RECLAMATION

Managing Water in the West

Flow Characterization Study

Instream Flow Assessment Selected Stream Segments-John Day and Middle Fork John Day River Sub-basins, Oregon

U.S. Department of the Interior
Bureau of Reclamation
Technical Service Center
Ecological Planning and Assessment Group
Denver, Colorado

March 2006

Mission Statements

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.

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.

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EXECUTIVE SUMMARY

The primary objective of this project was to conduct habitat studies on upper John Day River and Middle Fork John Day River drainages to identify stream flow needs to support relevant life history stages of summer steelhead (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and spring Chinook salmon (*Oncorhynchus tschawytscha*). The project was intended to address the Bureau of Reclamation's (Reclamation) Endangered Species Act (ESA) obligations under Reasonable and Prudent Alternative Action 149 of the Federal Columbia River Power System Biological Opinion of 2000. The study involved planning and execution of a Physical Habitat Simulation System (PHABSIM) study in selected stream segments of the upper John Day River and Middle Fork John Day River drainages.

PHABSIM predicts changes in relationships between instream flows and fish habitat for individual species and life stages. 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 based on biological needs of fish. Output of the model, habitat versus flow relationship, must be integrated with species life history knowledge and available water supply to determine flow needs. This methodology is scientifically tested and is generally an accepted technique for determining flows needed for fish.

Primary limiting factors for fisheries in the upper John Day and Middle Fork John Day rivers appear to be high summer water temperatures and low summer flows. Although high summer water temperature appears to limit fish survival in late July and early August, fish populations continue to exist within available physical habitat throughout the year. In fact, steelhead and Chinook salmon redd counts have been relatively stable since the late 1950s. There continues to be more evidence that juvenile fish are surviving in pockets of cooler water provided by tributaries and groundwater inputs. For specific flow restoration projects, temperature effects should be fully considered and the net benefit to increased habitat determined.

The following stream segments were selected for the study:

Upper John Day River Stream Segments:
Stream Segment 1 – Mainstem upper John Day River from confluence with Squaw Creek near Prairie City upstream to end of cottonwood zone (0.75 miles).

Stream Segment 2 – Lower Reynolds Creek between private property boundary and first upstream diversion on Forest Service property (~0.25 miles).

Stream Segment 3 – Dad's Creek from confluence with John Day River upstream to first diversion (0.5 miles).

Middle Fork John Day River Stream Segments:
Stream Segment 1 – Middle Fork John Day River from Caribou Creek upstream to Vincent Creek (2.0 miles).

Stream Segment 2 – Middle Fork John Day River from Camp Creek upstream to Big Boulder Creek (5 miles).

Stream Segment 3 – Lower Granite Boulder Creek between two diversions in undisturbed area (0.5 miles).

All life stages were habitat-modeled in each stream segment even if they do not presently occur because of the potential for future restoration. Modeling results provided insight into the relationships between flow and habitat and how these results relate to the natural hydrograph. For example, optimal habitat for juvenile steelhead in the Middle Fork John Day River between Caribou Creek and Vincent Creek occurred at 100 cfs. Downstream in the Middle Fork John Day River between Camp Creek and Big Boulder Creek, optimal habitat for juvenile steelhead occurred at 140 cfs. Results showed that flows greater than 32 cfs met 0.6 depth adult passage criteria at a shallow riffle in the Middle Fork John Day River between Caribou Creek and Vincent Creek. The accompanying natural hydrology report showed that average monthly flows in the Middle Fork John Day River between Clear Creek and Camp Creek were below 100 cfs June through November and above 200 cfs March through May. Thus, there is not enough available water in average water years to provide optimal flow conditions for juvenile steelhead habitat during summer and fall. However, steelhead passage conditions are met in the spring.

The next step would be to involve stakeholders in the process of developing instream flow recommendations for selected fish species using the tools and guidelines provided in this instream flow report and accompanying natural hydrology report. This process can also be used to prioritize and direct cost-effective actions to improve fish habitat for ESA-listed anadromous and resident native fish. These actions may include acquiring water during critical low-flow periods by voluntary water leasing or modifying irrigation delivery systems to minimize out-of-stream diversions. Ultimately, this information will be used by resource managers to guide habitat restoration efforts in the evaluation of potential fish habitat and passage improvements by addressing streamflow needs of fish.

1.0 INTRODUCTION

The National Marine Fisheries Service (NMFS) (National Oceanic Atmospheric Administration (NOAA) Fisheries) issued a Biological Opinion (BiOp) in December 2000 on continued operation and configuration of the Federal Columbia River Power System (FCRPS) (NMFS 2000). Unless actions identified in the Reasonable and Prudent Alternative (RPA) in the BiOp are taken, a jeopardy opinion may be 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 requires 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 is 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. Reclamation is the lead agency for these initiatives and will facilitate their implementation.

The BiOp identified priority sub-basins where addressing flow, passage, and screening problems could produce short term benefits. Reclamation was assigned 16 Columbia River sub-basins through the BiOp. In the John Day River Basin, assigned sub-basins include the upper John Day River, North Fork John Day River, and the Middle Fork John Day River sub-basins.

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 are 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 NOAA Fisheries protocol for estimating tributary streamflow to protect salmon listed under the ESA was the Physical Habitat Simulation System (PHABSIM) (Arthaud et al 2001 Draft). The only other method suggested was the hydrology-based Tennant method (Arthaud et al 2001 Draft). PHABSIM was considered a more appropriate methodology since it considers the biological requirements of the fish. The NOAA Fisheries 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 Draft).

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.

The primary objective of this project was to conduct habitat studies on upper John Day River and Middle Fork John Day drainages to identify stream flow needs to support relevant life history stages of summer steelhead (*Oncorhynchus mykiss*), bull trout (*Salvelinus confluentus*), and spring Chinook salmon (*Oncorhynchus tschawytscha*). The project was intended to address Reclamation's obligations under Action 149 and involved planning and execution of a PHABSIM study in selected stream segments of the John Day River and Middle Fork John Day River drainages. The Technical Service Center (TSC) of Reclamation in Denver, Colorado conducted this study. Another objective of this initial study was to demonstrate how the selected methodology works to the stakeholders, including landowners, in a few areas where Reclamation is currently allowed to work. Hopefully, cooperation with landowners will improve after seeing the results of this initial work to allow expansion of the study area into other stream segments of the sub-basin as needed for specific potential flow restoration projects.

Information obtained from these studies will be used by the public, State, and Federal agencies to direct management actions addressing stream flow needs of ESA-listed anadromous and resident native fish. The study results will only be used to determine a target flow or flows that Reclamation will be able to use as a basis for voluntary water acquisitions.

1.1 Background

Historically, the John Day River produced significant numbers of anadromous fish in the Columbia River Basin (CRITFC 1995, as cited in Barnes and Associates 2002). However, runs of spring Chinook salmon and summer steelhead are a fraction of their former abundance, and summer steelhead and bull trout are federally listed as threatened under the ESA. Human development has modified the original flow regime and habitat conditions thereby affecting migration and/or access to suitable spawning and rearing habitat for all of these fish.

Reclamation participates with many other Federal, State, local, Tribal, and private parties (stakeholders) to protect and restore ESA-listed anadromous and native fish species in the John Day River Basin. One part of this work involves providing sufficient stream flow for these fish. Although sufficient stream flows are essential for fish, flows in the basin are also used for agricultural, domestic, commercial, municipal, industrial, recreational and other purposes. There is considerable information available to identify the amount of stream flow needed and used by people; however, there is little information about how much 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.

1.2 Species of Interest and General Fish/Habitat Relationships

1.2.1 Steelhead

In the John Day Basin, summer steelhead are part of the Mid-Columbia River steelhead Evolutionary Significant Unit (ESU) which is listed as threatened by NMFS (Federal Register Vol. 64, No. 57, March 25 1999). The agency announced its final steelhead critical habitat designations for 19 ESUs on August 12, 2005, which included the project area. Federal Register notices on these designations were published September 2, 2005 and became effective January 2, 2006. Adult steelhead are widely distributed throughout the project area, but do not oversummer in the upper John Day River basin. Juveniles are present year-round.

Spawning and rearing habitats for steelhead include virtually all accessible areas of the John Day River Basin. Steelhead inhabit a wide range of diverse habitats during rearing, overwintering, and migrating through small and large streams. Habitat requirements of steelhead vary by season and life stage (Bjornn and Reiser 1991). Steelhead distribution and abundance may be influenced by water temperature, stream size, flow, channel morphology, riparian vegetation, cover type and abundance, and substrate size and quality (Reiser and Bjornn 1979). Sediment-free spawning gravel and rearing substrate, stream temperatures below 16°C, and fast moving well-oxygenated water adjacent to slow moving water, are essential habitat components for steelhead (Bustard and Narver 1975). Juveniles prefer cover (e.g., rootwads and overhead cover) with slow water velocity shelters (Shirvell 1990; Fausch 1993).

1.2.2 Bull Trout

Bull trout are part of the Columbia River bull trout Distinct Population Segment (DPS) which is listed as threatened (Federal Register, Vol. 63, No. 111, June 10 1998). 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 DPS of bull trout (Federal Register Vol. 68, No. 28, February 11, 2003). Final critical habitat designation by the FWS does not include the John Day River Basin (Federal Register, Vol. 69, No. 193, October 6, 2004).

Within the project area, bull trout are widely distributed but in low abundance, and mostly occupy the headwater tributaries of the North Fork, Middle Fork, and upper John Day sub-basins of the John Day River. They are present year-round.

All life history stages of bull trout are associated with complex forms of cover, including large woody debris, undercut banks, boulders, and pools (Fraley and Shepard 1989; Goetz 1989; Banish 2003). Bull trout have specific spawning habitat requirements, spawning only in a small percentage of the available stream habitat. Spawning areas are usually less than 2 percent gradient (Fraley and Shepard 1989) and water depths range from 0.1 to 0.6 m (4 to 23 in) and average 0.3 m (12 in) (Fraley et al. 1981). Bull trout redds are vulnerable to scouring during winter and early spring flooding and low winter flows or freezing substrate (Cross and Everest 1995). Cover, substrate composition, and water quality are important spawning habitat components (Reiser and Bjornn 1979). Cover, provided by overhanging vegetation, undercut banks, submerged logs and rocks, water depth, and turbulence protect spawning fish from disturbance or predation. Because some bull trout enter streams weeks or months before spawning, they are vulnerable without adequate cover (Fraley and Shepard 1989). Closeness to cover is also a major factor when bull trout select a spawning site (Fraley and Shepard 1989). Suitability of gravel substrates for spawning varies with size of fish (larger fish use larger substrates), and spawning occurs in loosely compacted gravel and cobble substrate at runs or pool tails (Fraley and Shepard 1989). Initiation of spawning appears to be strongly related to water temperature (5° to 9°C), and possibly also to photoperiod and streamflow (Shepard et al. 1984). Also, bull trout spawning occurs in areas influenced by groundwater (Ratliff 1992).

Bull trout fry typically use shallow and slow moving waters associated with edge habitats and cover (Tim Unterwegner, Oregon Department of Fish and Wildlife (ODFW), personal communication, March 16, 2004). Rearing juveniles disperse and use most of the suitable and accessible stream areas in a drainage (Leider et al. 1986). Water temperature and cover (substrate and large woody debris) determine distribution and abundance of juveniles (Fraley and Shepard 1989). Juveniles are rarely found in streams having water temperatures above 15°C and excess sediment that reduces useable rearing habitat and macroinvertebrate production (Fraley and Shepard 1989).

Channel stability, substrate composition, cover, water temperature, and migratory corridors are important for adult and young fluvial and adfluvial fish rearing and movement in streams (Rieman and McIntyre 1993). Deep pools with abundant cover (larger substrate, woody debris, and undercut banks) and water temperatures below 15°C are important habitat components for stream resident bull trout (Goetz 1989). Fluvial bull trout over-winter in pool and run habitats (Elle et al. 1994). Most fluvial bull trout remain in the same habitat type after entering the main river from tributaries (Elle et al. 1994). Lakes and reservoirs are very important for adfluvial bull trout, as they are the primary habitat for rearing and growth of young and adults (Leathe and Graham 1982). In large river systems, used as migratory corridors for fluvial and adfluvial bull trout, large oxbow lakes, groundwater influenced floodplain ponds and sloughs adjacent to the main channel are important habitat components in all seasons (Cavallo 1997). While resident bull trout spend their entire life in the headwaters, migratory bull trout travel downstream after 1-3 years to larger bodies of water where their growth can increase (Banish 2003). ODFW documented movement in late November through late April of sub-adult sized bull trout (240-300 mm fork length) downstream as far as Spray on the mainstem John Day River and as far downstream as Ritter on the Middle Fork John Day River (Tim Unterwegner, ODFW, personal communication, March 16, 2004).

1.2.3 Spring/Summer Chinook Salmon

Although spring Chinook salmon are not an ESA-listed species, Mid-Columbia River spring-run Chinook salmon are protected under the Magnuson-Stevens Fishery Conservation and Management Act (MSA) as amended by the Sustainable Fisheries Act of 1996 (Public Law 104-267). Recent runs (2,000-5,000 fish) are a fraction of their former abundance (Barnes and Associates, Inc. 2002). Essential fish habitat (EFH) has been designated by the Pacific Fishery Management Council for spring Chinook salmon, which includes the project action area (PFMC 1999). They spawn primarily in the mainstem and major tributaries of the North Fork, Middle Fork, and upper John Day Rivers. Spawning occurs from late August through early October. Juveniles reside in rearing areas for approximately 12 months before migrating downstream the following spring.

Habitat requirements of Chinook salmon vary by season and life stage, and fish occupy a diverse range of habitats. Cover type and abundance, water temperature, substrate size and quality, channel morphology, and stream size may influence distribution and abundance. Cover is essential for adults prior to spawning (Reiser and Bjornn 1979) and temperature may influence the suitability of spawning, rearing, and holding habitat. Fry concentrate in shallow, slow water near stream margins with cover (Hillman et al. 1989) and move to deeper pools with submerged cover during the day as they grow (Reiser and Bjornn 1979). Juveniles use pools and protected areas (e.g., undercut banks) for summer rearing (Brusven et al. 1986) and deeper waters and interstitial spaces between rocks (these areas protect fish from freezing and allow fish to rest in still water) for winter rearing (Marcus et al. 1990). Adult Chinook salmon use pools associated with cover (when available) for holding, typically in upper headwater streams before fall spawning (Berman and Quinn 1991; Price 1998; Torgersen 2002). In some instances, holding adult Chinook salmon also use deep riffles when pools are in short supply (Price 1998). Suspended sediment may affect juvenile fish by damaging gills, reducing feeding, avoidance of sedimented areas, reduced reactive distance, suppressed production, increased mortality, and reduced habitat capacity (Reiser and Bjornn 1979).

2.0 LIMITING FACTOR ANALYSIS

The main components in this analysis were existing hydrology, water temperature, and fish population data. Natural flow estimates, presented in a separate report (Reclamation 2005), and U.S. Geological Survey (USGS) gage data were used to describe recent historical hydrology. Existing fish population data were used as an index of fish populations in the study streams. Additionally, any existing water quality data, including water temperature, were evaluated to determine if water quality was limiting.

Reclamation monitored water temperature continuously during summer, 2004 at selected locations recommended by the Confederated Tribes of Warm Springs Reservation of Oregon (CTWSRO) (i.e., upper John Day River, Middle John Day River) using Onset TidBit data loggers to assess whether summer water temperatures limit fish populations.

Based on a review of existing fish population data, the John Day River supports one of the few remaining wild runs of spring Chinook salmon and summer steelhead in the Columbia Basin (USDI 2001). The upper John Day River produces an estimated 18 percent of the spring Chinook salmon and 16 percent of the summer steelhead in the John Day Basin (Oregon Water Resources Department (OWRD) 1986, as cited in USDI 2001). The North Fork and Middle Fork sub-basins produce approximately 82 percent of the spring Chinook salmon and 73 percent of the summer steelhead population in the John Day (OWRD 1986, as cited in USDI 2001). There have been no releases of hatchery anadromous fish in the John Day Basin since 1969. Self-sustaining fish populations exist for all three fish species of interest in the upper John Day River Basin (Table 1). Chinook salmon populations appear to have increased since 1959 (Figure 1). Steelhead redd surveys conducted by ODFW show a slight downward trend for the past 40 years (Figure 2). Since water is diverted between April 1 and September 30 each year for irrigation, these are the months when discharge restoration would occur. Thus, life stages that occur during these months were the focus of this study.

Bull trout populations exist throughout the project area in streams with excellent water quality and high quality habitat. The Middle Fork bull trout population is considered to be the most vulnerable and at the highest risk of extinction because they only exist in three tributaries - Granite Boulder Creek, Clear Creek, and Big Creek (Tim Unterwegner, ODFW, personal communication, January 12, 2005). A population assessment was conducted by ODFW in 1999 for bull trout in these three tributaries. The population in Big Creek was estimated at 2,590 age 1+ bull trout. The estimates for Clear Creek and Granite Boulder Creek were 640 and 368 age 1+ bull trout, respectively (Barnes & Associates, Inc. 2002; Tim Unterwegner, ODFW, personal communication, January 12, 2005). During bull trout presence/absence surveys conducted by ODFW in 2000, a single bull trout was found in Vinegar Creek.

Table 1. Fish use in upper John Day and Middle Fork John Day River Sub-basins.

