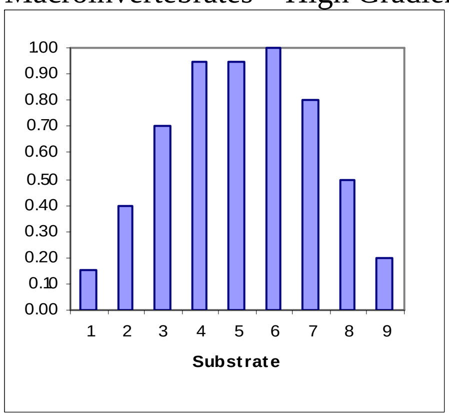
Macroinvertebrates – Low Gradient (< 0.005 slope).

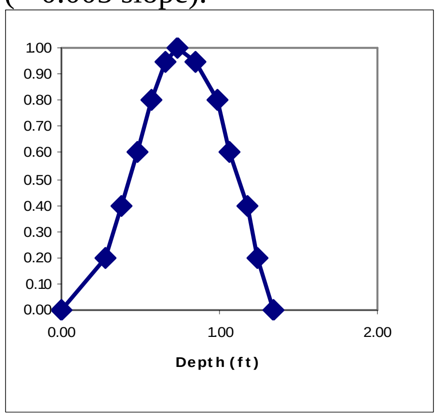


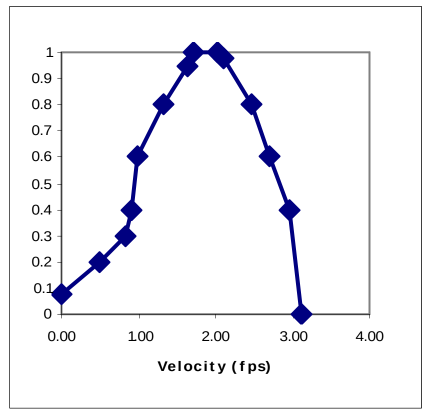




Macroinvertebrates – High Gradient (> 0.005 slope).







APPENDIX F – WEIGHTED USABLE AREA (WUA) VERSUS DISCHARGE RELATIONSHIPS

Hawley Creek, Reach 1 (Study Site 1):

Table F-1. Weighted usable area (WUA) versus discharge (cfs) relationships for steelhead at Hawley Creek, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.5	7489	1748	43	16.2	1.8
1	9493	2564	288	23.8	12.1
3	11935	4677	1460	43.4	61.2
5	14048	5982	1946	55.6	81.6
7	16154	6958	2179	64.6	91.4
9	17706	7821	2296	72.7	96.3
11	18354	8571	2357	79.6	98.9
13	18764	9120	2382	84.7	99.9
14.1	19072	9388	2384	87.2	100.0
15	19464	9585	2383	89.0	99.9
17	21216	10174	2363	94.5	99.1
19	22937	10764	2328	100.0	97.6

Table F-2. Weighted usable area (WUA) versus discharge (cfs) relationships for Chinook salmon at the Hawley Creek, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.5	7489	1748	43	16.2	1.8
1	9493	2564	288	23.8	12.1
3	11935	4677	1460	43.4	61.2
5	14048	5982	1946	55.6	81.6
7	16154	6958	2179	64.6	91.4
9	17706	7821	2296	72.7	96.3
11	18354	8571	2357	79.6	98.9
13	18764	9120	2382	84.7	99.9
14.1	19072	9388	2384	87.2	100.0
15	19464	9585	2383	89.0	99.9
17	21216	10174	2363	94.5	99.1
19	22937	10764	2328	100.0	97.6

Table F-3. Weighted usable area (WUA) versus discharge relationships for bull trout at the Hawley Creek, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.5	7489	1227	137	12.6	9.8
1	9493	2157	391	22.2	27.8
3	11935	4058	1002	41.7	71.3
5	14048	5469	1276	56.3	90.9
7	16154	6439	1360	66.2	96.9
9	17706	7142	1389	73.5	99.0
11	18354	7752	1404	79.7	100.0
13	18764	8169	1383	84.0	98.5
14.1	19072	8486	1356	87.3	96.6
15	19464	8677	1326	89.2	94.5
17	21216	9187	1256	94.5	89.5
19	22937	9722	1178	100.0	83.9

Table F-4. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at the Hawley Creek, Study Site 1.

	WUA (ft^2)/1,000 ft		Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
0.5	7489	3827	33.1
1	9493	5171	44.7
3	11935	7482	64.6
5	14048	8955	77.4
7	16154	10054	86.8
9	17706	10705	92.5
11	18354	10905	94.2
13	18764	10914	94.3
14.1	19072	10943	94.5
15	19464	10948	94.6
17	21216	11196	96.7
19	22937	11576	100.0

Table F-5. Passage criteria assessment for transect 3, Hawley Creek, Study Site 1, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
0.5	6	0	0	0	0
1	11	2	22	2	22
3	13	6	44	6	44
5	14	9	66	6	46
7	17	11	66	8	45
9	18	12	68	12	68
11	18	13	72	13	72
13	18	13	73	13	73
14.1	19	14	73	14	73
15	19	14	72	14	72
17	21	17	82	17	82
19	22	17	78	17	78
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
0.5	6	0	0	0	0
1	11	0	0	0	0
3	13	2	18	2	18
5	14	4	32	4	32
7	17	6	35	6	35
9	18	9	53	6	37
11	18	11	59	7	41
13	18	11	63	8	43
14.1	19	12	63	12	63
15	19	12	62	12	62
17	21	13	61	13	61
19	22	13	60	13	60
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
0.5	6	0	0	0	0
1	11	0	0	0	0
3	13	0	0	0	0
5	14	1	6	1	6
7	17	3	16	3	16
9	18	4	25	4	25
11	18	6	31	6	31
13	18	6	33	6	33
14.1	19	9	47	6	34
15	19	9	48	6	33
17	21	11	51	7	35
19	22	11	51	8	35

Hawley Creek, Reach 2 (Study Site 2):