Species/life stage	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Summer Steelhead												
Adult Migration		X[1,2]	X	X	X							
Adult Spawning			X	X	X	X						
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
Fry				X	X	X	X					
Bull Trout Fluvial												
Spawning									X	X	X	
Adult	X	X	X	X	X	X	X	X	X	X	X	X
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
Fry												
Bull Trout Resident (in tributaries)												
Spawning									X	X	X	
Adult	X	X	X	X	X	X	X	X	X	X	X	X
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
Fry												
Spring Chinook												
Adult Migration					X							
Adult Holding						X	X	X				
Adult Spawning								X	X	X		
Juvenile	X	X	X	X	X	X	X	X	X	X	X	X
Fry				X	X	X						

[1] X - Represents periods of species use based on observation
[2] Shading represents periods of presence based on professional judgment

Sources: Barnes & Associates, Inc. (2002); Tim Unterwegner, ODFW, personal communication, January 12, 2005

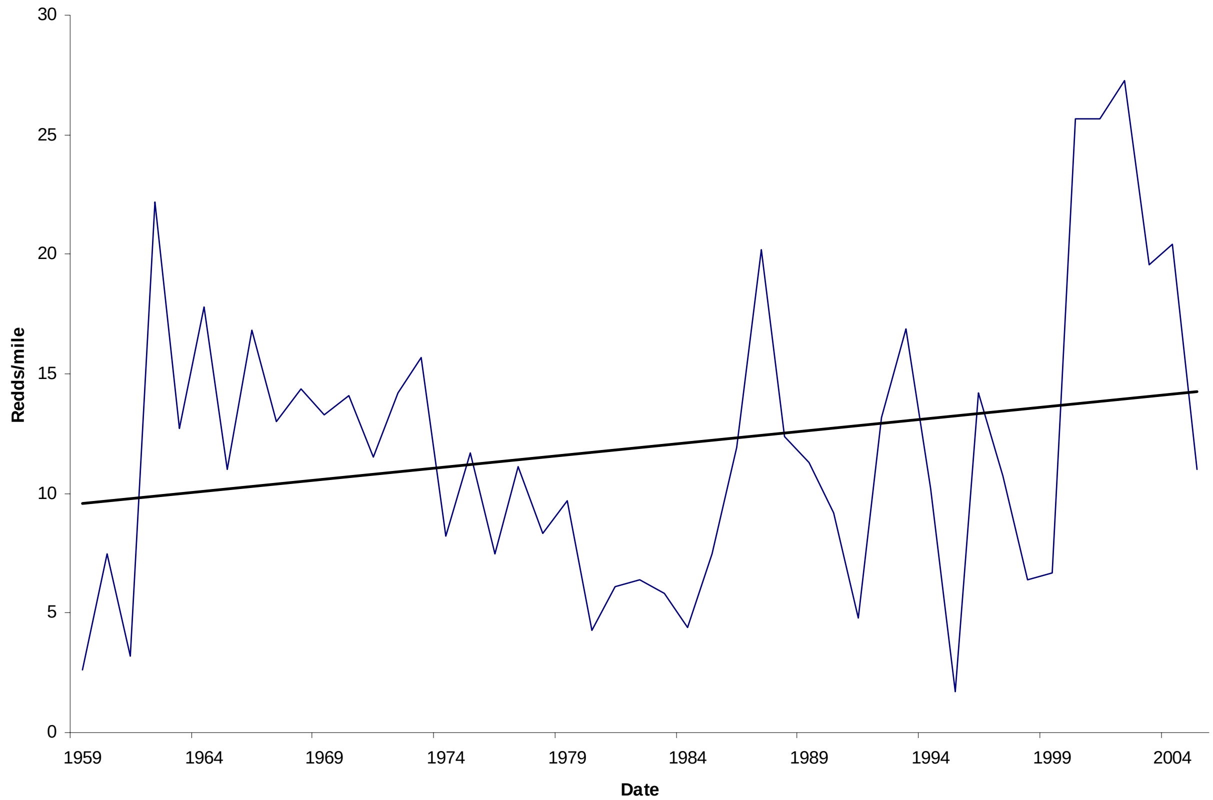


Figure 1. John Day River Basin spring Chinook salmon redd survey data (1959-2005) (ODFW database).

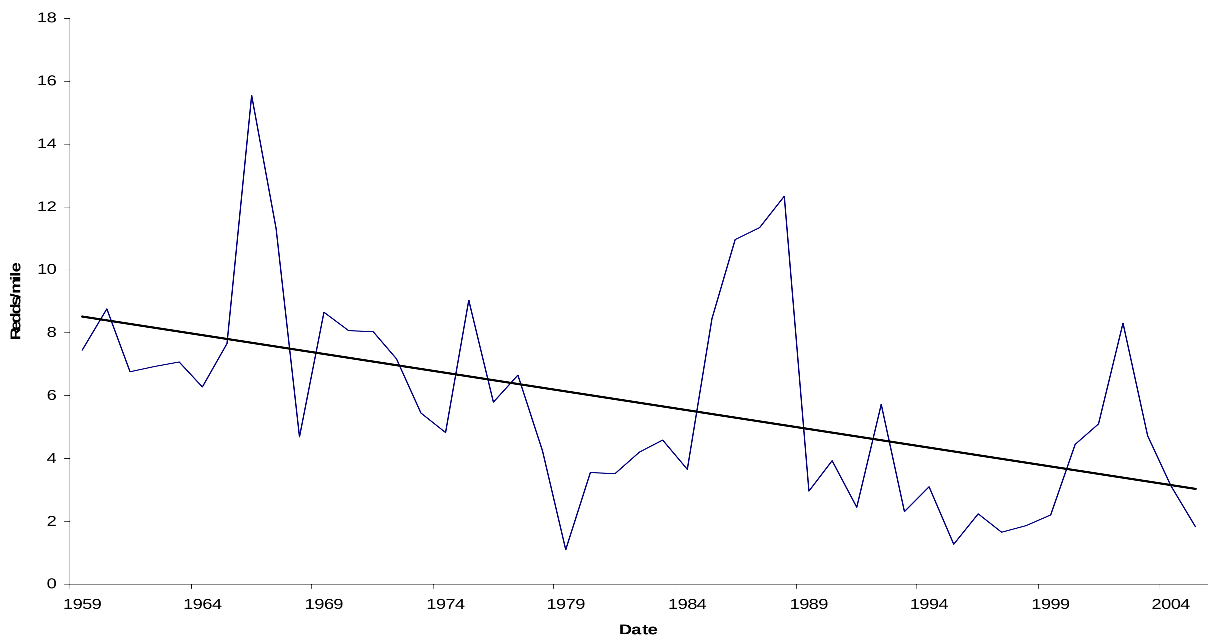


Figure 2. John Day River Basin steelhead redd survey data (1959-2005) (ODFW database).

Natural stream flow estimates characterize seasonal discharge variability in each stream segment (Reclamation 2005). Large fluctuations in discharge during the year are products of variable weather and the free-flowing condition of the John Day River as demonstrated at the USGS Blue Mountain Hot Springs gaging station, located upstream from most diversions on the upper John Day River (Figure 3).

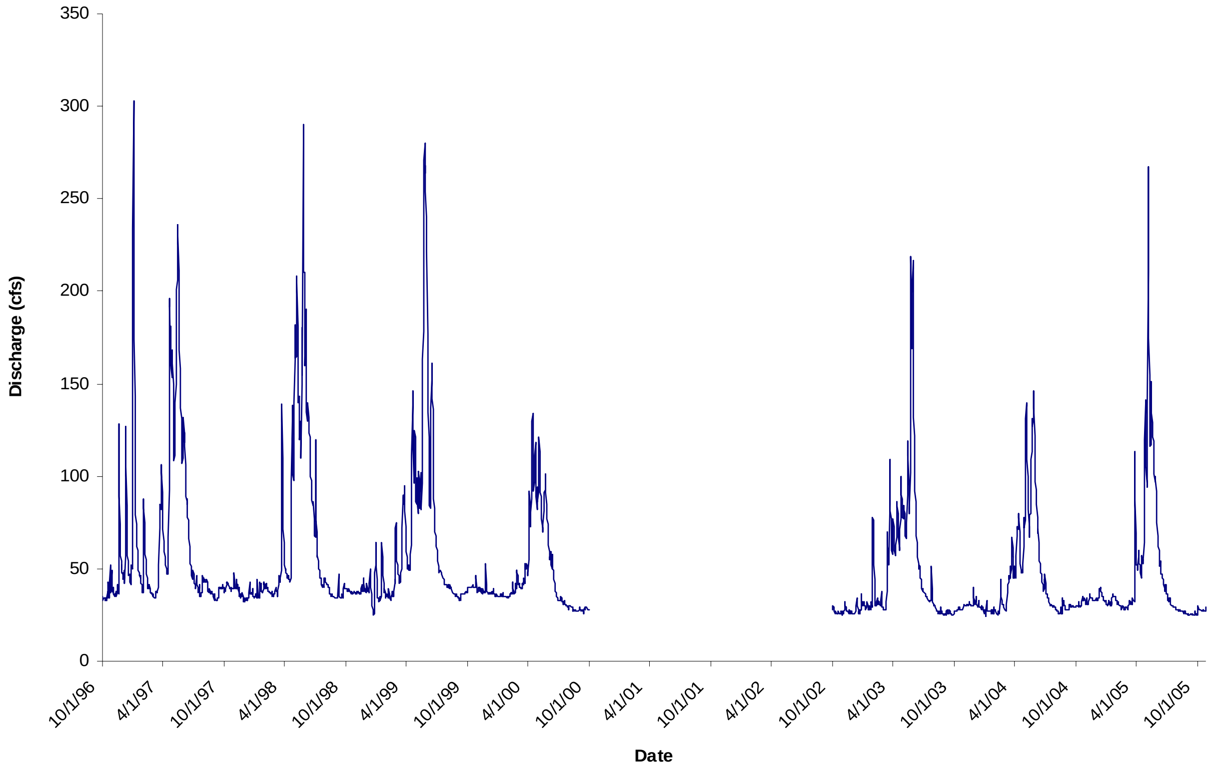


Figure 3. Recent discharge records at Blue Mountain Hot Springs gage on upper John Day River (USGS station number 14036860).

Figures 4-8 show graphs of average monthly natural flow estimates in the stream segments analyzed by Reclamation (2005). Discharge estimates for June, July, and August at 20, 50 and 80 percent exceedances and mean annual discharge (MAD) at these stream segments are summarized in Table 2. Additional detailed information, including exceedance flows for each month, is available in the hydrology report (Reclamation 2005). The main reason for the difference between the shape of upper John Day River hydrograph and the other hydrographs is the varying aspects, or directions, of the watersheds in the area (Tom Belinger, Reclamation, personal communication, December 22, 2005). The Strawberry Creek gage data was used as a base for the upper John Day River due to its better correlation with the gaged and computed flows in earlier studies. This was assumed to be the result of the high peaks on the south side of the mainstem John Day which are characterized by a large area of high precipitation. That high snowfall has a delayed peak runoff due to the north aspect of the slopes (as indicated by the Strawberry Creek gage) and appeared to be more controlling for the mainstem hydrograph. This was the case with all north-facing sloped watersheds in a previous

1990 study that contributed to the different hydrograph on the mainstem. The other watersheds in the Reclamation (2005) study are more southerly and west-facing. They are also characterized by less precipitation. For the Middle Fork John Day River, even though there are north-facing slopes that contribute to the flow, they have less precipitation than on the south-facing slopes; so the control of the peak flow is assumed to be more from the earlier peaking south facing part of the watershed. For these areas, the higher precipitation bands should peak much earlier due to their aspect.

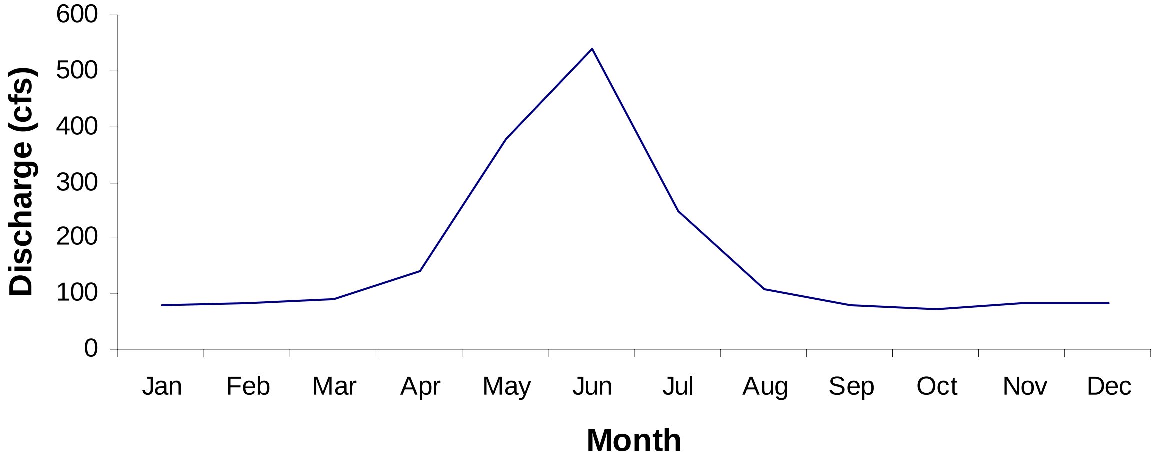


Figure 4. Average monthly estimated natural hydrology for John Day River between Rail Creek and Prairie City.

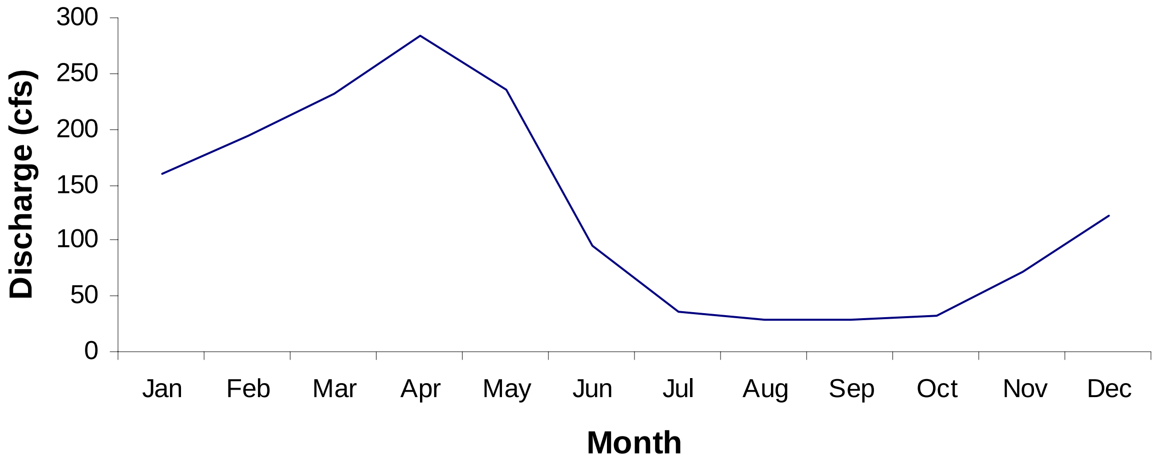


Figure 5. Average monthly estimated natural hydrology for Middle Fork John Day River between Clear Creek and Camp Creek.

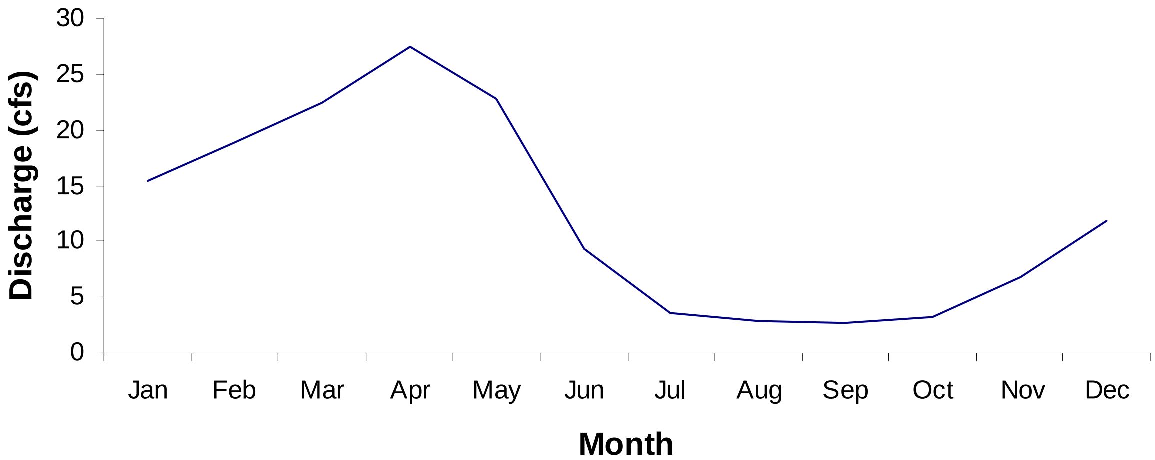


Figure 6. Average monthly estimated natural hydrology for Granite Boulder Creek.

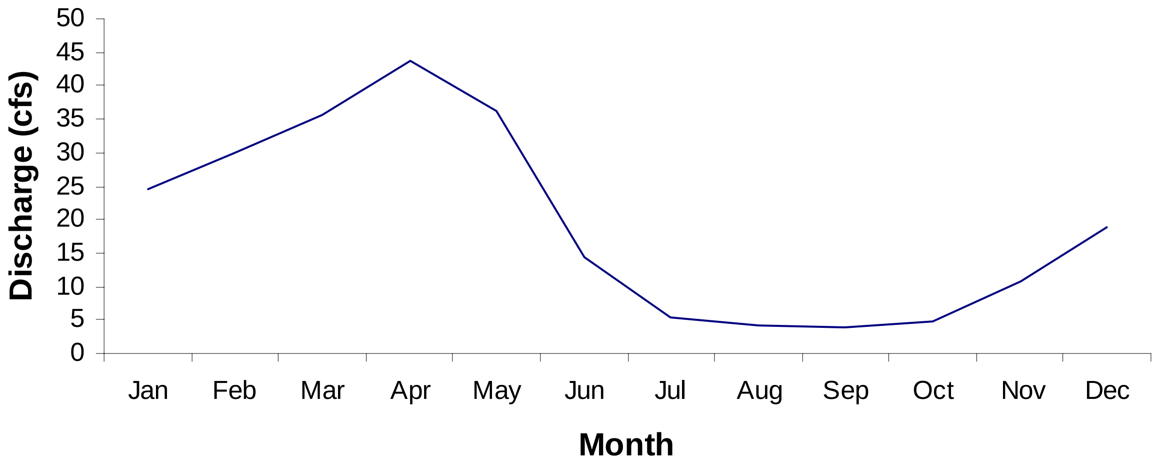


Figure 7. Average monthly estimated natural hydrology for Reynolds Creek.

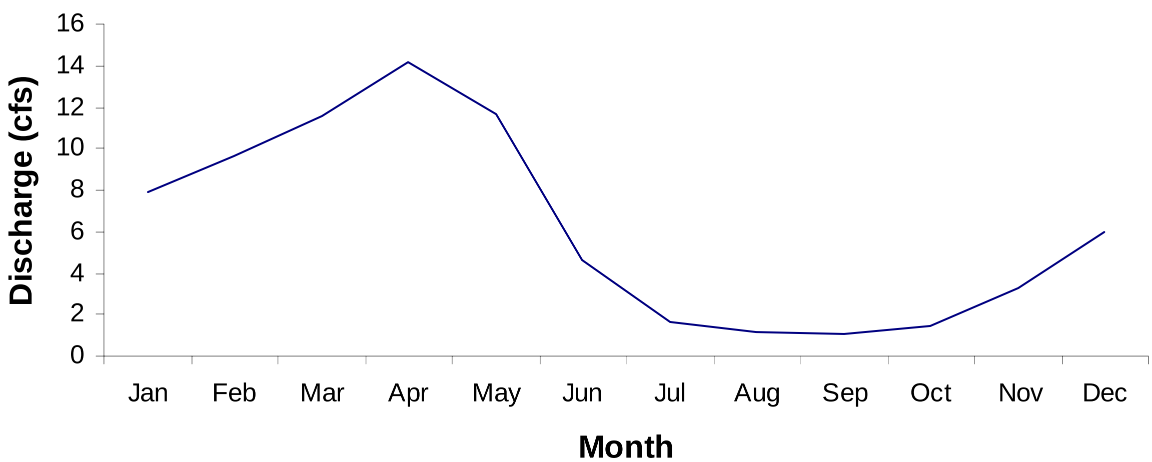


Figure 8. Average monthly estimated natural hydrology for Dad's Creek.

Table 2. Discharge estimates (cfs) for June, July, and August at 20, 50 and 80 percent exceedances and mean annual discharge at study stream segments (Source: Reclamation 2005)

Stream segment	Mean annual discharge (cfs)	June			July			August		
Exceedance level		20%	50%	80%	20%	50%	80%	20%	50%	80%
Upper John Day near Prairie City	169	322	505	768	144	217	325	81	100	138
Middle Fk John Day between Clear Cr. and Camp Cr.	126	55	86	123	31	35	39	26	28	31
Reynolds Creek	19	7	13	19	4	5	6	4	4	4
Granite Boulder Creek	12	5	8	12	3	3	4	3	3	3
Dad's Creek	6	3	4	6	1	2	2	1	1	1

Water withdrawals have degraded the aquatic resources in the John Day River Basin (Barnes & Associates, Inc. 2002). Water demand for irrigation use is substantial in magnitude, duration, and frequency with water appropriations exceeding natural discharges at times, most notably in summer (Figure 9). Water appropriation varies by season; the average proportion of consumptive use to natural discharge is two percent in winter, 15 percent in spring, 73 percent in summer and 14 percent in fall (Barnes & Associates, Inc. 2002). Artificially low stream flow limits the movement of fish, reduces the amount of physical habitat available for fish to live in, and reduces quality of habitat (see Section 1.2). Although the discharge/temperature relationship is not completely understood, evidence suggests that in some settings subsurface return flows from flood irrigation is cooler than the source supply of water and may provide pockets of cooler water instream.

Water quality in the Middle Fork John Day Sub-basin generally exhibits satisfactory chemical, physical, and biological quality (Barnes & Associates, Inc. 2002). The Middle Fork usually has worse water quality problems than its tributaries, with the most serious water quality problem being elevated summer temperatures. Although water quality is fair in the upper John Day River during most of the year, low summer discharges on the mainstem John Day River above Dayville contribute to elevated temperatures and high spring stream flows contribute to turbidity (Barnes & Associates, Inc. 2002). Upper John Day River and Middle Fork John Day River drainages are listed as water quality limited for temperature by Oregon Department of Environmental Quality (ODEQ) (www.deq.state.or.us/wq/303dlist/303dpage.htm). Oregon water temperature standards are seven-day average maximum temperatures of 13.0°C (55.4°F) for salmon and steelhead spawning and 18.0°C (64.4°F) for salmon and trout rearing (ODEQ 2004). Current trends in the seven-day maximum reading of water temperature in upper John Day and Middle Fork John Day Rivers indicate that the annual seven-day maximum occurs between the last week in July and the first week in August. However, spring Chinook salmon spawning adults and juveniles and summer steelhead juveniles exist during this period (Table 1).

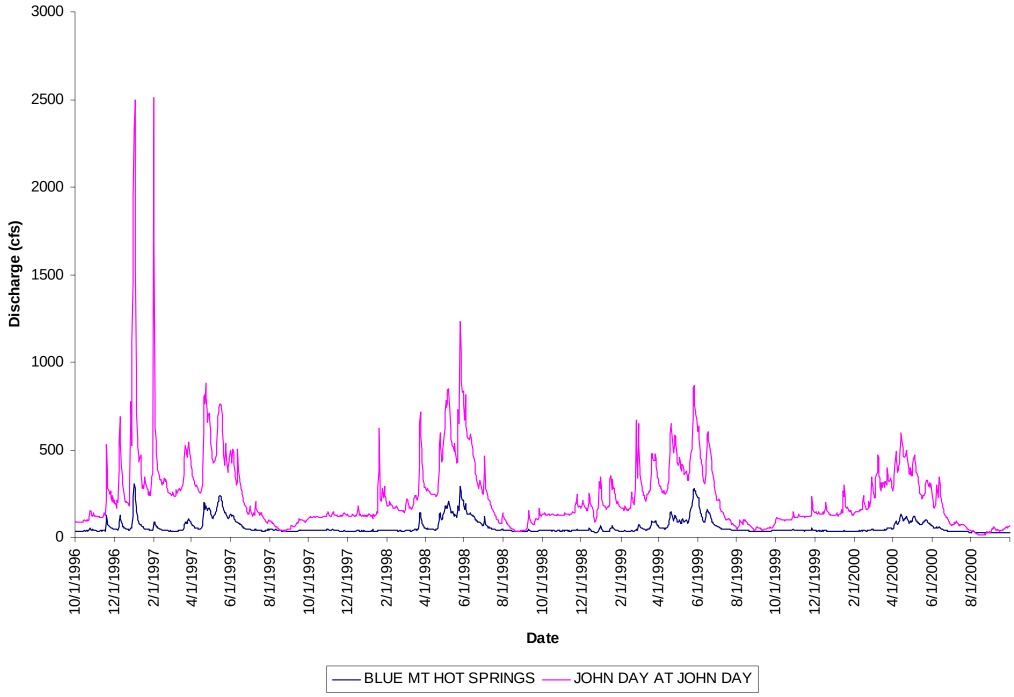


Figure 9. Comparison of daily stream flows between Blue Mountain Hot Springs gage (40 sq. mi. drainage area) and the John Day gage (386 sq. mi. drainage area) on the upper John Day River.

Water temperatures in upper John Day River and Middle Fork John Day River were recorded by Reclamation during summer, 2004. Oregon standards for rearing and salmon spawning were exceeded between July and late September. Temperature in the upper John Day River reached a maximum of 25.4°C (77.8°F) on August 12 (Figure 10). Maximum temperature in Middle Fork John Day River of 25.6°C (78.1°F) occurred on July 16 (Figure 11).

Stream temperature is driven by the interaction of many variables, including shade, geographic location, vegetation, climate, topography, and discharge. Discharge levels are affected by weather, snowpack, rainfall, and water withdrawal. Diverted water can reduce water quality. Shallower, slower water tends to warm faster than deeper, faster 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). The temperature at which 50% mortalities (LC-50) occur in juvenile Chinook salmon is 25°C (77°F), when acclimated to 15°C (59°F) (Armour 1991). The upper lethal limit is 24°C (75°F) for steelhead (Bell 1991).

Problem eutrophication is a partial result of irrigation return discharge (non-point source) and possibly cattle feedlots (point source). However, compared to elevated water temperature, agricultural runoff presents a low level of potential impact to water quality (Barnes & Associates, Inc. 2002).

Again, the objective of Action 149 is 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."

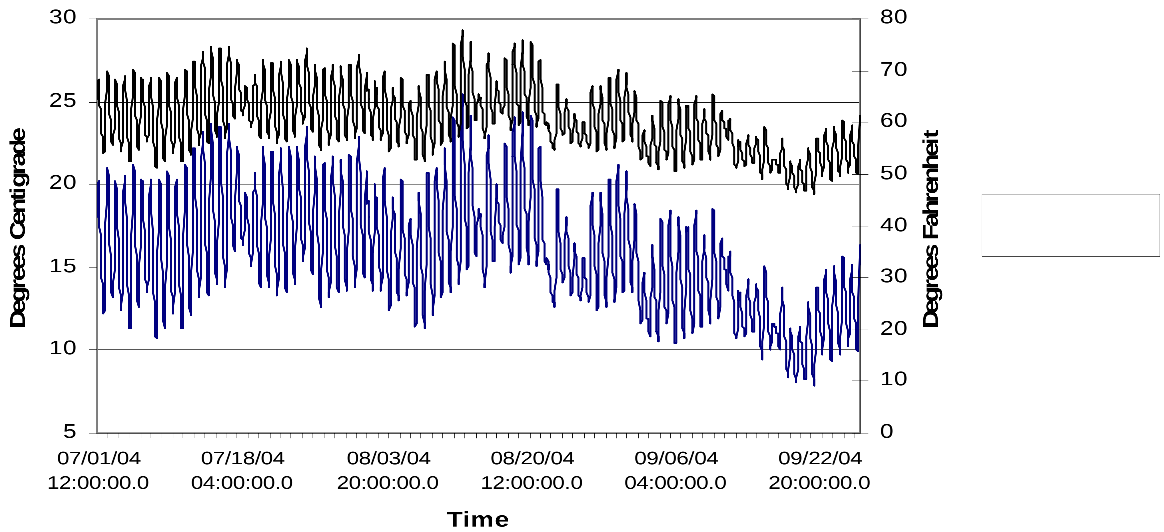


Figure 10. Temperatures measured in upper John Day River during summer, 2004.

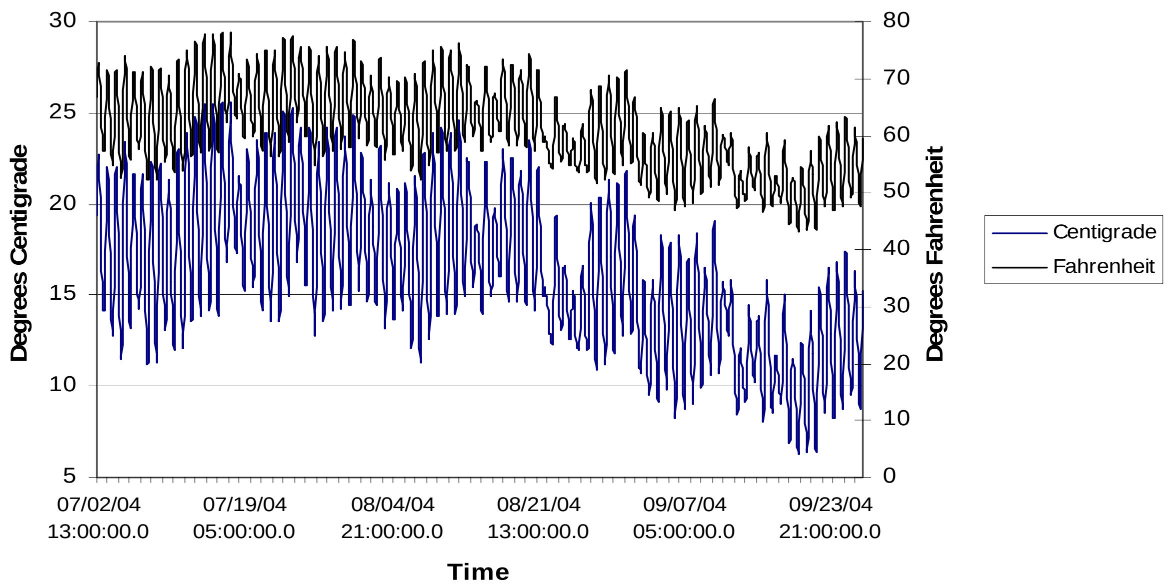


Figure 11. Temperatures measured in Middle Fork John Day River during summer, 2004.

Based on this analysis, primary limiting factors for fisheries in the upper John Day and Middle Fork John Day rivers appear to be high summer water temperatures and low summer flows. Although high summer water temperature appears to limit fish survival in late July and early August, fish populations continue to exist within available physical habitat throughout the year. There continues to be more evidence that juvenile fish are surviving in pockets of cooler water provided by tributaries and groundwater inputs. For specific flow restoration projects, temperature effects would be fully considered and the net benefit to increased habitat determined. Thus, PHABSIM was considered an appropriate methodology to use in the upper John Day and Middle Fork John Day rivers to evaluate flow-related habitat.

3.0 STUDY REGION

The first decisions related to geographic boundaries regard the number and aggregate length of streams incorporated in the habitat analysis (Bovee et al. 1998). The following definitions apply to this discussion:

Study area – The study area of a stream is bounded by the point at which the impact of flow alteration occurs to where it is no longer significant. Typically, only a small portion of a single stream makes up the study area.

Hydrologic segment – The portion of the study area that has a homogeneous flow regime. A study area may have one or more hydrologic segments (+/- 10% of the mean monthly flow).

Sub-segment – A physical aspect of the channel within a hydrologic segment that affects the microhabitat versus discharge relationship (e.g., channel morphology, slope, or land use).

Study site – A mesohabitat unit within a hydrologic segment or sub-segment.

The following sections describe the process and direction that Reclamation followed to identify the geographic area boundaries and stream segments that are impacted by diversions for this study.

3.1 Action 149 of the 2000 and Metric Goals in the 2004 FCRPS Biological Opinions

Action 149 of the 2000 FCRPS BiOp states, “The Federal Agencies have identified priority sub-basins where addressing flow, passage, and screening problems could produce short term benefits. This action initiates immediate work in three such sub-basins per year, beginning in the first year with the Lemhi, upper John Day, and Methow sub-basins. Sub-basins to be addressed in subsequent years will be determined in the annual and 5-year implementation plans. NMFS will consider the level of risk to individual ESU’s and spawning aggregations in the establishment of priorities for subsequent years. At the end of 5 years, work will be underway in at least 15 sub-basins. The objective of this action is 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.” These Action 149 objectives are 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.

3.2 Meeting Among Stakeholders

At a meeting among stakeholders on December 11, 2002, Reclamation discussed its obligation to restore stream flows under Action 149 and also introduced NOAA Fisheries accepted methodologies (i.e., PHABSIM and Tennant) to determine instream flow needs. At that meeting, stakeholders discussed how to identify and prioritize streams needed to be studied. ODFW provided information on work ODFW and OWRD had done on prioritizing watersheds for stream flow restoration. Reclamation assumed that the prioritization for ODFW was based on the need for flow restoration while OWRD's was based on potential to find water for flow restoration.

3.3 General Geographic Boundaries

Following the December 11th meeting and after further discussion with ODFW and OWRD to narrow down the number of study areas, Reclamation proposed the following geographical boundaries for instream flow studies in the Upper and Middle Fork John Day Rivers on January 31, 2003 (Figure 12):

UPPER JOHN DAY RIVER
The upper John Day River from the Forest Service boundary (Rail Creek) to Prairie City would be the initial target study area. This stream was chosen because it is a high priority to ODFW and OWRD in their ranking process. In general this stream has very valuable habitat for salmon, steelhead, bull trout, and native cutthroat and, as identified by OWRD, has the potential for water being available for instream flows. In addition, the hydrology of this reach is fairly well documented by the John Day River Blue Mountain Hot Springs Gage located near the upstream boundary of the reach. This gage is near the headwaters of the John Day and only a few small diversions occur above this gage. The CTWSRO may eventually install a river gage near Prairie City.

MIDDLE FORK JOHN DAY RIVER
The study area from Highway 20 near the former townsite of Bates downstream to Camp Creek would be the initial target reach. The Middle Fork is a high priority stream for ODFW and includes lands recently purchased by CTWSRO (Forrest and Oxbow Ranches) and lands owned by The Nature Conservancy (TNC) (Dunstan Preserve). The CTWSRO and TNC are actively managing these properties for anadromous fish recovery. The CTWSRO has funding through BPA to conduct irrigation return-flow studies to help in their long term management decisions on the properties. Since present access to other reaches of the Middle Fork is problematic because of landowner issues, instream flow studies in the proposed reach would compliment CTWSRO and TNC efforts.

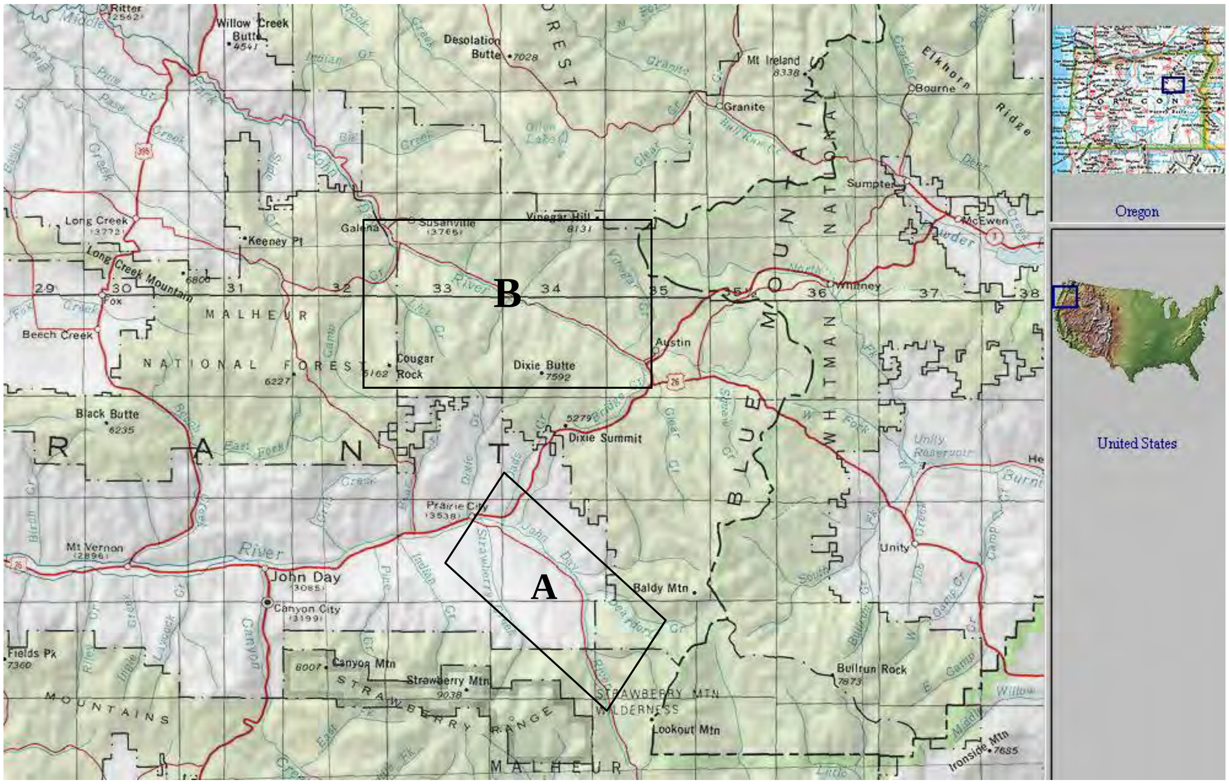


Figure 12. General geographic boundaries for initial instream flow studies in John Day River Basin (A = upper John Day River; B = Middle Fork John Day River).