Table F-6. Weighted usable area (WUA) versus discharge relationships for steelhead at Hawley Creek, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2	13227	2110	1790	35.9	31.4
3	13762	2629	2509	44.8	44.1
4	14822	3267	3178	55.6	55.8
5	15103	3611	3620	61.5	63.6
6	15335	4039	3964	68.8	69.6
7.2	15749	4372	4303	74.5	75.6
8.7	16124	4786	4793	81.5	84.2
10	17575	5192	5225	88.4	91.8
10.8	17658	5299	5397	90.3	94.8
14	17923	5751	5663	98.0	99.5
15	17999	5840	5694	99.5	100.0
16	18077	5844	5646	99.5	99.2
17	18169	5871	5610	100.0	98.5
18	18260	5862	5539	99.8	97.3
19	18348	5834	5420	99.4	95.2
20	18433	5770	5256	98.3	92.3
21	18515	5750	5182	97.9	91.0
22	18595	5674	5049	96.6	88.7
23	18677	5714	4927	97.3	86.5
24	18762	5672	4810	96.6	84.5
25	18846	5628	4742	95.9	83.3
26	18928	5577	4649	95.0	81.6
27	19009	5528	4533	94.1	79.6
28	19088	5477	4434	93.3	77.9
29	19159	5405	4307	92.1	75.6
30	19220	5365	4246	91.4	74.6

Table F-7. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Hawley Creek, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2	13227	2110	1790	35.9	31.4
3	13762	2629	2509	44.8	44.1
4	14822	3267	3178	55.6	55.8
5	15103	3611	3620	61.5	63.6
6	15335	4039	3964	68.8	69.6
7.2	15749	4372	4303	74.5	75.6
8.7	16124	4786	4793	81.5	84.2
10	17575	5192	5225	88.4	91.8
10.8	17658	5299	5397	90.3	94.8
14	17923	5751	5663	98.0	99.5
15	17999	5840	5694	99.5	100.0
16	18077	5844	5646	99.5	99.2
17	18169	5871	5610	100.0	98.5
18	18260	5862	5539	99.8	97.3
19	18348	5834	5420	99.4	95.2
20	18433	5770	5256	98.3	92.3
21	18515	5750	5182	97.9	91.0
22	18595	5674	5049	96.6	88.7
23	18677	5714	4927	97.3	86.5
24	18762	5672	4810	96.6	84.5
25	18846	5628	4742	95.9	83.3
26	18928	5577	4649	95.0	81.6
27	19009	5528	4533	94.1	79.6
28	19088	5477	4434	93.3	77.9
29	19159	5405	4307	92.1	75.6
30	19220	5365	4246	91.4	74.6

Table F-8. Weighted usable area (WUA) versus discharge relationships for bull trout at Hawley Creek, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
2	13227	778	1411	37.8	35.9
3	13762	920	1993	44.7	50.7
4	14822	983	2577	47.8	65.5
5	15103	996	2887	48.4	73.4
6	15335	1067	3063	51.8	77.9
7.2	15749	1124	3258	54.6	82.8
8.7	16124	1287	3556	62.5	90.4
10	17575	1359	3930	66.0	100.0
10.8	17658	1334	3932	64.8	100.0
14	17923	1483	3739	72.0	95.1
15	17999	1539	3690	74.8	93.9
16	18077	1558	3556	75.7	90.4
17	18169	1697	3472	82.4	88.3
18	18260	1719	3362	83.5	85.5
19	18348	1723	3276	83.7	83.3
20	18433	1709	3221	83.0	81.9
21	18515	1701	3168	82.6	80.6
22	18595	1699	3075	82.5	78.2
23	18677	1869	2966	90.8	75.4
24	18762	1944	2921	94.5	74.3
25	18846	2010	2861	97.6	72.8
26	18928	2058	2819	100.0	71.7
27	19009	2101	2796	102.1	71.1
28	19088	2136	2762	103.8	70.2
29	19159	2181	2688	105.9	68.4
30	19220	2209	2644	107.3	67.2

Table F-9. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Hawley Creek, Study Site 2.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
2	13227	6059	67.4
3	13762	6784	75.5
4	14822	7498	83.5
5	15103	7856	87.4
6	15335	8051	89.6
7.2	15749	8252	91.8
8.7	16124	8541	95.1
10	17575	8984	100.0
10.8	17658	8966	99.8
14	17923	8445	94.0
15	17999	8223	91.5
16	18077	8035	89.4
17	18169	7890	87.8
18	18260	7706	85.8
19	18348	7481	83.3
20	18433	7339	81.7
21	18515	7176	79.9
22	18595	7024	78.2
23	18677	6993	77.8
24	18762	6925	77.1
25	18846	6878	76.6
26	18928	6880	76.6
27	19009	6845	76.2
28	19088	6840	76.1
29	19159	6789	75.6
30	19220	6770	75.4

Table F-10. Passage criteria assessment for transect 1, Hawley Creek Study Site 2, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
2	12	0	0	0	0
3	13	1	4	0	2
4	13	1	9	1	5
5	13	2	13	1	8
6	13	6	46	3	25
7	13	7	53	4	27
9	13	8	61	4	29
10	16	11	68	11	68
11	16	11	69	11	69
14	16	11	70	11	70
15	16	12	73	12	73
16	16	12	73	12	73
17	16	12	74	12	74
18	16	12	74	12	74
19	16	12	74	12	74
20	16	12	74	12	74
21	16	12	75	12	75
22	16	12	75	12	75
23	16	13	78	13	78
24	17	13	78	13	78
25	17	13	78	13	78
26	17	13	78	13	78
27	17	13	78	13	78
28	17	13	78	13	78
29	17	13	78	13	78
30	17	13	78	13	78
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
2	12	0	0	0	0
3	13	0	0	0	0
4	13	0	0	0	0
5	13	0	0	0	0
6	13	0	0	0	0
7	13	0	0	0	0
9	13	0	0	0	0
10	16	1	4	0	2
11	16	1	6	0	3
14	16	2	11	1	6
15	16	6	35	3	19
16	16	6	38	3	20
17	16	7	41	3	21
18	16	7	43	4	22
19	16	7	45	4	22
20	16	8	48	4	23
21	16	8	50	4	24
22	16	9	52	4	24
23	16	11	65	11	65