After receiving verbal concurrence from NOAA Fisheries on the proposed geographical boundaries, Reclamation proceeded with the stream segmentation process using the following steps:

1. Reclamation conducted a reconnaissance to generally define study areas impacted by upstream diversions within the larger geographic boundaries.
2. Stream segments were initially identified based on flow regimes (i.e., > 10% accretions from tributaries) using available data sources.
3. Using USGS topographic maps, longitudinal gradients were plotted for each of these streams. Sub-segment boundaries were identified on these plots using slope changes.
4. Stream study area boundaries were refined based on estimated locations of diversions using aerial photos and identified from GIS coverage.

3.4 Stream Segment Selection

Final stream segments were prioritized using the steps described above and were selected for initial study because they represented the few areas in the upper John Day River and Middle Fork John Day River drainages that shared the following characteristics:

- Uniform gradient and flow regime within segment;
- Known salmon, steelhead, and bull trout use;
- Potential for flow restoration (upstream diversions);

- No anthropogenic channel disturbances (e.g., channelization, vegetation removal); and
- Reclamation has landowner permission at all times in at least a portion of the segment.

Table 3 is a summary of the criteria checklist used to help prioritize stream segments. The site reconnaissance and aerial photos assisted in determining changes in channel morphology resulting from anthropogenic disturbances (e.g., channelization; riparian woody vegetation clearing; land use practices). This list is subject to change based on additional or new information.

Each segment was checked to see if it was of similar gradient, channel morphology, and flow regime throughout the segment before starting the study. Study segments for tributary streams were primarily defined based on the location of the first upstream major diversions without landowner restrictions. Prioritization included locating segments below diversions so that Reclamation can identify the impact of acquiring water for instream habitat needs. Considering these restrictions, criteria, and objectives, the following stream segments, although not all inclusive, were recommended for the pilot study:

Upper John Day River Stream Segments:
Stream Segment 1 – Mainstem upper John Day River from confluence with Squaw Creek near Prairie City upstream to end of cottonwood zone (T13S, R33E, Sec.11) (0.75 miles).

Stream Segment 2 – Lower Reynolds Creek (T13S, R35E, Sec.30) between private property boundary and first upstream diversion on Forest Service property (~0.25 miles).

Stream Segment 3 – Dad's Creek from confluence with John Day River upstream to first diversion (T13S, R34E, Sec.7) (0.5 miles).

Middle Fork John Day River Stream Segments:
Stream Segment 1 – Middle Fork John Day River from Caribou Creek upstream to Vincent Creek (T11S,R34E,Sec.13) (2.0 miles).

Stream Segment 2 – Middle Fork John Day River from Camp Creek upstream to Big Boulder Creek (T11S,R34E,Sec.10 and 11) (5 miles).

Stream Segment 3 – Lower Granite Boulder Creek (T11S,R34E,Sec.6) between two diversions in undisturbed area (0.5 miles).

While an ideal instream flow study would involve selecting stream segments based on flow regime, slope, and channel morphology throughout the entire sub-basin of interest, current lack of landowner cooperation to allow permission on private property in the John Day River Basin has resulted in a situation where the opportunity to conduct an ideal study is severely limited. For example, habitat inventory surveys cannot be conducted to collect mesohabitat-specific information on which to base study site selections where landowners do not allow access.

Table 3. Stream segment prioritization checklist for John Day River flow characterizations.

Stream Segment (upstream to downstream)	Known salmon, steelhead, and bull trout use	Currently undisturbed	Potential for flow restoration (diversions)	Landowner permission
Upper John Day River mainstem:				
Between Rail Cr and Deardorff Cr	X	X	X	No - private
Between Deardorff Cr and Reynolds Cr	X	X	X	No – private
Between Reynolds Cr and braided channel	X	X	X	No – private
Braided north channel		X	X	No – private
Braided south channel	X	X	X	No – private
Between braided channel and Dad's Cr	X		X	No - private
Between Dad's Cr and cottonwood zone	X		X	Yes - tribal
Between cottonwood zone and Squaw Cr.	X	X	X	Not lower reach – private
upper John Day River tributaries:				
Deardorff Cr	X	X	X	Not lower reach – private
Reynolds Cr	X	X	X	Not lower reach – private
Dad's Cr	X	X	X	Not lower middle reach - private
Middle Fk John Day River mainstem:				
Between Clear Cr and Bridge Cr	X		X	No – private
Between Bridge Cr and Davis Cr	X	X (fenced)	X	Not Aug-Sept - tribal
Between Davis Cr and Vinegar Cr	X	X (fenced)	X	Yes - tribal
Between Vinegar Cr and Vincent Cr	X	X (fenced)	X	Not Aug-Sept - tribal
Between Vincent Cr and Caribou Cr	X	X (fenced)	X	Yes - tribal
Between Caribou Cr and braided channel	X	X	X	Yes – Forest Service
Braided channel at "Squatter Flat"	X		X	Yes - tribal
Between braided channel and Big Boulder Cr	X	X	X	Yes – tribal; Forest Service; TNC
Between Big Boulder Cr and Camp Cr	X	X	X	No from Hwy 36 bridge upstream to Coyote Creek – private; Yes above Coyote Creek - TNC
Middle Fk John Day River tributaries:				
Clear Cr	X	Lower reach disturbed	X	Not lower reach - private
Bridge Cr		X	X	Not lower reach - private
Davis Cr		X	X	Yes – Forest Service; tribal
Vinegar Cr		X	X	Yes – Forest Service; tribal
Vincent Cr		X	X	Yes – Forest Service; tribal
Dead Cow Gulch		X	X	Yes – Forest Service; tribal
Butte Cr	X	X	X	Yes – Forest Service; tribal
Ruby Cr		X	X	Yes – Forest Service; tribal
Granite Boulder Cr	X	Lower reach disturbed	X	Yes – Forest Service; tribal

4.0 METHODS

4.1 Physical Habitat Simulation System

Studies utilizing PHABSIM require extensive data collection and analyses. Figures 13 and 14 illustrate in general how site-specific hydraulic data is integrated with HSCs to develop the habitat-discharge relationship output from PHABSIM. More detailed steps are briefly outlined below.

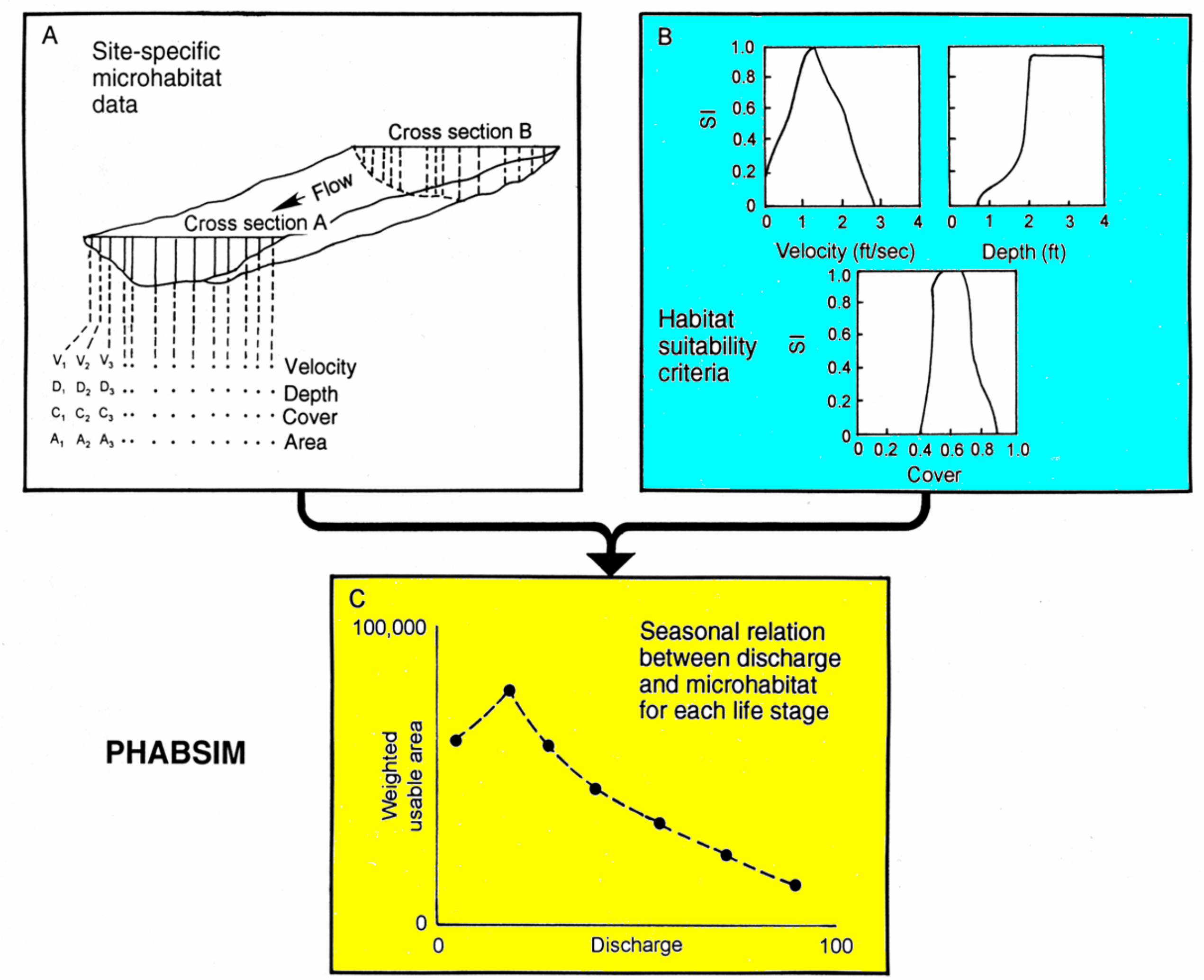


Figure 13. PHABSIM process of integrating hydraulic data with habitat suitability criteria to develop a habitat-discharge relationship.

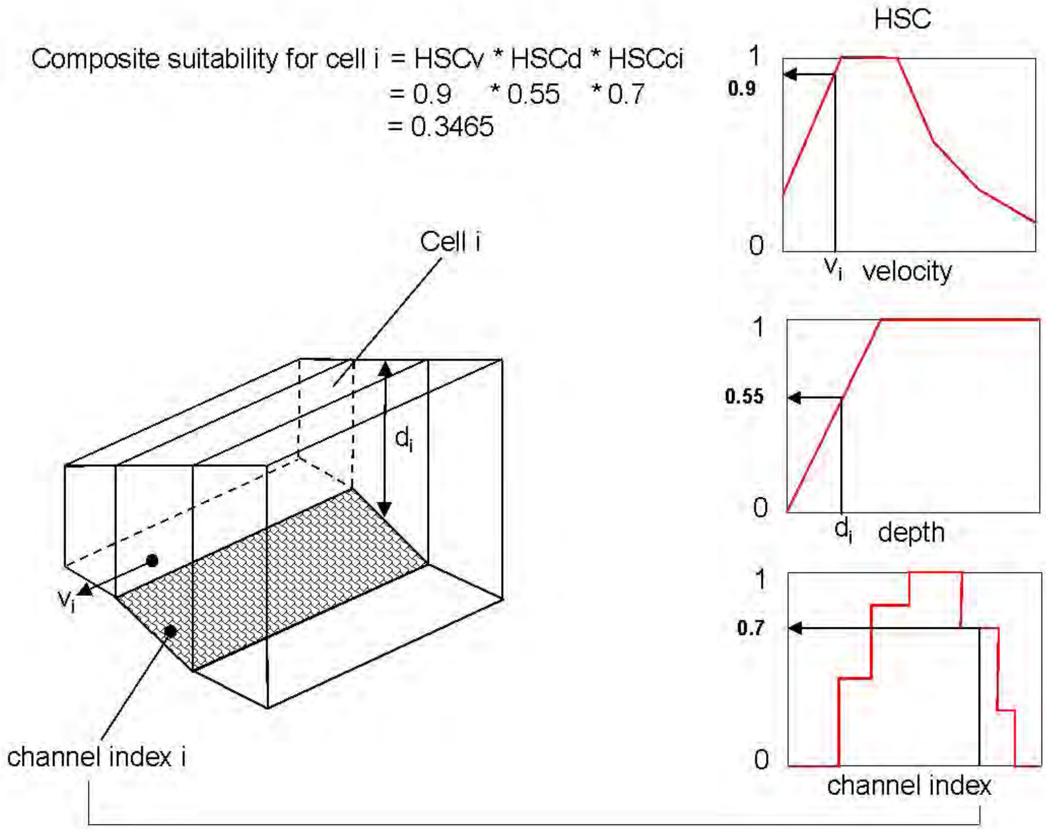


Figure 14. Example of composite habitat suitability calculation procedure to determine weighted usable area (WUA) in one cell.

4.1.1 Mesohabitat Classification and Inventory

Specific procedures at each stream segment included mapping habitat features. Habitat mapping, or mesohabitat typing, conducted in late August, 2003, started at the lower segment boundary and proceeded upstream to the upper boundary in accessible reaches. 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 variability (e.g., backwater and slopes). The following mesohabitat classification scheme was used:

- low gradient riffles and runs (slope),
- moderate gradient riffles and runs (slope),
- high gradient riffles and runs (slope),
- shallow pools (<2 ft) (backwater), and
- deep pools (≥2 ft)) (backwater).

Linear distance of each major habitat type and total length mapped were recorded at the end of each segment. The mapped data were used to help select transects and to determine percentages of each habitat type. The results of mapping where Reclamation had permission to work was assumed to represent areas of the segment that contained landowner restrictions based on hydrology and gradient similarities.

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. Hydraulic sub-models within PHABSIM include STGQ, WSP, and MANSQ. Field data collection was designed to accommodate any of these models. PHABSIM data collection included several steps:

- Transects were selected by Ron Sutton and Mark Croghan (Reclamation), Rick Kruger (ODFW), and Jim Henriksen (USGS) on September 16-17, 2003. Transects were placed in each major mesohabitat type with the number of transects dependent upon the physical and hydraulic variability of each habitat type as determined from habitat mapping. The ODFW minimum of three transects per mesohabitat type (Rick Kruger, ODFW, personal communication) was used as a guide. Transect groupings determined study site locations.

- Additional non-habitat simulation transects were placed at hydraulic controls by professional judgment, with an additional hydraulic control transect placed at pool-riffle interfaces to aid in hydraulic calibrations. The shallowest riffles within the study area addressed 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, and reference photos of the study site and of each transect within each habitat type. In addition, stream-bed profile, total depth at each wet vertical, mean column velocity at each vertical, water surface elevation, linear distance (stationing) between transect headpins for WSP sub-model, substrate composition, and cover were recorded. Three velocity calibration sets (low, mid, and high discharges) were collected using a Marsh McBirney Model 2000 velocity meter at all transects except hydraulic controls.

- Vertical elevations were established throughout each habitat type using a total station instrument (Bovee 1997). A benchmark was established at each study site (with rebar) and assigned the arbitrary elevation of 100.00 feet. All differential leveling was referenced to this benchmark. Coordinates of each benchmark were recorded using a Garmin Model 12 Global Positioning System (GPS) unit (NAD 83).

- Water surface elevation (stage)-discharge measurements collected during each of the velocity surveys at each site provided the data necessary for model calibration and extending the discharge range for hydraulic simulations. The applicability of the range of discharges simulated to actual discharges in the stream was dependent on the discharges measured.

4.1.3 Habitat Suitability Criteria (HSC)

Species HSCs for depth, velocity, and channel index (substrate and/or cover) are required for PHABSIM analysis. Habitat suitability criteria are interpreted on a suitability index (SI) scale of 0 to 1, with 0 being unsuitable and 1 being most utilized or preferred. Criteria that accurately reflect the habitat requirements of the species 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 involves using existing curves and literature to develop suitability criteria for the species of interest. No site-specific HSCs are available in the John Day River Basin and time and budgetary constraints precluded sampling of all streams within the basin or developing HSCs specific to each individual stream within the basin. Thus, as a second option, the TSC conducted two workshops (June 29-30, 2004 and July 25-26, 2005) with stakeholders to evaluate existing HSCs appropriate for the John Day River Basin and develop HSCs that could be applied across the entire basin, and which represented the general habitat requirements of each particular fish species and life stage for John Day River Basin streams. Notes from these workshops are located in Appendix C. Table 4 summarizes species, life stages, and variables modeled as a result of the workshops.

Table 4. Habitat suitability criteria variables for selected fish species/life stages for the John Day River instream flow study.

Species/life stage	Depth (ft)	Velocity (ft/sec)	Substrate	Cover
Chinook Salmon				
Adult holding	X	X		X
Fry	X	X		X
Juvenile	X	X		X
Spawning	X	X	X	
Bull Trout				
Adult resident and fluvial	X	X		X
Fry	X	X		X
Juvenile resident and fluvial	X	X		X
Spawning resident and fluvial	X	X	X	X
Steelhead				
Fry	X	X		X
Juvenile	X	X		X
Spawning	X	X	X	X

Mean column velocity HSCs were used for all life stages except bull trout fry, juveniles, and adults where nose velocity HSC developed for the upper Salmon River in Idaho (EA Engineering, Science, and Technology 1991) was used. For these life stages, the nose velocity equation used in PHABSIM was a 1/mth power law equation:

$Vn/V=(1+m)[Dn/D]^{1/m}$
and where m was calculated using
$m=c/n \times D^{0.1667}$
where: V = mean column velocity
Vn = nose velocity
Dn = nose depth
D = total depth

n = Manning's roughness coefficient
c = 0.105
The value of m was determined for each cell. A nose depth (Dn) of 0.2 ft off the bottom and a Manning's n value of 0.06 were used.

One issue that developed during the study was the value of "escape cover" for fry and juvenile life stages (Randy Tweten and Jim Morrow, NMFS, personal communication, April 7, 2005). This is a relatively new issue regarding PHABSIM that has been addressed in detail in the Klamath River, located in northern California (Hardy et al. 2005, in press). Escape cover is defined as the riverine component that is used, or that could be used, for protection or concealment when fleeing from predators or a threat.

As a result of interest in incorporating escape cover HSC into PHABSIM, Reclamation helped fund a modification of the USGS version of PHABSIM (Version 1.3) to include an additional user-defined variable (e.g., escape cover) as part of the habitat calculation. This technique implies that one variable (e.g., escape cover) has a greater effect than the others. This variable is multiplied outside the geometric mean calculation for each cell. The Composite Suitability Factor (CF) is computed as:

$CF=(f(v) \times g(d) \times h(ci))^{0.333} \times i(ud)$,

where

f(v), g(d), h(ci), and i(ud) = variable preferences for velocity, depth, channel index, and user defined index, respectively.

In addition, Reclamation re-visited each transect used in the PHABSIM analysis on the John Day River instream flow study to record escape cover at each cell during low summer flow conditions (August 30-September 2, 2005) (Table 5).

Table 5. Discharges measured at upper John Day River and Middle Fork John Day River stream segments during escape cover data collection.