24	17	11	65	11	65
25	17	11	65	11	65
26	17	11	65	11	65
27	17	11	65	11	65
28	17	11	66	11	66
29	17	11	66	11	66
30	17	11	66	11	66
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
2	12	0	0	0	0
3	13	0	0	0	0
4	13	0	0	0	0
5	13	0	0	0	0
6	13	0	0	0	0
7	13	0	0	0	0
9	13	0	0	0	0
10	16	0	0	0	0
11	16	0	0	0	0
14	16	0	0	0	0
15	16	0	0	0	0
16	16	0	0	0	0
17	16	0	0	0	0
18	16	0	0	0	0
19	16	0	0	0	0
20	16	0	0	0	0
21	16	0	0	0	0
22	16	0	0	0	0
23	16	0	1	0	1
24	17	0	2	0	1
25	17	1	3	0	2
26	17	1	4	0	2
27	17	1	5	1	3
28	17	1	6	1	4
29	17	1	7	1	4
30	17	1	8	1	5

Hawley Creek, Reach 3 – Diversion (Study Site 3 - Diversion):

Table F-11. Weighted usable area (WUA) versus discharge relationships for steelhead at Hawley Creek, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7605	1435	1032	28.4	45.8
2.6	10960	2652	1854	52.4	82.3
2.9	11347	2791	1897	55.2	84.1
3	11523	2920	1918	57.7	85.1
3.6	12062	3107	1985	61.5	88.1
4	12319	3339	2033	66.0	90.2
5	12563	3652	2108	72.2	93.5
6	12786	3999	2177	79.1	96.6
7	13906	4364	2254	86.3	100.0
8	14104	4744	2232	93.8	99.0
9	14295	4934	2217	97.6	98.4
10	14473	5057	2158	100.0	95.7

Table F-12. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Hawley Creek, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7605	1435	1032	28.4	45.8
2.6	10960	2652	1854	52.4	82.3
2.9	11347	2791	1897	55.2	84.1
3	11523	2920	1918	57.7	85.1
3.6	12062	3107	1985	61.5	88.1
4	12319	3339	2033	66.0	90.2
5	12563	3652	2108	72.2	93.5
6	12786	3999	2177	79.1	96.6
7	13906	4364	2254	86.3	100.0
8	14104	4744	2232	93.8	99.0
9	14295	4934	2217	97.6	98.4
10	14473	5057	2158	100.0	95.7

Table F-13. Weighted usable area (WUA) versus discharge relationships for bull trout at Hawley Creek, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7605	316	1148	12.9	36.2
2.6	10960	1190	2449	48.7	77.2
2.9	11347	1226	2560	50.2	80.6
3	11523	1362	2713	55.7	85.5
3.6	12062	1385	2992	56.7	94.3
4	12319	1552	3103	63.5	97.8
5	12563	1645	3174	67.3	100.0
6	12786	1695	3085	69.4	97.2
7	13906	1889	2909	77.3	91.7
8	14104	1971	2633	80.7	83.0
9	14295	2095	2292	85.7	72.2
10	14473	2443	1979	100.0	62.4

Table F-14. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Hawley Creek, Study Site 3.

	WUA (ft^2)/1,000 ft		Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
1	7605	3458	50.2
2.6	10960	5342	77.5
2.9	11347	5583	81.0
3	11523	5753	83.5
3.6	12062	6087	88.3
4	12319	6269	90.9
5	12563	6495	94.2
6	12786	6608	95.9
7	13906	6894	100.0
8	14104	6806	98.7
9	14295	6696	97.1
10	14473	6654	96.5

Table F-15. Passage criteria assessment for transect 3, Eighteenmile Creeek, Study Site 3 (Diversion), 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	8	0	0	0	0
3	15	1	6	0	3
3	15	1	7	1	3
3	15	1	7	1	4
4	15	1	10	1	5
4	15	3	19	2	16
5	15	3	22	3	17
6	16	4	24	3	19
7	16	4	27	3	20
8	16	6	38	6	38
9	16	6	39	6	39
10	16	6	40	6	40
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	8	0	0	0	0
3	15	0	0	0	0
3	15	0	0	0	0
3	15	0	0	0	0
4	15	0	0	0	0
4	15	0	0	0	0
5	15	0	0	0	0
6	16	0	0	0	0
7	16	0	0	0	0
8	16	0	1	0	1
9	16	1	4	0	2
10	16	1	6	0	3
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	8	0	0	0	0
3	15	0	0	0	0
3	15	0	0	0	0
3	15	0	0	0	0
4	15	0	0	0	0
4	15	0	0	0	0
5	15	0	0	0	0
6	16	0	0	0	0
7	16	0	0	0	0
8	16	0	0	0	0
9	16	0	0	0	0
10	16	0	0	0	0

Hawley Creek, Reach 4 (Study Site 4 – Reference Site):

Table F-16. Weighted usable area (WUA) versus discharge relationships for steelhead at Hawley Creek, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
5	13009	4937	4244	67.7	59.9
7	13381	5637	5124	77.3	72.4
9	13793	6053	5619	83.0	79.4
10.7	13932	6309	5892	86.5	83.2
11	13991	6423	5928	88.1	83.7
12.9	14215	6714	6266	92.1	88.5
13	14231	6743	6280	92.5	88.7
15	14497	6968	6570	95.6	92.8
17	14688	7124	6796	97.7	96.0
19.1	14984	7266	7036	99.7	99.4
21	15021	7291	7055	100.0	99.6
23	15439	7290	7081	100.0	100.0
25	15536	7219	7015	99.0	99.1
27	15627	7219	6847	99.0	96.7
29	15714	7231	6782	99.2	95.8
31	15797	7160	6647	98.2	93.9
33	15876	7035	6390	96.5	90.3
35	15952	6845	6035	93.9	85.2
37	16016	6782	5911	93.0	83.5
39	16071	6638	5676	91.0	80.2
41	16125	6376	5258	87.4	74.3
43	16177	6301	5113	86.4	72.2
45	16228	6174	4919	84.7	69.5
47	16279	5996	4620	82.2	65.2
49	16328	5876	4406	80.6	62.2
50	16352	5848	4306	80.2	60.8