Stream Site	Discharge (cfs)	Dates
Upper John Day River-Cottonwood Galley	27	August 30, 2005
Dad's Creek	0	August 30, 2005
Middle Fork John Day River-Camp Creek to Big Boulder Creek	19	August 31, 2005
Middle Fork John Day River-Caribou Creek to Vincent Creek	12	September 1, 2005
Granite Boulder Creek	2	September 1, 2005
Reynolds Creek	15	September 2, 2005

The following steps were used to collect fry and juvenile escape cover data at each transect:

1) At each vertical station (cell boundaries) along each transect, the observer recorded percentage of dominant and sub-dominant escape cover codes within a 6-foot radius of the vertical. If more than two escape cover components were identified, percentages of each component were visually estimated.

2) The distance in feet to each escape cover component was recorded. Escape cover located at the point of the vertical was given a distance of “0”. This was often the case for the dominant cover component.
3) For verticals in water at each cell boundary, depths of escape cover components were recorded to the nearest 0.1 ft.

Data input into PHABSIM involved entering, for each cell along each transect, the escape cover component code (user defined index) with the highest suitability value within the threshold distance (i.e., 2 ft for fry and 6 ft for juveniles). Channel index (functional cover) was coded as follows:
No velocity shelter – SI=0.5
Velocity shelter – SI=1.0

Table 6 lists the John Day escape cover HSC coding system used in the final PHABSIM analysis, based on expert opinion from a December 14, 2005 meeting among ODFW (Tim Unterwegner), NMFS (Randy Tweten), and Reclamation (Ron Sutton and Mark Croghan) and minor subsequent refinements. It should be understood that, as with the other HSCs, these escape cover codes and SIs were developed for the upper John Day River and Middle Fork John Day River drainages and are not transferable to other river basins without evaluation of site-specific applicability.

There was general agreement among the involved agency representatives regarding the codes selected and SI values selected for use in the upper John Day study. A dissenting opinion felt that an alternative habitat model run using escape cover coding from the Klamath River below Iron Gate Dam in northern California (Table 7) should be considered. It should be noted that the Klamath River coding was based on site-specific field observations of fall Chinook fry, which do not occur in the John Day study area (Tim Unterwegner, ODFW, personal communication, February 14, 2006). In addition, there are distinct differences between the two river systems. The upper John Day is a small river where this study was conducted. Estimated natural August flows in the Middle Fork and upper mainstem John Day rivers average 28 cfs and 100 cfs, respectively. Comparatively, the Klamath is a very large regulated river. Below Iron Gate dam (the upper extent of fall Chinook spawning), flows are about 1,000 cfs during low summer periods. Thus, after discussions with the involved agencies, it was decided to place the requested alternative habitat model outputs using Klamath escape cover coding in an appendix and an example output in the main text.

Table 6. Escape cover components and suitability indices (SI) for fry and juvenile life stages used in John Day study.

Code	Components	Fry SI	Juvenile Chinook and Steelhead SI	Juvenile/adult Bull Trout SI
0	No cover	NA[1]	NA	NA
1	Undercut bank	1.0 (0.2)[2]	1.0 (0.6)[2]	1.0 (0.6)[2]
2	Non-emergent rooted aquatic	0.6	0.6	0.6
3	Overhanging vegetation	0.3	0.5	0.8
4	Grass, emergent rooted aquatic	0.6	0.4	0.4
5	Trees	1.0	1.0	1.0
6	Willow, bushes	0.7	0.6	0.6
7	Fine organic debris	0.3	0.1	0.1
8	Large wood (LWD & SWD)	0.6	0.6	1.0
9	Logjam	1.0	1.0	1.0
10	Rootwad	1.0	1.0	1.0
11	Turbulence	NA (0.3)[3]	NA (1.0)[3]	NA (1.0)[3]
12	Sand-large gravel, 0.1-3”	0.05	0.05	0.05
13	Very large gravel-large cobble, 3-11”	0.4	0.2	0.2
14	Small-medium boulder, 12-48”	0.4	0.6	0.6
15	Large boulder, >34”	0.2	0.5	0.5
16	Bedrock	0.2	0.2	0.2

[1] NA – Not applicable

[2] Undercut bank SI increased to 1.0 based on the need for undercut bank habitat for all sizes of salmonids (Raleigh et al. 1986; Brusven et al. 1986; White 1991; Hunter 1991)

[3] Turbulence removed because PHABSIM could not simulate changes in turbulence at each discharge

Table 7. Klamath River Escape Cover Coding System - adapted from Hardy et al. (2005).

Code	**Description** **Vegetative Components**	**Suitability Index**
1	Filamentous Algae	0.12
2	Non-emergent rooted aquatic	0.60
3	Emergent rooted aquatic	0.26
4	Grass, Sedges	1.00
5	Trees	0.09
6	Cockle Burrs,Vines,Willows	0.23
7	Duff, leaf litter, organic debris	0.04
8	LWD >4x12"	0.03
9	SMD <4x12"	0.15
10	Rootwad	0.09
11	Aggregates small veg	0.10
	Substrate Components	
12	Coarse Sand, .1-.2"	0.00
13	Small Gravel .2-1"	0.00
14	Medium Gravel, 1-2"	0.00
15	Large Gravel, 2-3"	0.00
16	Very Large Gravel, 3-6"	0.03
17	Medium Cobble, 6-9"	0.03
18	Large Cobble, 9-12"	0.02
19	Small Boulder, 12-24"	0.06
20	Medium Boulder, 24-48"	0.02
21	Large Boulder, >48"	0.04
22	Bedrock	0.04

The major advantage of the escape cover modification is that it increases flexibility and number of options in PHABSIM by incorporating an additional channel index parameter that may be considered very important to a specific life stage; in this case, escape cover for fry and juveniles. One weakness of this modification is that the model does not decide whether an escape cover component within a certain distance threshold is actually usable. For example, an escape cover component, such as grass, may be within the threshold distance to a wetted cell at a particular flow. However, the revised model in its present form gives that wetted cell the same escape cover SI for grass whether or not the grass is on dry ground or in water that meets some depth and velocity threshold so that it could actually be used by the fish. This weakness could be resolved by including a "search" algorithm in the model that determines whether escape cover meets distance, depth, and velocity threshold criteria. However, this does not solve an even bigger weakness. Since PHABSIM is a transect-based model, it does not "look" upstream or downstream from a transect for escape cover, only left and right along the transect. Thus, it cannot determine the usability of escape cover that is not on a transect. The only way to solve this problem is to use a 2-dimensional hydrodynamic model, such as River2D (see Section 4.1.5), that could be modified to search around each node for escape cover that meets the threshold criteria necessary for fish use (see Hardy et al. 2005, in press).

Passage criteria guidelines for adult Chinook salmon, steelhead trout, and bull trout by ODFW and taken from Thompson (1972) and Scott et al. (1981) were modified for the John Day River Basin by HSC workshop participants (Table 8). To determine the recommended flow for passage, the shallowest bar most critical to passage of adult fish was located, and a linear transect was measured which followed the shallowest course from bank to bank. A flow was computed for conditions which met the minimum depth criteria (Table 8) 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).

Table 8. Suggested John Day River Basin salmonid passage criteria from HSC workshop.

Species	Minimum Depth (ft)
Adult steelhead, Chinook salmon, fluvial bull trout	0.6
Juvenile steelhead, resident bull trout	0.4

4.1.4 Model Selection and Calibration

Reclamation used the USGS Windows version of PHABSIM (Waddle 2001). PHABSIM has several sub-models 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 discharge measurements to extend the predictive range. Depending on model performance, 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:

- Entered field data into appropriate format for water surface simulations;
- Calibrated simulated water surface elevations for each study site using STGQ, MANSQ or WSP (depending on site specific conditions) to within 0.05 feet of measured water surface elevations;
- Documented calibration procedure;
- Simulated a range of discharges to predict water surface elevations for each study site;
- Combined transects from all study sites, numbered sequentially from downstream to upstream, and predicted water surface elevations within a stream segment into one IFG4 data set for the entire stream segment;
- Simulated depths and velocities using the velocity model in PHABSIM for Windows and three velocity calibration sets;
- Evaluated simulation range based on comparisons of measured and observed velocities;
- Documented acceptable range of simulations;
- Conducted simulation velocity production run for applicable range of discharges;
- Conducted habitat simulations using HABTAE sub-model (geometric mean computation) for each species and life stage of interest to develop WUA versus discharge relationships for each stream segment. Transect lengths in HABTAE were based on habitat mapping proportions and summed to give 1,000 feet of stream. Thus, WUA output was ft^2/1,000 ft reach. Different HSCs for channel indices required separate PHABSIM projects for various life stages.

4.1.5 Description of River2D Hydrodynamic Model

River2D is a two-dimensional depth averaged finite element hydrodynamic model developed by the University of Alberta that has been customized for fish habitat evaluation studies (Steffler and Blackburn 2002). Two-dimensional models are useful for describing more detailed physics (hydrodynamics) of the streamflow than one-dimensional models (e.g., PHABSIM). For example, such things as eddies, split channels and secondary channels associated with islands and flow reversals are more accurately described using two-dimensional models ((Waddle et al. 2000). The River2D model suite consists of several programs typically used in succession. First, a bed topography file is created from raw field data using R2D_Bed. Then the resulting bed topography file is used in the R2D_Mesh program to develop a computational discretization as input to River2D. The River2D program solves for water depths and velocities and is finally used to visualize and intrepret the results and perform PHABSIM-type fish habitat analyses. Although not included in the original scope of this study, two-dimensional modeling was conducted at one study site on the Middle Fork John Day River to compare with one-dimensional PHABSIM results.

4.2 Quality Control

Data security and quality control were essential to the study. Field data sheets were copied and filed in a secure location. Jim Henriksen from USGS in Fort Collins, Colorado, who has extensive experience conducting PHABSIM studies, provided quality control with selection of transects and surveying techniques in the field, facilitated the first day of the 2004 HSC workshop, provided PHABSIM modeling guidance, and peer-reviewed a draft version of this report. Dr. William Miller of Miller Ecological Consultants, another PHABSIM expert, also peer-reviewed a draft. Dr. Thom Hardy from Utah State University (USU) facilitated the first day of the 2005 HSC workshop and provided valuable insight on the escape cover issue.

5.0 RESULTS AND DISCUSSION

5.1 Hydraulic Calibration

Measured and simulated discharges and dates of field surveys are summarized in Tables 9 and 10. Only two surveys were conducted at Dad's Creek because the stream channel was dry during the other visits.

Written descriptions, photos, and cross-sectional profiles of each selected study site are provided in Appendix A. Hydraulic calibration results (WSLs) for each study site are summarized in Appendix B. Simulated water surface elevations calibrated to within 0.05 feet of measured water surface elevations at all sites and flows.

Multiple velocity calibration data sets were used as independent data sets for velocity modeling purposes. The velocity adjustment factor (VAF) is an index used by the velocity simulation model to adjust individual cell velocities/cell discharges. The VAF is the ratio of the flow requested for simulation and the flow calculated from velocity simulations. The VAF adjusts individual cell velocities by multiplying the VAF times the initial velocity to give a new velocity. Generally, the relationship between discharge and VAF is such that at simulated flows lower than the velocity calibration flows, the VAF is less than 1.0 and at simulated flows greater than the velocity calibration flow, VAF is greater than 1.0 (Waddle 2001). Appendix B presents VAFs for all stream segments over a range of simulated flows. The apparent "breaks" in VAF (i.e., occasional declines in VAF as flows increase) are due to using different velocity calibration sets to produce the velocity templates used for velocity simulation. Within the range of discharges for which a particular set of calibration velocity measurements were used to develop the velocity template, ascending VAF versus flow relationships indicated the expected outcome of velocity simulations. There is no basis for judging the "validity" or quality of the hydraulic simulations based strictly on the magnitude of the range in computed VAF values (i.e., no specific set of envelope values that the VAF should absolutely lie within) (Waddle 2001). The "shape" of the VAF versus discharge plot is a better indicator of model performance than the VAF magnitude. Based on this criterion, Appendix B calibration results indicate that VAFs generally increase with discharge for each velocity calibration set, suggesting good model performance.

Table 9. Discharges measured from lowest to highest at upper John Day River and Middle Fork John Day River stream segments during field surveys in 2003-2005.

Stream Site	Discharge (cfs)	Survey Dates
Upper John Day River-Cottonwood Galley	44	September 20-21, 2003
	83	July 1-2, 2004
	175	April 15, 2004
Reynolds Creek	14	September 21-22, 2003
	18	July 3, 2004
	32	April 14, 2004
Dad's Creek	0.1	March 11, 2005
	5	April 13, 2004
Middle Fork John Day River-Camp Creek to Big Boulder Creek	29	November 19-20, 2003
	63	July 5-7, 2004
	279	April 19, 20, and 22, 2004
Middle Fork John Day River-Caribou Creek to Vincent Creek	13	September 23-24, 2003
	31	July 2 and 6, 2004
	172	April 18-19, 2004
Granite Boulder Creek	3	November 18, 2003
	16	July 4, 2004
	35	April 16, 2004

Table 10. Discharges simulated at upper John Day River and Middle Fork John Day River stream segments.

Stream Site	Discharge range (cfs)
Upper John Day River-Cottonwood Galley	20-175
Reynolds Creek	8-46
Dad's Creek	0.1-14.5
Middle Fork John Day River-Camp Creek to Big Boulder Creek	10-280
Middle Fork John Day River-Caribou Creek to Vincent Creek	6-175
Granite Boulder Creek	2-54

Also, measured velocities across each transect closely matched simulated velocities at the calibration flows (i.e., within ± 0.2 ft/sec). Figure 15 is an example of how velocities were examined for one transect in the upper John Day River-Cottonwood Galley. The output overlays simulated and calibration (measured) velocities at three different flows. The best velocity simulations occurred using PHABSIM's velocity adjustment factor (VAF) option with three velocity calibration sets and running the velocity regression to simulate velocities between calibration sets. Thus, we have high confidence in the habitat modeling results within the simulated range of flows (Table 9). We were not able to simulate flows much higher than the highest measured flows on the mainstem stream segments because the measured high water levels inundated some transect headpins.

Habitat suitability criteria (HSCs) developed from the HSC workshops are presented in Appendix C which shows various life stages and variables used to describe microhabitat. This appendix also includes meeting notes from the workshops.

Total linear distances and proportions of each major mesohabitat type are summarized in Table 11 for each stream segment. These data were used to calculate longitudinal lengths and weights of individual transects for the habitat modeling.

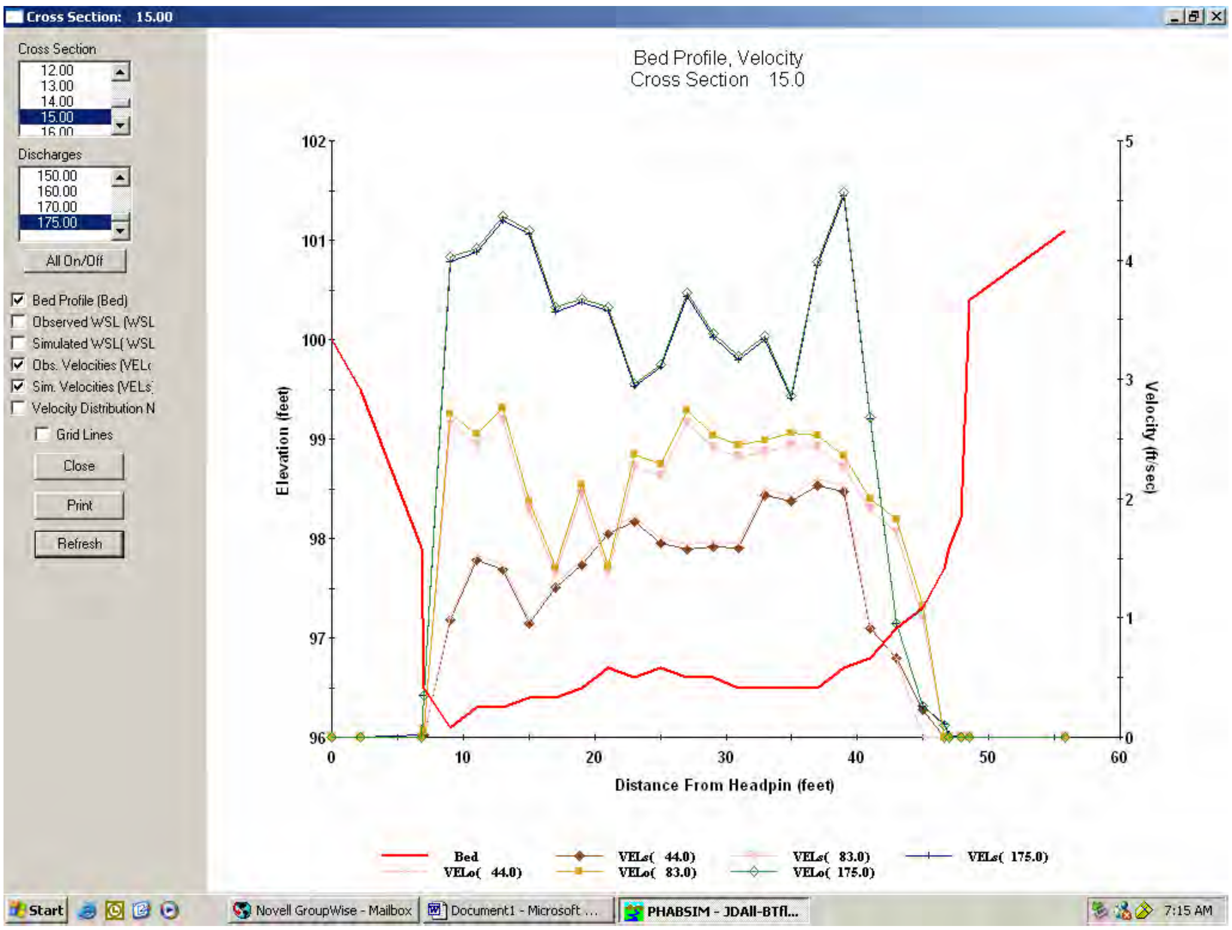


Figure 15. Example of velocity simulation output at one transect in the upper John Day River.

Table 11. Mesohabitat mapping proportions in selected stream segments for John Day River instream flow assessment.