Table F-17. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Hawley Creek, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
5	13009	4937	4244	67.7	59.9
7	13381	5637	5124	77.3	72.4
9	13793	6053	5619	83.0	79.4
10.7	13932	6309	5892	86.5	83.2
11	13991	6423	5928	88.1	83.7
12.9	14215	6714	6266	92.1	88.5
13	14231	6743	6280	92.5	88.7
15	14497	6968	6570	95.6	92.8
17	14688	7124	6796	97.7	96.0
19.1	14984	7266	7036	99.7	99.4
21	15021	7291	7055	100.0	99.6
23	15439	7290	7081	100.0	100.0
25	15536	7219	7015	99.0	99.1
27	15627	7219	6847	99.0	96.7
29	15714	7231	6782	99.2	95.8
31	15797	7160	6647	98.2	93.9
33	15876	7035	6390	96.5	90.3
35	15952	6845	6035	93.9	85.2
37	16016	6782	5911	93.0	83.5
39	16071	6638	5676	91.0	80.2
41	16125	6376	5258	87.4	74.3
43	16177	6301	5113	86.4	72.2
45	16228	6174	4919	84.7	69.5
47	16279	5996	4620	82.2	65.2
49	16328	5876	4406	80.6	62.2
50	16352	5848	4306	80.2	60.8

Table F-18. Weighted usable area (WUA) versus discharge relationships for bull trout at Hawley Creek, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
5	13009	3164	3871	83.2	63.9
7	13381	3542	4809	93.2	79.4
9	13793	3720	5456	97.9	90.1
10.7	13932	3660	5780	96.3	95.4
11	13991	3801	5847	100.0	96.6
12.9	14215	3568	5986	93.9	98.8
13	14231	3594	5996	94.5	99.0
15	14497	3620	6056	95.2	100.0
17	14688	3512	5888	92.4	97.2
19.1	14984	3369	5319	88.6	87.8
21	15021	3373	5264	88.7	86.9
23	15439	3291	4990	86.6	82.4
25	15536	3158	4691	83.1	77.5
27	15627	3067	4404	80.7	72.7
29	15714	3126	4081	82.2	67.4
31	15797	3160	3820	83.1	63.1
33	15876	3313	3585	87.2	59.2
35	15952	3398	3334	89.4	55.0
37	16016	3442	3055	90.5	50.4
39	16071	3460	2903	91.0	47.9
41	16125	3454	2820	90.9	46.6
43	16177	3449	2719	90.7	44.9
45	16228	3391	2588	89.2	42.7
47	16279	3364	2466	88.5	40.7
49	16328	3345	2303	88.0	38.0
50	16352	3341	2263	87.9	37.4

Table F-19. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Hawley Creek, Study Site 4.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
5	13009	7983	83.7
7	13381	8744	91.7
9	13793	9214	96.6
10.7	13932	9396	98.5
11	13991	9471	99.3
12.9	14215	9534	99.9
13	14231	9540	100.0
15	14497	9452	99.1
17	14688	9144	95.9
19.1	14984	8518	89.3
21	15021	8461	88.7
23	15439	8059	84.5
25	15536	7812	81.9
27	15627	7439	78.0
29	15714	7147	74.9
31	15797	6780	71.1
33	15876	6525	68.4
35	15952	6292	65.9
37	16016	6040	63.3
39	16071	5808	60.9
41	16125	5550	58.2
43	16177	5388	56.5
45	16228	5125	53.7
47	16279	4924	51.6
49	16328	4632	48.6
50	16352	4582	48.0

Table F-20. Passage criteria assessment for transect 4, Hawley Creek, Study Site 4 – Reference Site, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
5	12	0	0	0	0
7	13	5	39	5	39
9	13	6	47	6	46
11	14	8	59	7	52
11	14	8	61	7	53
13	14	11	78	11	78
13	14	11	78	11	78
15	15	11	78	11	78
17	15	12	78	12	78
21	16	12	78	12	78
21	16	12	78	12	78
23	16	12	78	12	78
25	16	13	79	13	79
27	16	13	80	13	80
29	16	13	82	13	82
31	16	14	83	14	83
33	16	14	84	14	84
35	17	14	86	14	86
37	17	14	87	14	87
39	17	15	88	15	88
41	17	15	89	15	89
43	17	15	90	15	90
45	17	15	91	15	91
47	17	16	92	16	92
49	17	16	93	16	93
50	17	16	93	16	93
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
5	12	0	0	0	0
7	13	0	0	0	0
9	13	0	0	0	0
11	14	0	0	0	0
11	14	0	0	0	0
13	14	4	29	4	29
13	14	4	30	4	30
15	15	5	35	5	35
17	15	6	40	6	40
21	16	9	57	7	47
21	16	9	58	8	48
23	16	11	70	11	70
25	16	11	71	11	71
27	16	12	72	12	72
29	16	12	73	12	73
31	16	12	73	12	73
33	16	12	74	12	74
35	17	12	75	12	75
37	17	13	76	13	76

39	17	13	77	13	77
41	17	13	77	13	77
43	17	13	79	13	79
45	17	14	80	14	80
47	17	14	81	14	81
49	17	14	82	14	82
50	17	14	83	14	83

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
5	12	0	0	0	0
7	13	0	0	0	0
9	13	0	0	0	0
11	14	0	0	0	0
11	14	0	0	0	0
13	14	0	0	0	0
13	14	0	0	0	0
15	15	0	0	0	0
17	15	0	0	0	0
21	16	0	0	0	0
21	16	0	0	0	0
23	16	4	27	4	27
25	16	5	31	5	31
27	16	6	35	6	35
29	16	7	41	6	39
31	16	8	49	7	43
33	16	9	56	8	46
35	17	11	67	11	67
37	17	11	68	11	68
39	17	11	69	11	69
41	17	12	69	12	69
43	17	12	70	12	70
45	17	12	71	12	71
47	17	12	71	12	71
49	17	12	72	12	72
50	17	12	72	12	72

Eighteenmile Creek, Reach 1:

Table F-21. Weighted usable area (WUA) versus discharge relationships for steelhead at Eighteenmile Creek, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7720	1575	856	32.1	24.8
1.2	7898	1794	1149	36.6	33.3
2	8418	2512	1938	51.3	56.1
2.5	8575	2827	2261	57.7	65.5
3	8877	3094	2345	63.1	67.9
4	9101	3478	2599	71.0	75.3
5	9439	3759	2754	76.7	79.8
6.1	9654	4019	2923	82.0	84.7
7	9855	4170	3041	85.1	88.1
8	10195	4326	3140	88.3	91.0
9	10666	4431	3188	90.4	92.3
10	11055	4570	3240	93.3	93.8
11	11511	4738	3318	96.7	96.1
12	11650	4782	3365	97.6	97.5
13	11782	4802	3376	98.0	97.8
14	11906	4854	3417	99.1	99.0
15	12119	4899	3453	100.0	100.0

Table F-22. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Eighteenmile Creek, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7720	1575	856	32.1	24.8
1.2	7898	1794	1149	36.6	33.3
2	8418	2512	1938	51.3	56.1
2.5	8575	2827	2261	57.7	65.5
3	8877	3094	2345	63.1	67.9
4	9101	3478	2599	71.0	75.3
5	9439	3759	2754	76.7	79.8
6.1	9654	4019	2923	82.0	84.7
7	9855	4170	3041	85.1	88.1
8	10195	4326	3140	88.3	91.0
9	10666	4431	3188	90.4	92.3
10	11055	4570	3240	93.3	93.8
11	11511	4738	3318	96.7	96.1
12	11650	4782	3365	97.6	97.5
13	11782	4802	3376	98.0	97.8
14	11906	4854	3417	99.1	99.0
15	12119	4899	3453	100.0	100.0

Table F-23. Weighted usable area (WUA) versus discharge relationships for bull trout at Eighteenmile Creek, Study Site 1.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7720	728	925	34.5	22.7
1.2	7898	872	1191	41.4	29.2
2	8418	1359	2083	64.4	51.1
2.5	8575	1533	2563	72.7	62.8
3	8877	1598	2813	75.7	68.9
4	9101	1848	3274	87.6	80.2
5	9439	1997	3607	94.7	88.4
6.1	9654	2030	3913	96.2	95.9
7	9855	2037	4041	96.6	99.0
8	10195	2011	4080	95.3	100.0
9	10666	2085	4035	98.8	98.9
10	11055	2107	3886	99.9	95.2
11	11511	2103	3731	99.7	91.4
12	11650	2048	3547	97.1	86.9
13	11782	2052	3348	97.3	82.1
14	11906	2089	3127	99.0	76.7
15	12119	2110	2960	100.0	72.5

Table F-24. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Eighteenmile Creek, Study Site 1.

	WUA (ft^2)/1,000 ft		Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
1	7720	3813	57.7
1.2	7898	4028	61.0
2	8418	4732	71.6
2.5	8575	5028	76.1
3	8877	5345	80.9
4	9101	5758	87.1
5	9439	6081	92.0
6.1	9654	6232	94.3
7	9855	6334	95.9
8	10195	6407	97.0
9	10666	6506	98.4
10	11055	6580	99.6
11	11511	6608	100.0
12	11650	6540	99.0
13	11782	6394	96.8
14	11906	6187	93.6
15	12119	5958	90.2

Table F-25. Passage criteria assessment for transect 5, Eighteenmile Creek, Study Site 1, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	10	0	0	0	0
1	10	0	0	0	0
2	10	0	0	0	0
3	10	0	0	0	0
3	10	0	0	0	0
4	11	4	36	3	33
5	11	5	43	4	36
6	11	9	87	9	87
7	11	10	87	10	87
8	11	10	87	10	87
9	11	10	87	10	87
10	11	10	87	10	87
11	11	10	87	10	87
12	12	10	88	10	88
13	12	10	88	10	88
14	12	10	88	10	88
15	12	10	88	10	88
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	10	0	0	0	0
1	10	0	0	0	0
2	10	0	0	0	0
3	10	0	0	0	0
3	10	0	0	0	0
4	11	0	0	0	0
5	11	0	0	0	0
6	11	0	0	0	0
7	11	0	0	0	0
8	11	0	0	0	0
9	11	3	31	3	29
10	11	4	35	4	31
11	11	4	39	4	33
12	12	9	81	9	81
13	12	9	81	9	81
14	12	10	82	10	82
15	12	10	82	10	82
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	10	0	0	0	0
1	10	0	0	0	0
2	10	0	0	0	0
3	10	0	0	0	0
3	10	0	0	0	0
4	11	0	0	0	0
5	11	0	0	0	0
6	11	0	0	0	0
7	11	0	0	0	0

8	11	0	0	0	0
9	11	0	0	0	0
10	11	0	0	0	0
11	11	0	0	0	0
12	12	0	0	0	0
13	12	0	0	0	0
14	12	0	0	0	0
15	12	0	0	0	0

Eighteenmile Creek, Reach 2 (Study Site 2):

Table F-26. Weighted usable area (WUA) versus discharge relationships for steelhead at Eighteenmile Creek, Study Site 2.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.4	7169	688	199	16.5	3.6
1	7547	1201	1214	28.8	22.2
1.6	7725	1769	2185	42.4	40.0
1.7	7816	2084	2832	49.9	51.9
2	7855	2273	3201	54.5	58.6
3	8019	2777	3877	66.5	71.0
4	8154	3147	4126	75.4	75.6
5	8272	3468	4396	83.1	80.5
6	8378	3676	4632	88.1	84.8
7	8474	3816	4808	91.4	88.0
8	8563	3910	4965	93.7	90.9
9	8646	3978	5129	95.3	93.9
11	8831	4144	5398	99.3	98.9
12	8936	4174	5460	100.0	100.0
13	9034	4163	5456	99.7	99.9

Table F-27. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Eighteenmile Creek, Study Site 2.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.4	7169	688	199	16.5	3.6
1	7547	1201	1214	28.8	22.2
1.6	7725	1769	2185	42.4	40.0
1.7	7816	2084	2832	49.9	51.9
2	7855	2273	3201	54.5	58.6
3	8019	2777	3877	66.5	71.0
4	8154	3147	4126	75.4	75.6
5	8272	3468	4396	83.1	80.5
6	8378	3676	4632	88.1	84.8
7	8474	3816	4808	91.4	88.0
8	8563	3910	4965	93.7	90.9
9	8646	3978	5129	95.3	93.9
11	8831	4144	5398	99.3	98.9
12	8936	4174	5460	100.0	100.0
13	9034	4163	5456	99.7	99.9