Stream Segment	Distance mapped proportions	
	Feet	Percentage of total
Upper John Day River-Cottonwood Galley		
Riffle	326	23.83
Pool	419	30.63
Glide	548	40.06
Backwater-connected to main channel	75	5.48
Total	1,368	100
Reynolds Creek		
Riffle	612	28.37
Pool	307	14.23
Glide	1,237	57.35
Total	2,156	100
Dad's Creek		
Riffle	753	57.97
Pool	78	6.00
Glide	468	36.03
Total	1,299	100
Middle Fork John Day River-Camp Creek to Big Boulder Creek		
Riffle	7,594	44.87
Pool	1,564	9.24
Glide	7,768	45.89
Total	16,926	100
Middle Fork John Day River-Caribou Creek to Vincent Creek		
Riffle	2,310	22.42
Pool	3,464	33.62
Glide	4,529	43.96
Total	10,303	100
Granite Boulder Creek		
Riffle	1,013	43.80
Pool	375	16.20
Glide	686	29.63
Pocketwater	241	10.41
Total	2,315	100

5.2 PHABSIM Output

Complete habitat modeling output results (i.e., WUA vs discharge) are summarized in Appendix D for each stream segment. Graphical representations of normalized WUA versus discharge relationships are presented for each segment (Figures 16 to 51). All life stages were habitat-modeled in each stream segment even if they do not presently occur because of the potential for future restoration. Habitat modeling results (i.e., curve shapes) reflected differences in existing stream channel hydraulics among study sites. WUA is a measure of the existing available habitat for each segment at various discharges. WUA does not necessarily represent the amount of habitat available under pristine or un-altered conditions. Comparisons of stream segments showed that less flow was typically needed to optimize fish habitat in the narrower, more confined stream channels with less wetted surface area per given flow. For example, the stream channel in the Middle Fork John Day River between Caribou Creek and Vincent Creek was deeper and narrower than the Middle Fork John Day River downstream between Camp Creek and Big Boulder Creek. Optimal Chinook salmon fry habitat in the Middle Fork John Day River between Caribou Creek and Vincent Creek occurred at 6 cfs and trended downward at higher flows before flattening out (Figure 38). In contrast, Chinook fry WUA increased as flows increased up to 40 cfs downstream in the Middle Fork John Day River between Camp Creek and Big Boulder Creek (Figure 32). The primary reason for this difference was that the upstream stream segment depths at flows between 10 and 40 cfs averaged 0.95 to 1.22 ft, respectively, and were less suitable for fry than the average corresponding depths of 0.49-0.75 ft in the downstream segment, based on depth HSCs (Appendix C). Thus, less flow was needed for optimal fish habitat in Caribou Creek to Vincent Creek reach of the Middle Fork John Day River than the downstream reach between Camp Creek and Big Boulder Creek given present stream channel morphology.

The WUA vs discharge curves also provide information in terms of how much benefit can be achieved with incremental flow changes. For example, Figure 37 overlays percent of maximum WUA for Chinook spawning and adult holding life stages in the Middle Fork John Day River between Caribou Creek and Vincent Creek. Examination of this figure shows that if flows increase from 10 to 30 cfs, habitat for spawning dramatically increases from about 30 to 90 percent of maximum. Comparatively, for adult holding, habitat only increases from about 40 to 60 percent. This helps decision-makers determine whether additional water substantially benefits the species.

Fry and juvenile WUA vs discharge curves had relatively flat relationships at mid-high flows in most stream segments. These flat curves suggest that incremental flow increases beyond a certain minimum flow that maximizes habitat does not substantially affect habitat. The reason for the flat nature of these curves is illustrated in Figures 52 and 53 which show steelhead fry and juvenile WUA plan map views of the John Day Cottonwood Galley site at low, mid, and high flows. Each rectangle represents a cell within the 1000-ft reach and is color-coded based on the amount of WUA (ft^2) within the cell. Dark (blue) shaded cells indicate no habitat is present. The shaded legends are misleading and need to be examined closely (i.e., same shades with different amounts of WUA at 100 and 175 cfs).

Examination of these maps shows that habitat occurs throughout most of the channel at low flows and is more restricted to the stream margins at higher flows, particularly for fry. This makes sense with escape cover giving greatest effect among variables in the modified geometric mean calculation for habitat (i.e., most habitat occurs along the stream margin where grass has a higher escape cover suitability criteria than the hard substrates in the stream channel). Also, although velocities restrict habitat in channel center at higher flows, more habitat is created along the stream margins as depths and velocities become more suitable. Figure 54 shows low to high flow close-ups of transects

1-3 at the John Day stream segment for fry steelhead and is intended to better illustrate how the model works. At 20 cfs, most of the wetted channel contains some low quantity habitat, resulting from a combination of depths, velocities, channel index, and escape cover values within suitable ranges for fry steelhead. At 100 cfs, more of the center of the channel becomes unusable for fry due to velocities exceeding their upper suitability limits. Most habitat occurs along the shallow stream margin in slower velocity water and better escape cover (grass). At 175 cfs, less total area is suitable habitat due to higher velocities, but the area that is available has a higher weight than 100 cfs due to higher velocity and depth suitabilities. Thus, more area of low-quality habitat at 100 cfs produces the same amount of WUA as a small area of high-quality habitat at 175 cfs, resulting in relatively little overall habitat change between 100 and 175 cfs.

For juvenile steelhead, flow that gives maximum habitat occurs at 100 cfs. Since juveniles utilize higher velocities than fry, more juvenile habitat is available in the center of the channel at higher flows. Also, since juveniles prefer deeper water than fry, less shallow margin habitat is available at all flows and velocity starts limiting juvenile habitat at flows higher than 100 cfs.

Figures 17, 23, 29, and 47 appear to show more habitat for fluvial bull trout spawning at lower flows than resident bull trout spawning. This is because the plots show percent of optimal habitat, not actual WUA. In fact, there is much more actual fluvial spawning habitat than resident spawning habitat at all flows (Appendix D). However, resident spawning habitat occurs in smaller substrates than fluvial spawning and most smaller substrates generally occur on the stream margin which are available at higher flows than required for fluvial spawning.

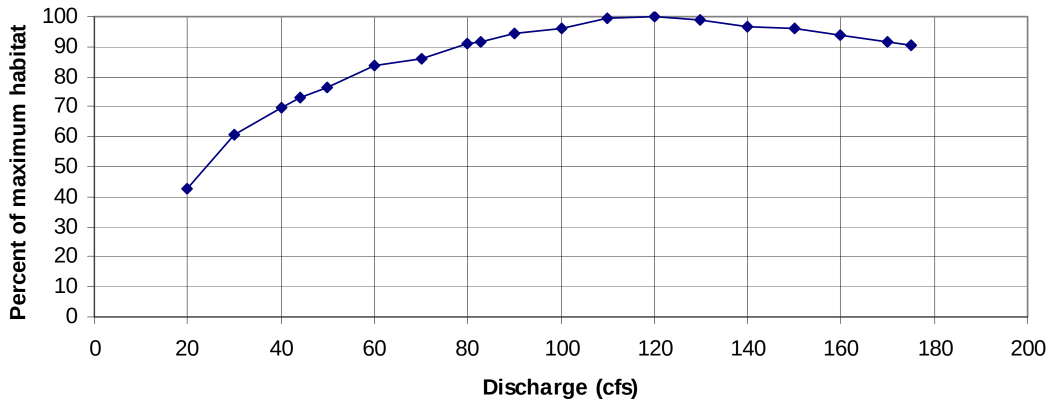


Figure 16. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationship for steelhead spawning in upper John Day River – cottonwood galley.

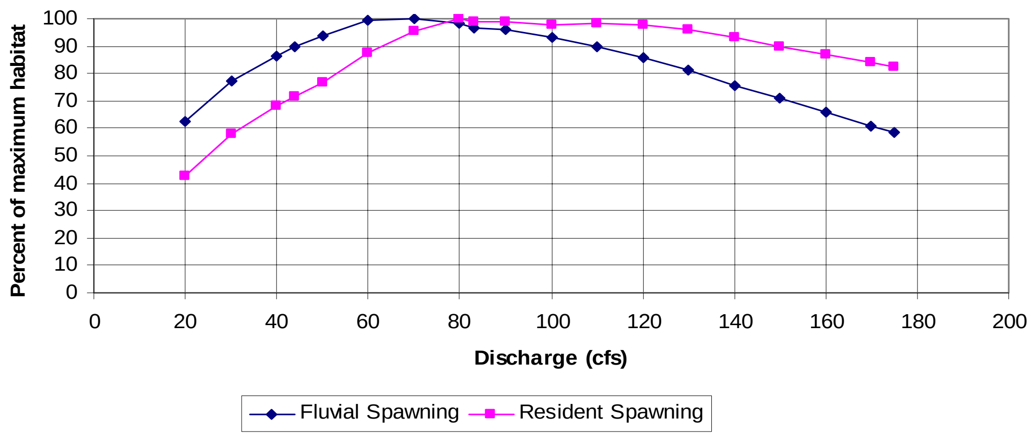


Figure 17. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout spawning in upper John Day River – cottonwood galley.

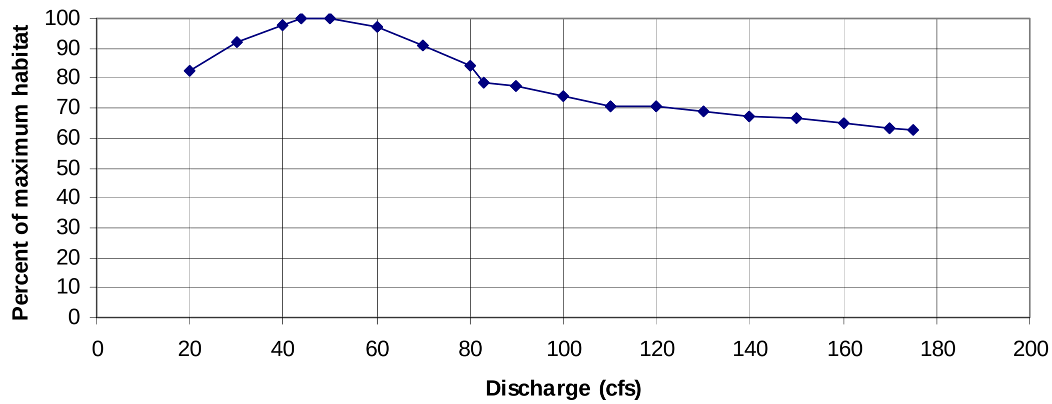


Figure 18. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout fluvial adult rearing in upper John Day River – cottonwood galley.

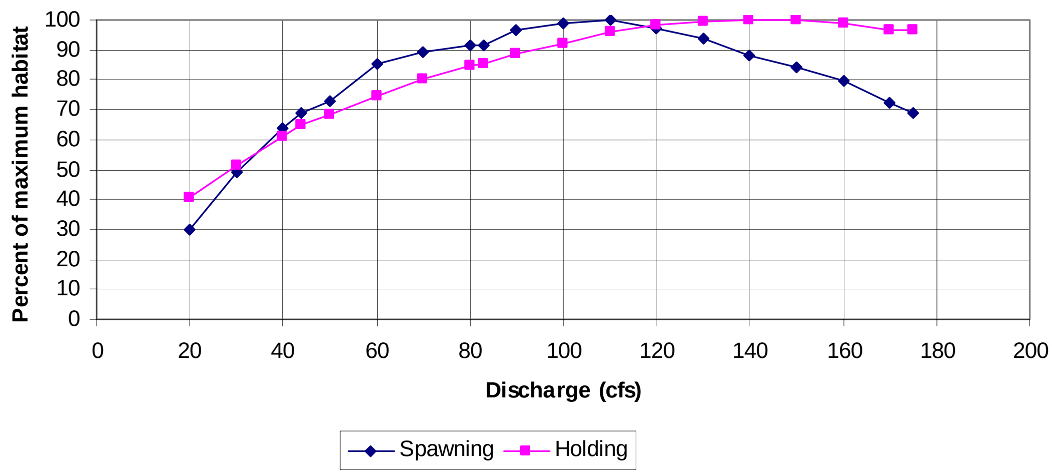


Figure 19. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon spawning and holding in upper John Day River – cottonwood galley.

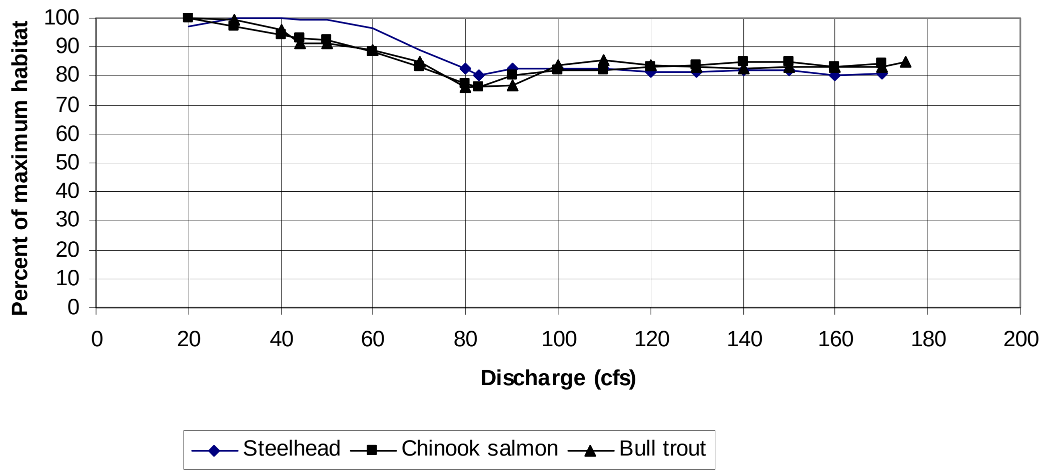


Figure 20. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry in upper John Day River – cottonwood galley.

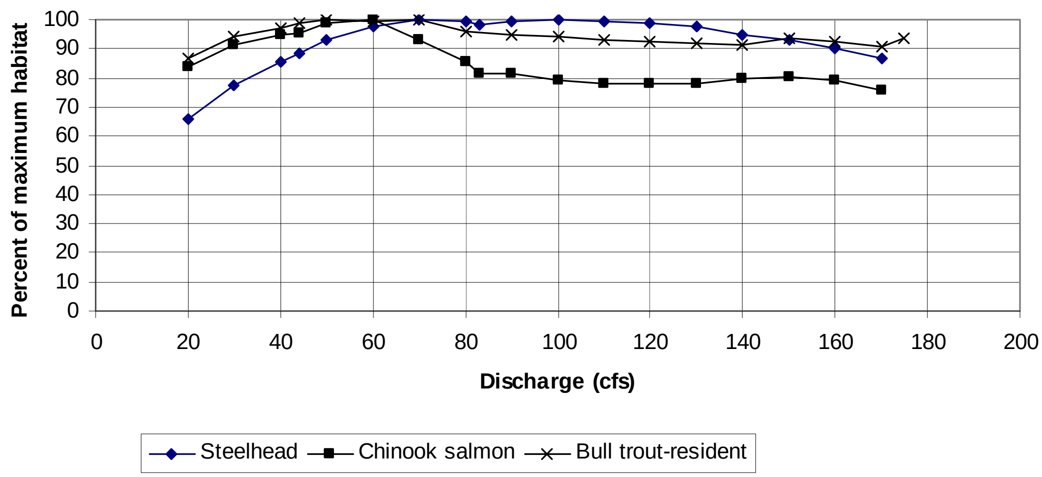


Figure 21. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles in upper John Day River – cottonwood galley.

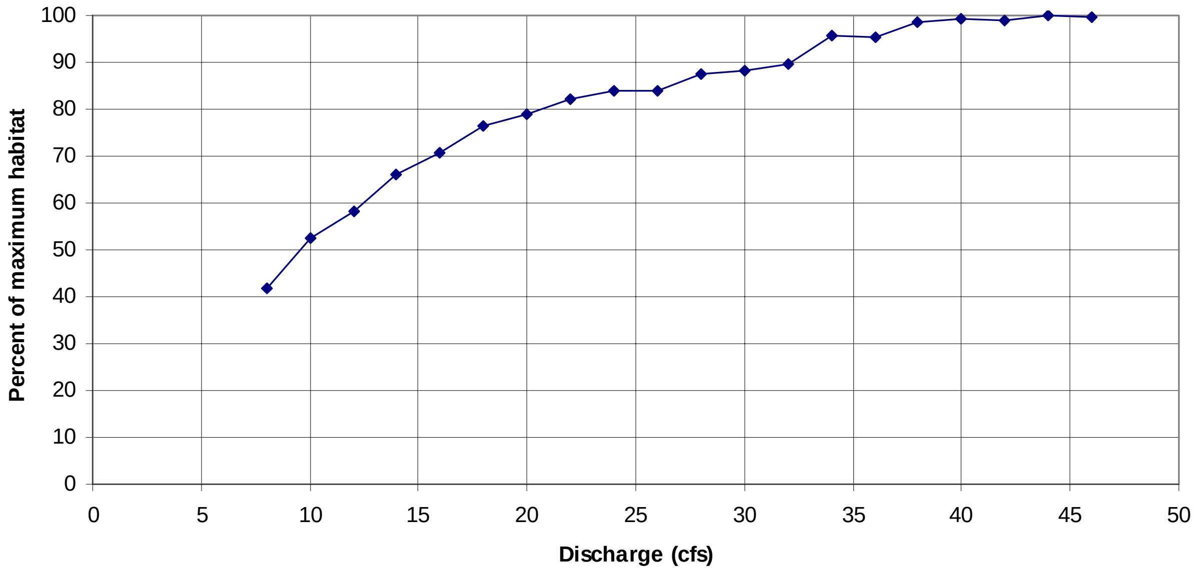


Figure 22. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead spawning in Reynolds Creek.

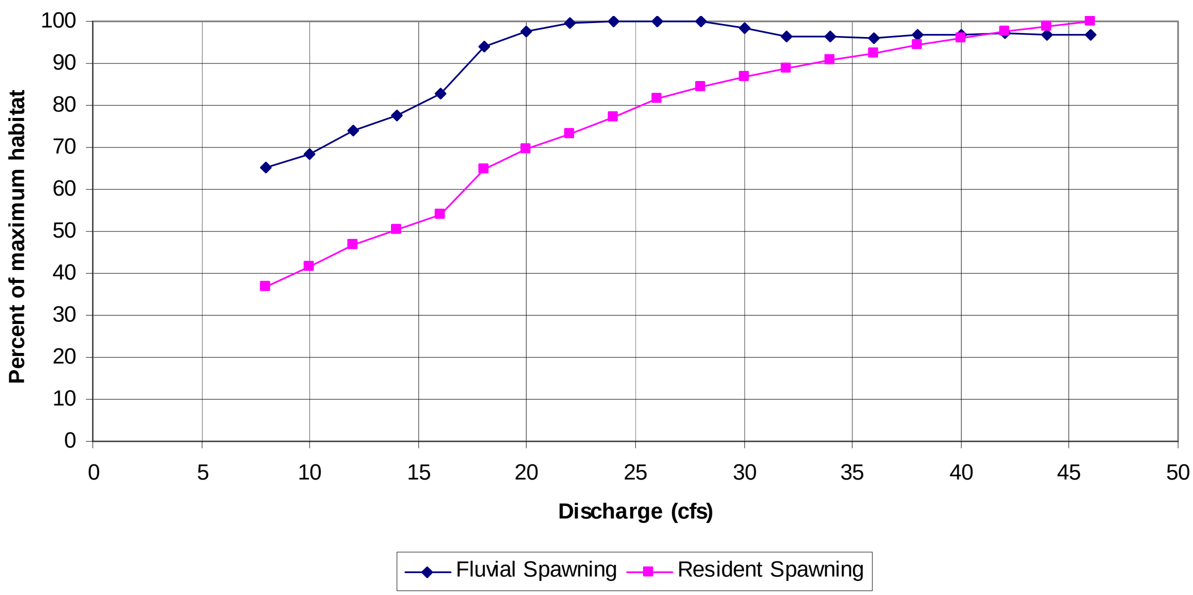


Figure 23. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout spawning in Reynolds Creek.