Table F-28. Weighted usable area (WUA) versus discharge relationships for bull trout at Eighteenmile Creek, Study Site 2.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
0.4	7169	229	408	17.5	7.5
1	7547	539	1031	41.3	19.1
1.6	7725	701	1796	53.8	33.2
1.7	7816	777	2408	59.5	44.6
2	7855	944	2760	72.4	51.1
3	8019	1245	3789	95.5	70.1
4	8154	1180	4412	90.5	81.6
5	8272	1234	4908	94.6	90.8
6	8378	1304	5239	100.0	96.9
7	8474	1285	5404	98.5	100.0
8	8563	1243	5382	95.4	99.6
9	8646	1161	5245	89.0	97.1
11	8831	1241	4726	95.2	87.5
12	8936	1276	4404	97.8	81.5
13	9034	1248	3993	95.7	73.9

Table F-29. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Eighteenmile Creek, Study Site 2.

	WUA (ft^2)/1,000 ft		Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
0.4	7169	3178	51.5
1	7547	3890	63.1
1.6	7725	4277	69.4
1.7	7816	4562	74.0
2	7855	4696	76.1
3	8019	5253	85.2
4	8154	5685	92.2
5	8272	5955	96.6
6	8378	6105	99.0
7	8474	6167	100.0
8	8563	6146	99.7
9	8646	6022	97.6
11	8831	5380	87.2
12	8936	5061	82.1
13	9034	4779	77.5

Table F-30. Passage criteria assessment for transect 2, Eighteenmile Creek, Study Site 2, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	7	0	0	0	0
1	8	0	0	0	0
1	8	1	14	1	14
2	8	1	15	1	15
2	8	1	16	1	16
3	8	2	30	2	27
4	8	3	40	2	29
5	8	6	75	4	52
6	8	7	78	5	54
7	9	7	80	5	55
8	9	7	85	7	80
9	9	8	86	7	80
11	9	8	88	8	88
12	9	8	87	8	87
13	9	8	87	8	87
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	7	0	0	0	0
1	8	0	0	0	0
1	8	0	0	0	0
2	8	0	0	0	0
2	8	0	0	0	0
3	8	0	0	0	0
4	8	0	0	0	0
5	8	1	13	1	13
6	8	1	15	1	15
7	9	1	17	1	17
8	9	3	30	2	26
9	9	3	36	2	27
11	9	6	70	4	49
12	9	7	72	5	50
13	9	7	73	5	51
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	7	0	0	0	0
1	8	0	0	0	0
1	8	0	0	0	0
2	8	0	0	0	0
2	8	0	0	0	0
3	8	0	0	0	0
4	8	0	0	0	0
5	8	0	0	0	0
6	8	0	0	0	0
7	9	0	0	0	0
8	9	0	0	0	0
9	9	0	0	0	0
11	9	1	13	1	13

12	9	1	14	1	14
13	9	1	15	1	15

Eighteenmile Creek, Reach 3 (Study Site 3):

Table F-31. Weighted usable area (WUA) versus discharge relationships for steelhead at Eighteenmile Creek, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7209	2329	1192	41.9	40.0
2	7760	2947	1822	53.1	61.2
2.4	8365	3291	2054	59.3	68.9
3	8590	3495	2161	62.9	72.5
4	9571	3785	2359	68.2	79.2
5	10433	4019	2530	72.4	84.9
6	10847	4207	2660	75.8	89.3
7	11083	4438	2773	79.9	93.1
8	11332	4743	2854	85.4	95.8
9	11581	5181	2915	93.3	97.9
10	11821	5552	2979	100.0	100.0

Table F-32. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Eighteenmile Creek, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7209	2329	1192	41.9	40.0
2	7760	2947	1822	53.1	61.2
2.4	8365	3291	2054	59.3	68.9
3	8590	3495	2161	62.9	72.5
4	9571	3785	2359	68.2	79.2
5	10433	4019	2530	72.4	84.9
6	10847	4207	2660	75.8	89.3
7	11083	4438	2773	79.9	93.1
8	11332	4743	2854	85.4	95.8
9	11581	5181	2915	93.3	97.9
10	11821	5552	2979	100.0	100.0

Table F-33. Weighted usable area (WUA) versus discharge relationships for bull trout at Eighteenmile Creek, Study Site 3.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	7209	2329	1192	41.9	40.0
2	7760	2947	1822	53.1	61.2
2.4	8365	3291	2054	59.3	68.9
3	8590	3495	2161	62.9	72.5
4	9571	3785	2359	68.2	79.2
5	10433	4019	2530	72.4	84.9
6	10847	4207	2660	75.8	89.3
7	11083	4438	2773	79.9	93.1
8	11332	4743	2854	85.4	95.8
9	11581	5181	2915	93.3	97.9
10	11821	5552	2979	100.0	100.0

Table F-34. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Eighteenmile Creek, Study Site 3.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
1	7209	4417	64.2
2	7760	4934	71.7
2.4	8365	5281	76.7
3	8590	5490	79.8
4	9571	5866	85.2
5	10433	6220	90.4
6	10847	6437	93.5
7	11083	6560	95.3
8	11332	6707	97.4
9	11581	6804	98.8
10	11821	6884	100.0

Table F-35. Passage criteria assessment for transect 1, Eighteenmile Creek, Study Site 3, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	8	0	0	0	0
2	10	0	0	0	0
3	10	0	0	0	0
4	10	0	0	0	0
5	10	0	0	0	0
6	11	0	0	0	0
7	11	0	0	0	0
8	11	0	0	0	0
9	11	0	1	0	1
10	13	1	6	0	3
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	8	0	0	0	0
2	10	0	0	0	0
3	10	0	0	0	0
4	10	0	0	0	0
5	10	0	0	0	0
6	11	0	0	0	0
7	11	0	0	0	0
8	11	0	0	0	0
9	11	0	0	0	0
10	13	0	0	0	0
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	8	0	0	0	0
2	10	0	0	0	0
3	10	0	0	0	0
4	10	0	0	0	0
5	10	0	0	0	0
6	11	0	0	0	0
7	11	0	0	0	0
8	11	0	0	0	0
9	11	0	0	0	0
10	13	0	0	0	0

Eighteenmile Creek, Reach 4 (Study Site 4):

Table F-36. Weighted usable area (WUA) versus discharge relationships for steelhead at Eighteenmile Creek, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	5727	2203	632	48.6	27.1
1.8	6262	2729	990	60.2	42.5
2	6311	2738	1045	60.4	44.8
2.7	6461	2966	1255	65.4	53.8
2.8	6597	3062	1427	67.5	61.2
4	7055	3310	1915	73.0	82.1
5	7462	3533	2144	77.9	91.9
6	7910	3736	2275	82.4	97.6
7	8366	4104	2331	90.5	100.0
8	8953	4365	2327	96.3	99.8
9	9493	4533	2278	100.0	97.7

Table F-37. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Eighteenmile Creek, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	5727	2203	632	48.6	27.1
1.8	6262	2729	990	60.2	42.5
2	6311	2738	1045	60.4	44.8
2.7	6461	2966	1255	65.4	53.8
2.8	6597	3062	1427	67.5	61.2
4	7055	3310	1915	73.0	82.1
5	7462	3533	2144	77.9	91.9
6	7910	3736	2275	82.4	97.6
7	8366	4104	2331	90.5	100.0
8	8953	4365	2327	96.3	99.8
9	9493	4533	2278	100.0	97.7

Table F-38. Weighted usable area (WUA) versus discharge relationships for bull trout at Eighteenmile Creek, Study Site 4.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	5727	1964	1003	49.3	36.3
1.8	6262	2360	1794	59.2	65.0
2	6311	2356	1884	59.1	68.2
2.7	6461	2445	2206	61.4	79.9
2.8	6597	2538	2335	63.7	84.6
4	7055	2792	2668	70.1	96.6
5	7462	2962	2761	74.4	100.0
6	7910	3135	2728	78.7	98.8
7	8366	3308	2705	83.0	98.0
8	8953	3699	2617	92.9	94.8
9	9493	3983	2494	100.0	90.3

Table F-39. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Eighteenmile Creek, Study Site 4.

	WUA (ft^2)/1,000 ft		Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
1	5727	3774	81.5
1.8	6262	4218	91.1
2	6311	4291	92.6
2.7	6461	4416	95.3
2.8	6597	4461	96.3
4	7055	4632	100.0
5	7462	4493	97.0
6	7910	4228	91.3
7	8366	3863	83.4
8	8953	3814	82.3
9	9493	3948	85.2

Table F-40. Passage criteria assessment for transect 3, Eighteenmile Creek, Study Site 4, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	5	0	0	0	0
2	6	1	14	1	12
3	6	1	19	1	14
3	6	1	21	1	15
4	7	3	41	3	38
5	7	4	59	4	59
6	7	4	60	4	60
7	8	5	61	5	61
8	8	5	61	5	61
9	8	5	61	5	61
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	5	0	0	0	0
2	6	0	0	0	0
3	6	0	0	0	0
3	6	0	0	0	0
4	7	0	0	0	0
5	7	1	9	1	9
6	7	1	13	1	11
7	8	1	17	1	13
8	8	3	34	2	33
9	8	3	37	3	34
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	5	0	0	0	0
2	6	0	0	0	0
3	6	0	0	0	0
3	6	0	0	0	0
4	7	0	0	0	0
5	7	0	0	0	0
6	7	0	0	0	0
7	8	0	0	0	0
8	8	0	0	0	0
9	8	0	0	0	0

Eighteenmile Creek, Reach 5 (Study Site 5):

Table F-41. Weighted usable area (WUA) versus discharge relationships for steelhead at Eighteenmile Creek, Study Site 5.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	5280	1523	872	50.4	26.3
1.1	5429	1572	1118	52.0	33.7
2.3	5807	2206	2468	73.0	74.4
3	6041	2428	2839	80.3	85.6
5	6799	2839	3228	93.9	97.3
7	7430	3023	3316	100.0	100.0
9	7595	2977	3195	98.5	96.3
12	7898	2964	3058	98.1	92.2
13	7987	2961	2955	98.0	89.1
15	8703	2908	2625	96.2	79.1
17	9021	2681	2126	88.7	64.1
19	9328	2472	1634	81.8	49.3

Table F-42. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Eighteenmile Creek, Study Site 5.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	5280	1523	872	50.4	26.3
1.1	5429	1572	1118	52.0	33.7
2.3	5807	2206	2468	73.0	74.4
3	6041	2428	2839	80.3	85.6
5	6799	2839	3228	93.9	97.3
7	7430	3023	3316	100.0	100.0
9	7595	2977	3195	98.5	96.3
12	7898	2964	3058	98.1	92.2
13	7987	2961	2955	98.0	89.1
15	8703	2908	2625	96.2	79.1
17	9021	2681	2126	88.7	64.1
19	9328	2472	1634	81.8	49.3

Table F-43. Weighted usable area (WUA) versus discharge relationships for bull trout at Eighteenmile Creek, Study Site 5.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	5280	1196	1206	77.7	37.2
1.1	5429	1217	1328	79.0	41.0
2.3	5807	1479	2497	96.0	77.0
3	6041	1506	2865	97.8	88.4
5	6799	1540	3241	100.0	100.0
7	7430	1414	3208	91.8	99.0
9	7595	1308	2743	84.9	84.6
12	7898	934	2012	60.6	62.1
13	7987	867	1701	56.3	52.5
15	8703	879	1099	57.1	33.9
17	9021	930	780	60.4	24.1
19	9328	1059	606	68.8	18.7

Table F-44. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Eighteenmile Creek, Study Site 5.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
1	5280	3194	74.1
1.1	5429	3259	75.6
2.3	5807	3795	88.0
3	6041	3988	92.5
5	6799	4311	100.0
7	7430	4255	98.7
9	7595	4038	93.7
12	7898	3265	75.7
13	7987	2996	69.5
15	8703	2891	67.1
17	9021	2833	65.7
19	9328	2728	63.3