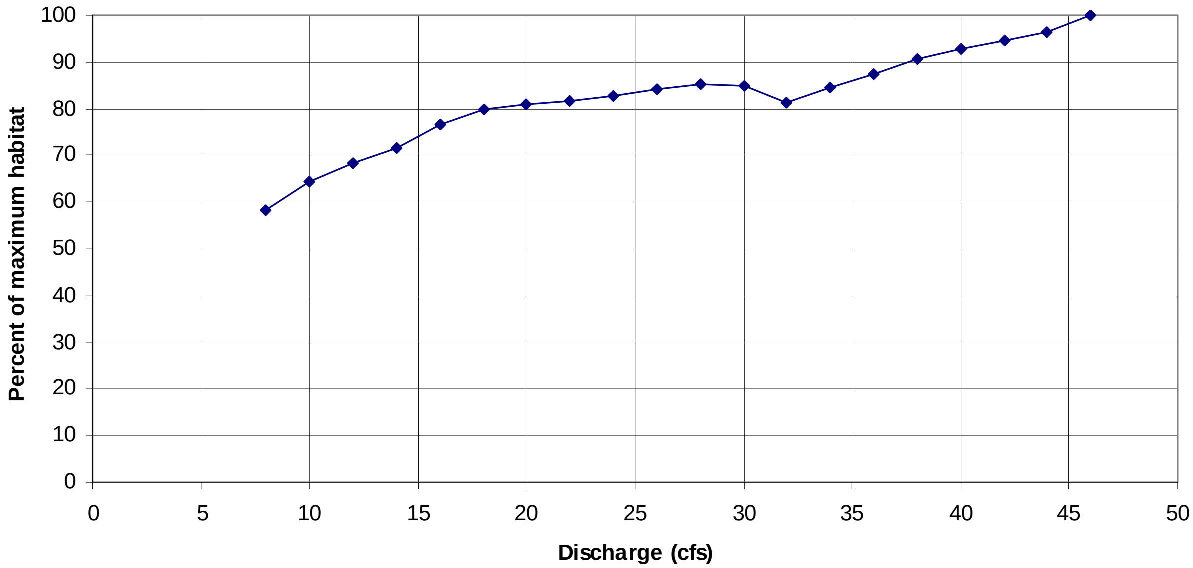


Figure 24. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout fluvial adult rearing in Reynolds Creek.

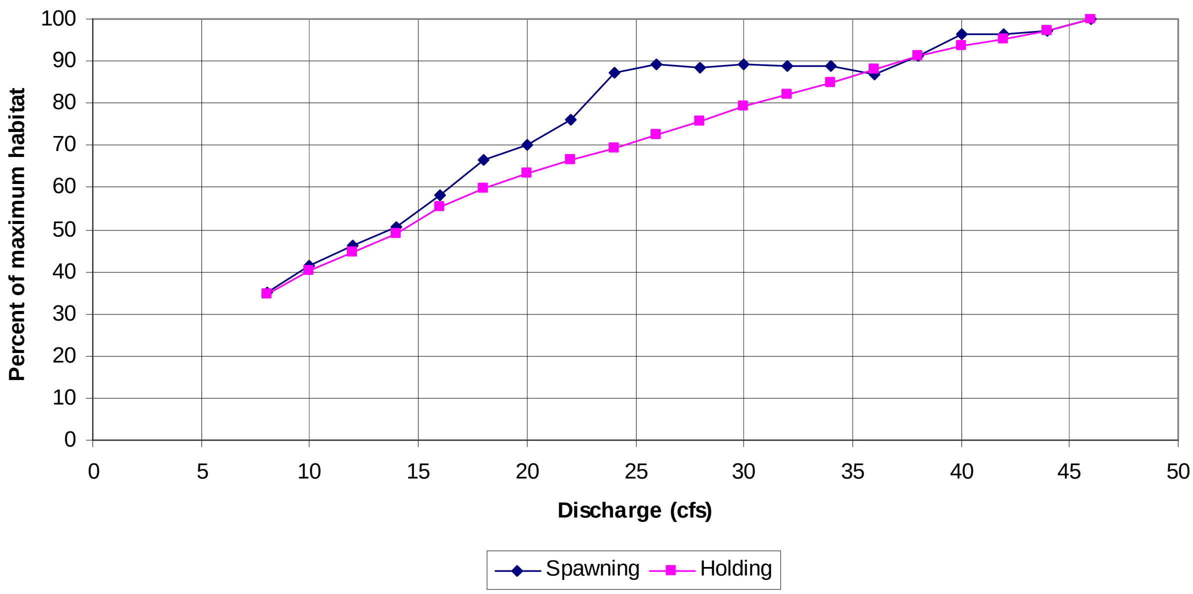


Figure 25. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon spawning and holding in Reynolds Creek.

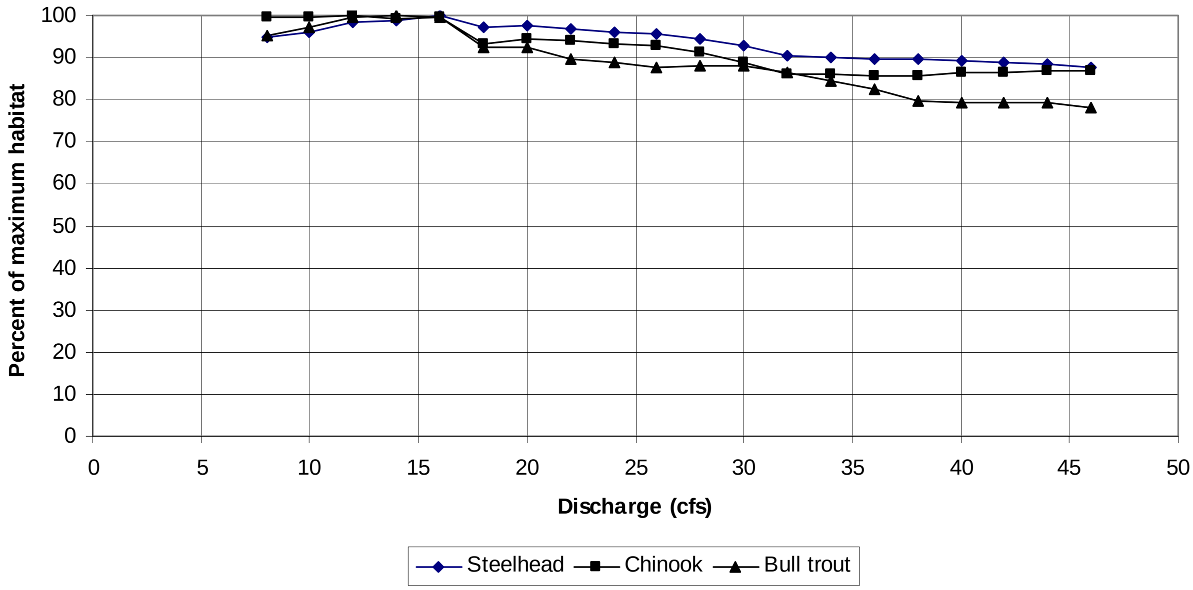


Figure 26. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry in Reynolds Creek.

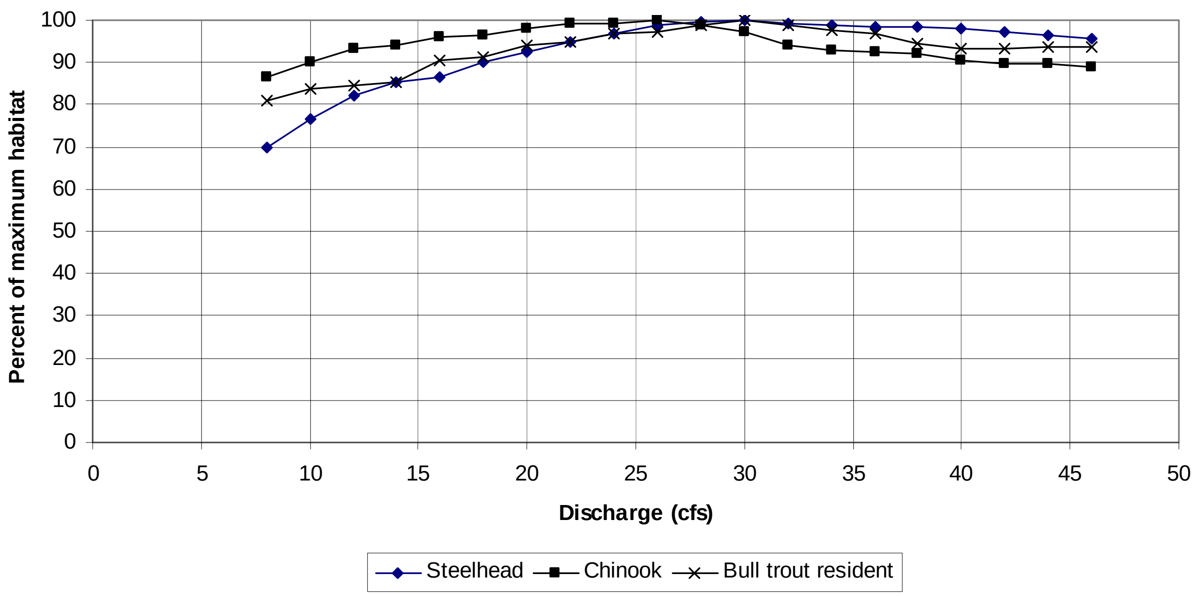


Figure 27. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles in Reynolds Creek.

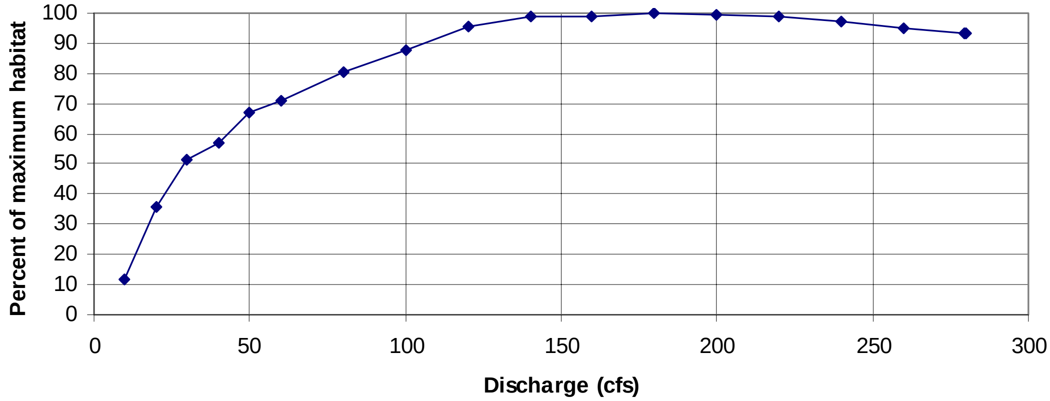


Figure 28. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead spawning in Middle Fork John Day River-Camp Creek to Big Boulder Creek.

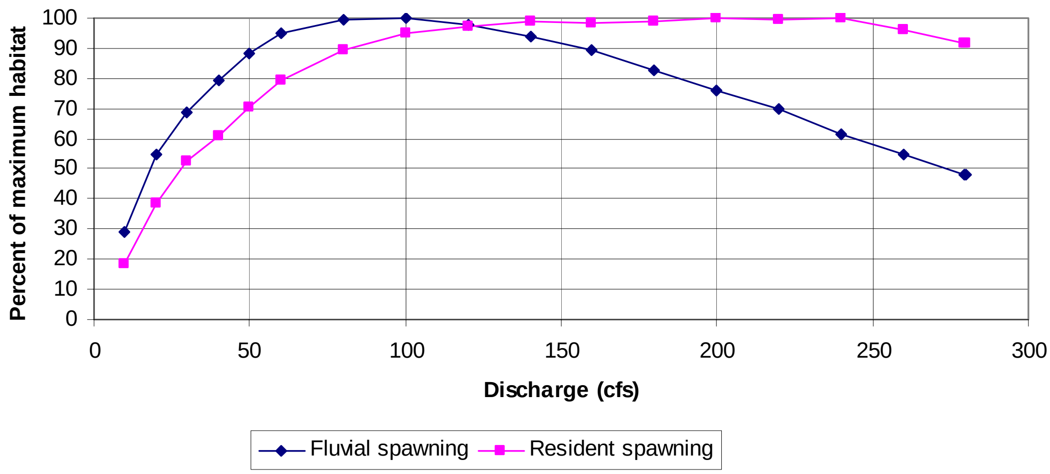


Figure 29. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout spawning in Middle Fork John Day River-Camp Creek to Big Boulder Creek.

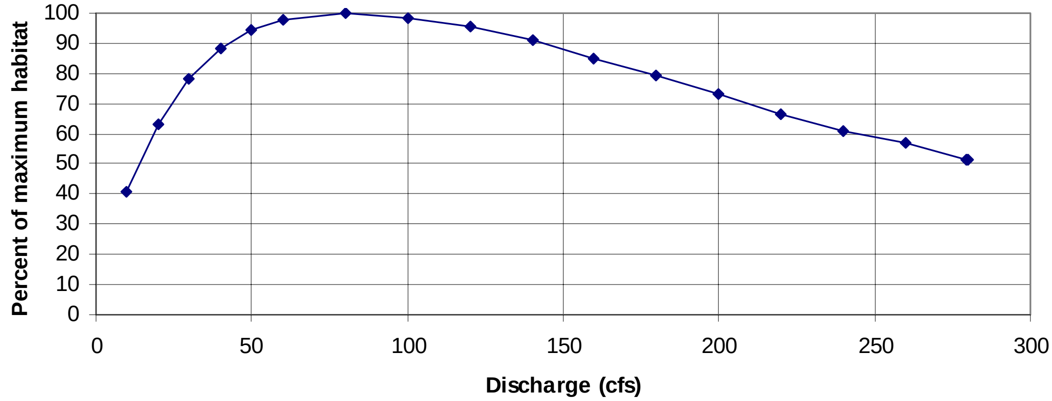


Figure 30. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout fluvial adult rearing in Middle Fork John Day River-Camp Creek to Big Boulder Creek.

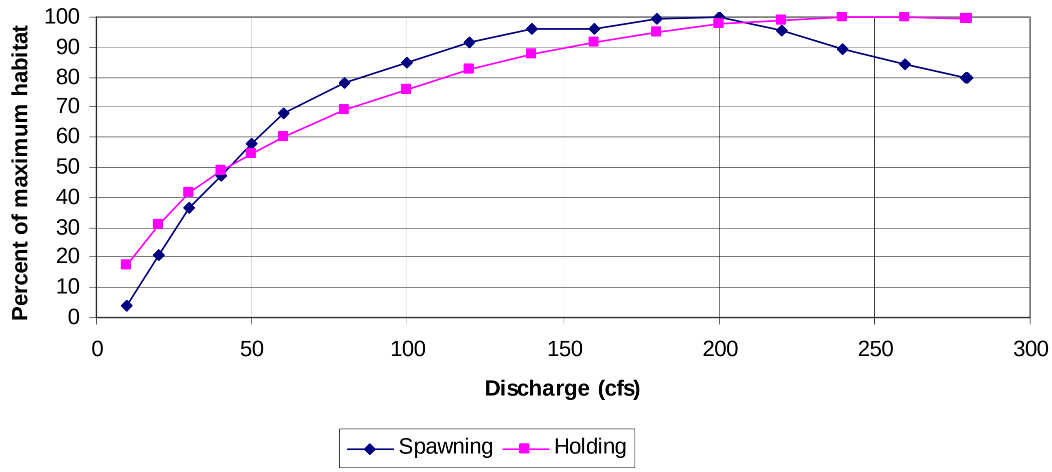


Figure 31. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon spawning and holding in Middle Fork John Day River-Camp Creek to Big Boulder Creek.

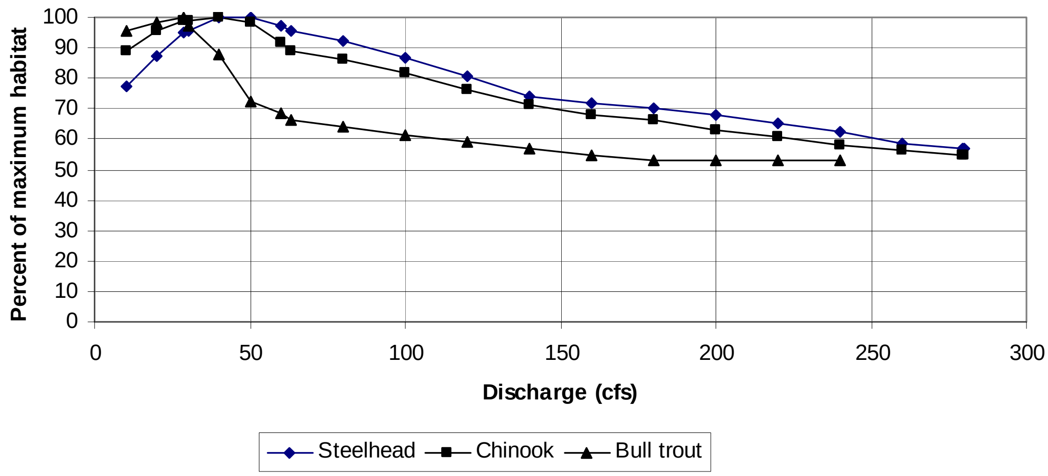


Figure 32. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry in Middle Fork John Day River-Camp Creek to Big Boulder Creek.