Table F-45. Passage criteria assessment for transect 1, Eighteenmile Creek, Study Site 5, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	8	0	0	0	0
2	8	1	9	1	9
3	8	1	11	1	11
5	9	6	64	5	58
7	9	7	80	7	80
9	10	8	81	8	81
12	10	8	82	8	82
13	10	8	82	8	82
15	10	8	81	8	81
17	11	8	77	8	77
19	11	8	74	8	74
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	8	0	0	0	0
2	8	0	0	0	0
3	8	0	0	0	0
5	9	0	0	0	0
7	9	1	8	1	8
9	10	1	11	1	11
12	10	6	58	5	52
13	10	6	60	5	53
15	10	7	73	7	73
17	11	8	71	8	71
19	11	8	69	8	69
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	8	0	0	0	0
2	8	0	0	0	0
3	8	0	0	0	0
5	9	0	0	0	0
7	9	0	0	0	0
9	10	0	0	0	0
12	10	0	0	0	0
13	10	0	0	0	0
15	10	1	7	1	7
17	11	1	9	1	9
19	11	5	46	5	43

Eighteenmile Creek, Reach 6 (Study Site 6 - Reference Site):

Table F-46. Weighted usable area (WUA) versus discharge relationships for steelhead at Eighteenmile Creek, Study Site 6.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	12683	1834	1099	18.2	16.0
2	15482	2572	1805	25.5	26.2
6.1	19725	5432	4063	53.8	59.0
11	20297	7442	6068	73.7	88.1
16	21154	8598	6838	85.2	99.3
21	21722	9070	6889	89.9	100.0
26	22836	9280	6609	91.9	95.9
29.3	23344	9477	6594	93.9	95.7
31	23584	9523	6519	94.4	94.6
36	24733	9698	6411	96.1	93.1
41	25291	9908	6457	98.2	93.7
46	26037	10093	6228	100.0	90.4

Table F-47. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Eighteenmile Creek, Study Site 6.

	WUA (ft^2)/1,000 ft			Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	12683	1834	1099	18.2	16.0
2	15482	2572	1805	25.5	26.2
6.1	19725	5432	4063	53.8	59.0
11	20297	7442	6068	73.7	88.1
16	21154	8598	6838	85.2	99.3
21	21722	9070	6889	89.9	100.0
26	22836	9280	6609	91.9	95.9
29.3	23344	9477	6594	93.9	95.7
31	23584	9523	6519	94.4	94.6
36	24733	9698	6411	96.1	93.1
41	25291	9908	6457	98.2	93.7
46	26037	10093	6228	100.0	90.4

Table F-48. Weighted usable area (WUA) versus discharge relationships for bull trout at Eighteenmile Creek, Study Site 6.

		WUA (ft^2)/1,000 ft		Percent of optimal habitat	
Discharge	Total Area	Adult	Spawning	Adult	Spawning
1	12683	933	960	13.9	16.3
2	15482	1404	1617	20.9	27.5
6.1	19725	2667	3639	39.6	61.9
11	20297	3939	5239	58.5	89.2
16	21154	4713	5740	70.0	97.7
21	21722	5256	5876	78.1	100.0
26	22836	5707	5740	84.8	97.7
29.3	23344	5958	5697	88.5	96.9
31	23584	6087	5631	90.4	95.8
36	24733	6376	5433	94.7	92.5
41	25291	6585	5374	97.8	91.4
46	26037	6734	5232	100.0	89.0

Table F-49. Weighted usable area (WUA) versus discharge relationships for macroinvertebrates at Eighteenmile Creek, Study Site 6.

		WUA (ft^2)/1,000 ft	Percent of optimal habitat
Discharge	Total Area	Macroinvertebrate	Macroinvertebrate
1	12683	5477	46.6
2	15482	7374	62.8
6.1	19725	10776	91.7
11	20297	11471	97.7
16	21154	11720	99.8
21	21722	11746	100.0
26	22836	11324	96.4
29.3	23344	11250	95.8
31	23584	11277	96.0
36	24733	11173	95.1
41	25291	10943	93.2
46	26037	11037	94.0

Table F-50. Passage criteria assessment for transect 5, Eighteenmile Creek Study Site 6 – Reference Site, 2006.

Discharge (cfs)	stream width (ft)	Total stream width greater than 0.4 ft depth	Percent stream width greater than 0.4 ft depth	Contiguous stream width greater than 0.4 ft depth	Percent contiguous stream width greater than 0.4 ft depth
1	7	0	0	0	0
2	9	0	0	0	0
6	13	3	23	2	12
11	13	7	52	5	34
16	14	9	67	6	41
21	14	12	90	12	90
26	14	13	90	13	90
29	16	13	84	13	84
31	16	13	82	13	82
36	19	13	70	13	70
41	19	13	70	13	70
46	19	14	70	14	70
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.6 ft depth	Percent stream width greater than 0.6 ft depth	Contiguous stream width greater than 0.6 ft depth	Percent contiguous stream width greater than 0.6 ft depth
1	7	0	0	0	0
2	9	0	0	0	0
6	13	0	0	0	0
11	13	1	6	1	6
16	14	4	29	2	16
21	14	7	49	4	32
26	14	8	56	5	36
29	16	9	59	6	36
31	16	10	61	6	37
36	19	12	66	12	66
41	19	13	69	13	69
46	19	13	68	13	68
Discharge (cfs)	stream width (ft)	Total stream width greater than 0.8 ft depth	Percent stream width greater than 0.8 ft depth	Contiguous stream width greater than 0.8 ft depth	Percent contiguous stream width greater than 0.8 ft depth
1	7	0	0	0	0
2	9	0	0	0	0
6	13	0	0	0	0
11	13	0	0	0	0
16	14	0	0	0	0
21	14	1	4	1	4
26	14	3	20	1	10
29	16	4	26	2	15
31	16	5	29	3	17
36	19	7	36	4	24
41	19	8	41	5	27
46	19	9	47	6	29