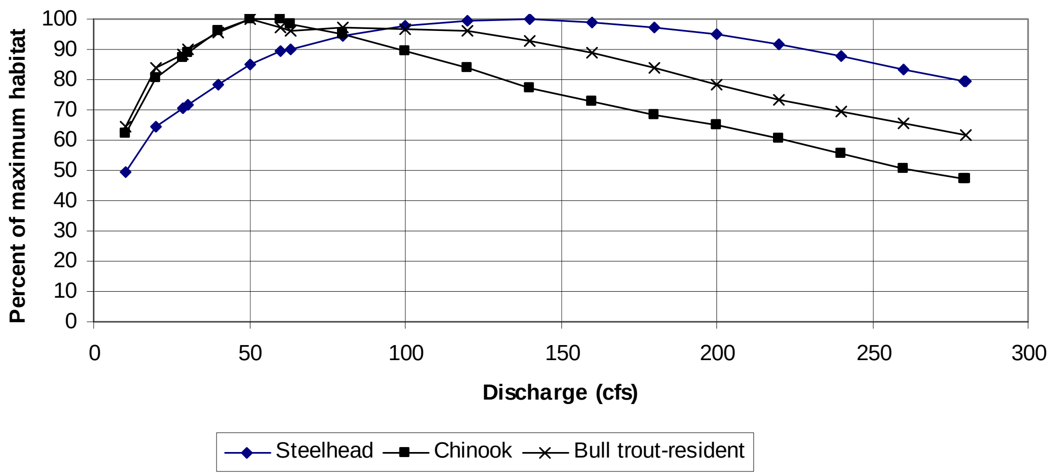


Figure 33. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles in Middle Fork John Day River-Camp Creek to Big Boulder Creek.

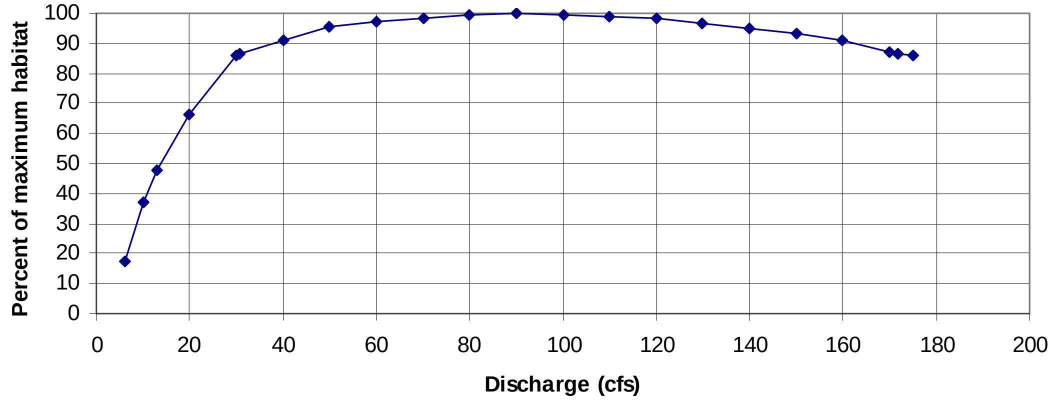


Figure 34. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead spawning in Middle Fork John Day River-Caribou Creek to Vincent Creek.

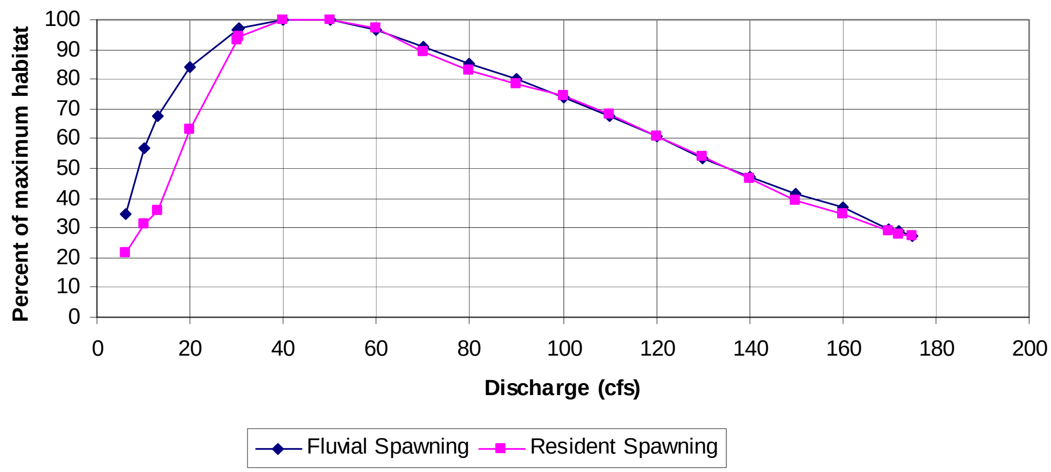


Figure 35. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout spawning in Middle Fork John Day River-Caribou Creek to Vincent Creek.

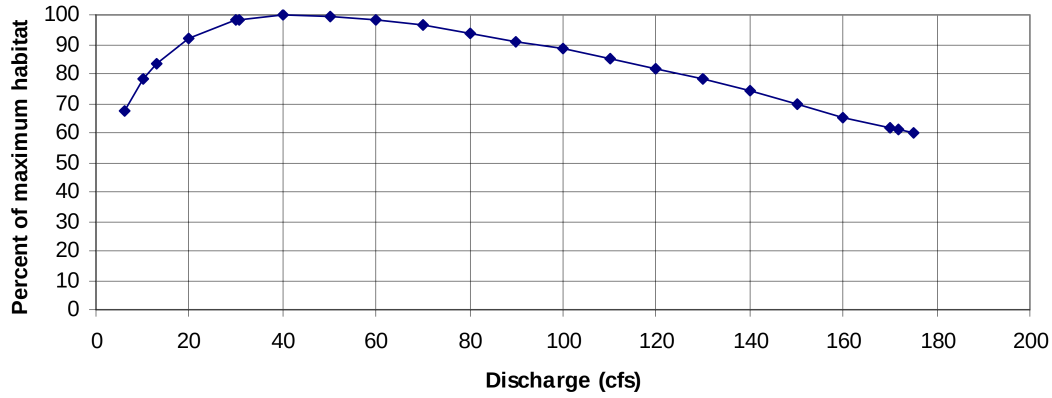


Figure 36. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout fluvial adult rearing in Middle Fork John Day River-Caribou Creek to Vincent Creek.

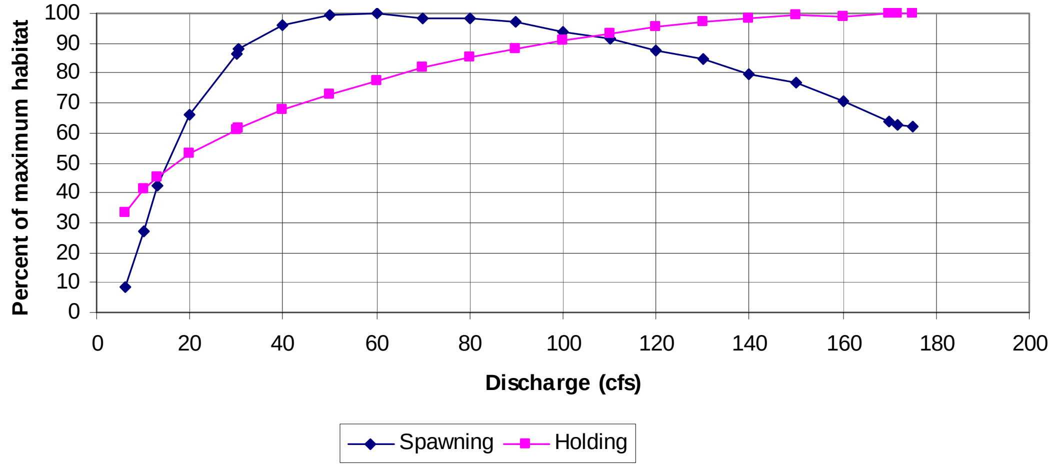


Figure 37. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon spawning and holding in Middle Fork John Day River-Caribou Creek to Vincent Creek.

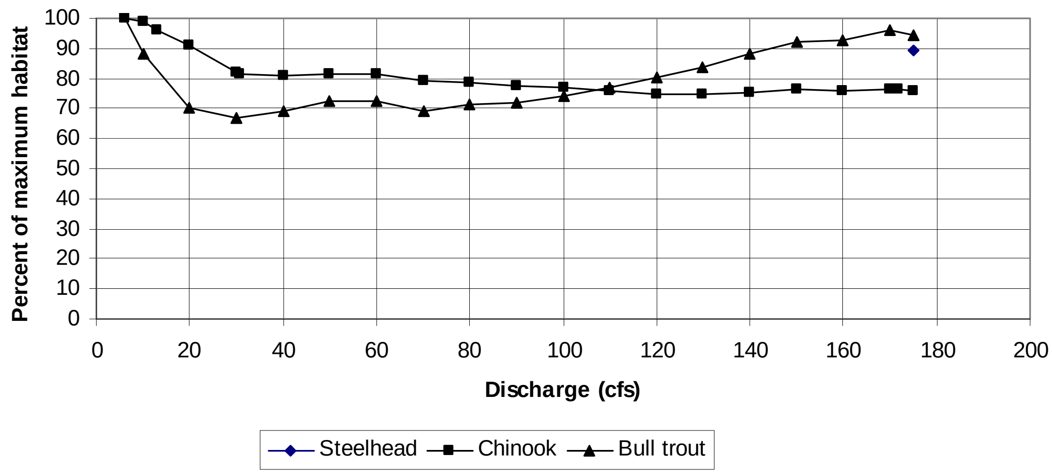


Figure 38. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry in Middle Fork John Day River-Caribou Creek to Vincent Creek.

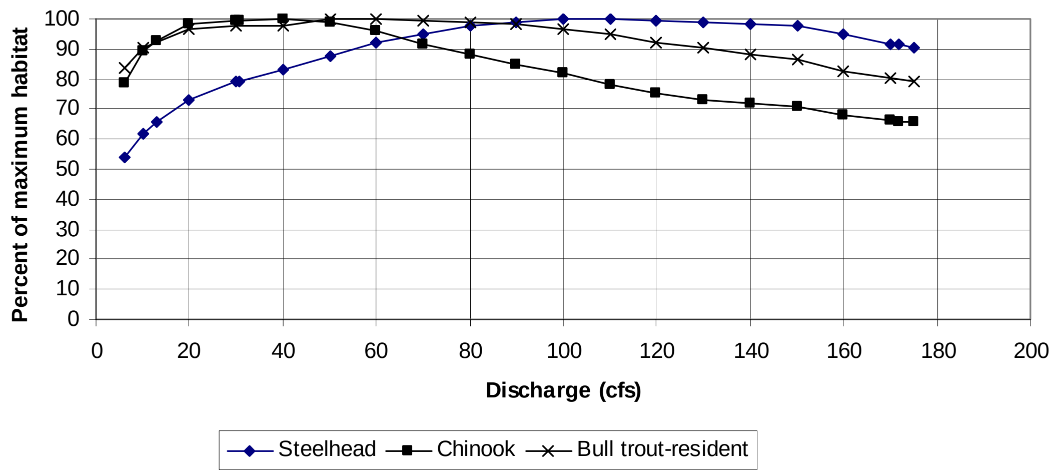


Figure 39. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles in Middle Fork John Day River-Caribou Creek to Vincent Creek.

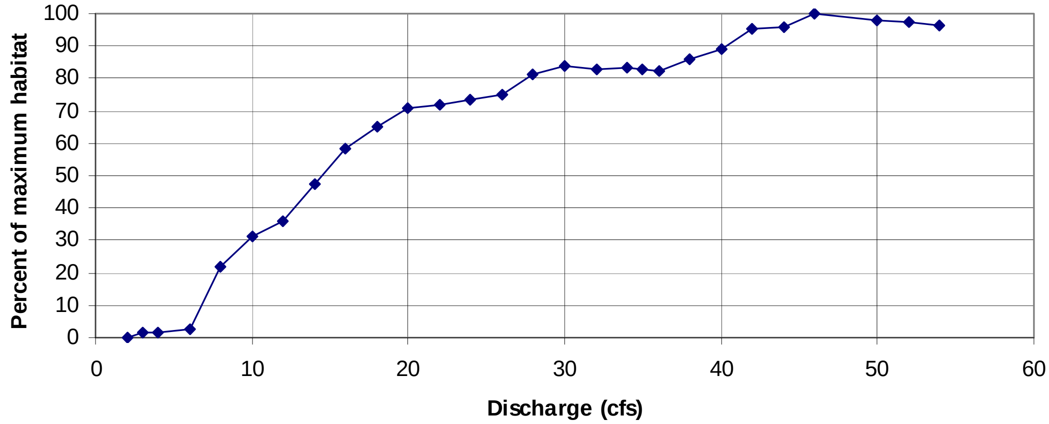


Figure 40. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead spawning in Granite Boulder Creek.

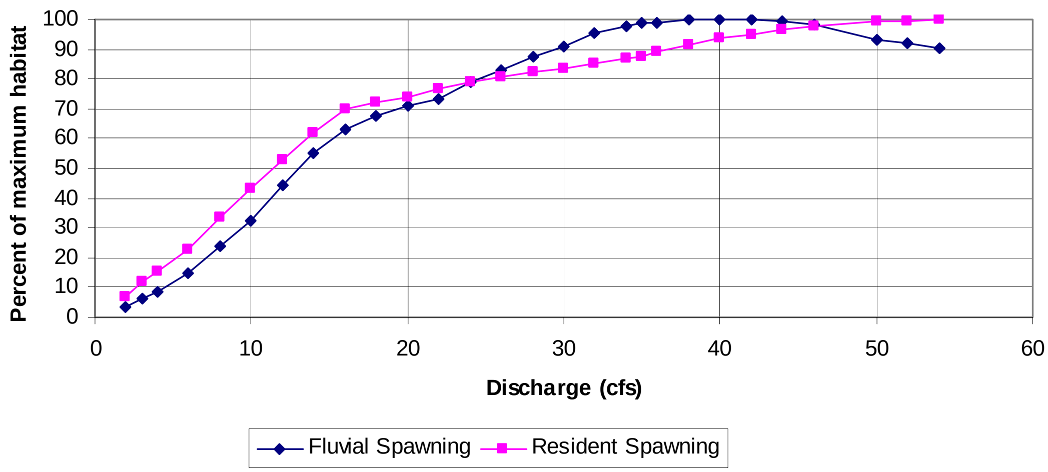


Figure 41. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout spawning in Granite Boulder Creek.

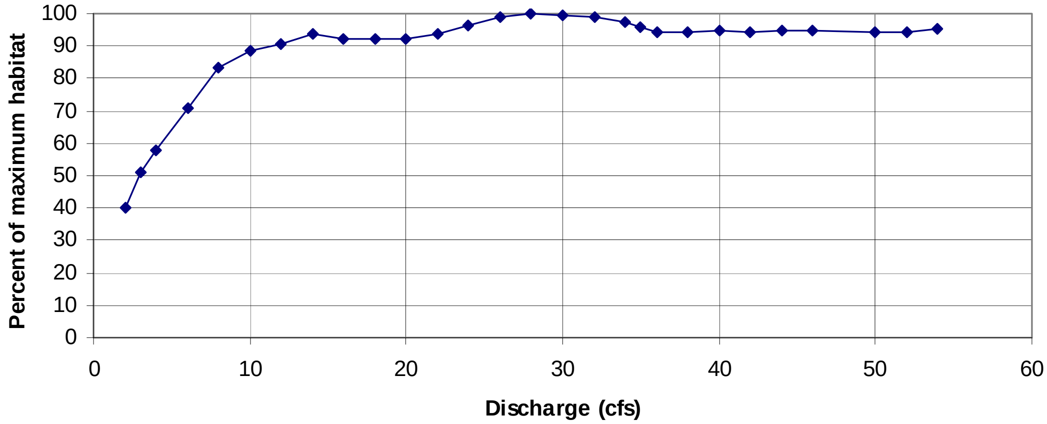


Figure 42. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout fluvial adult rearing in Granite Boulder Creek.

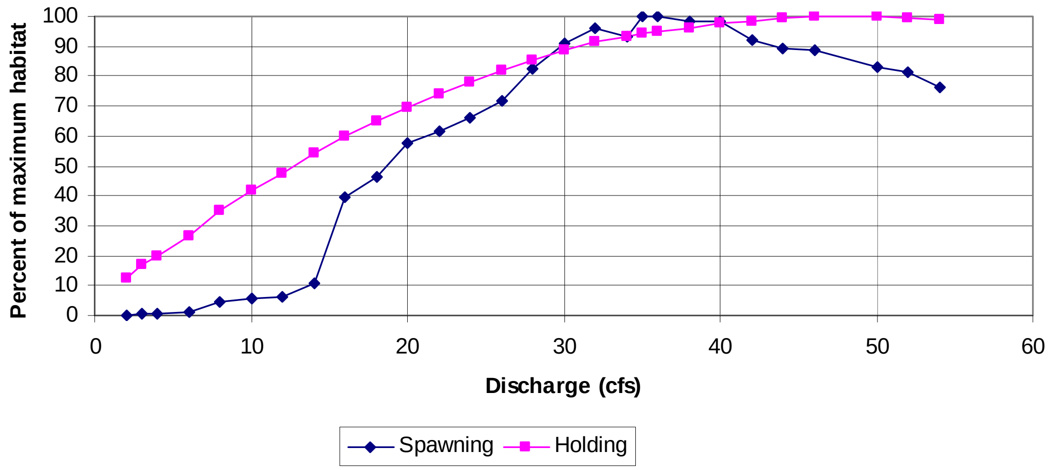


Figure 43. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon spawning and holding in Granite Boulder Creek.

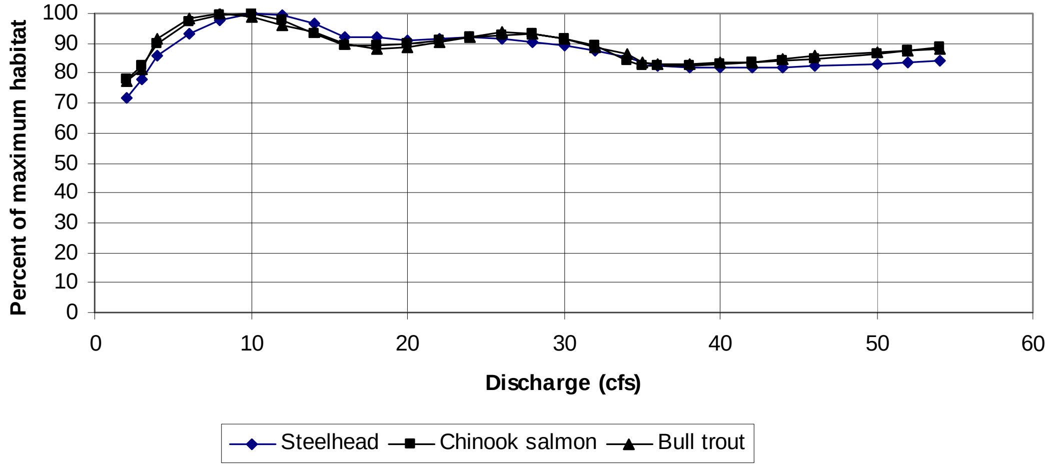


Figure 44. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry in Granite Boulder Creek.

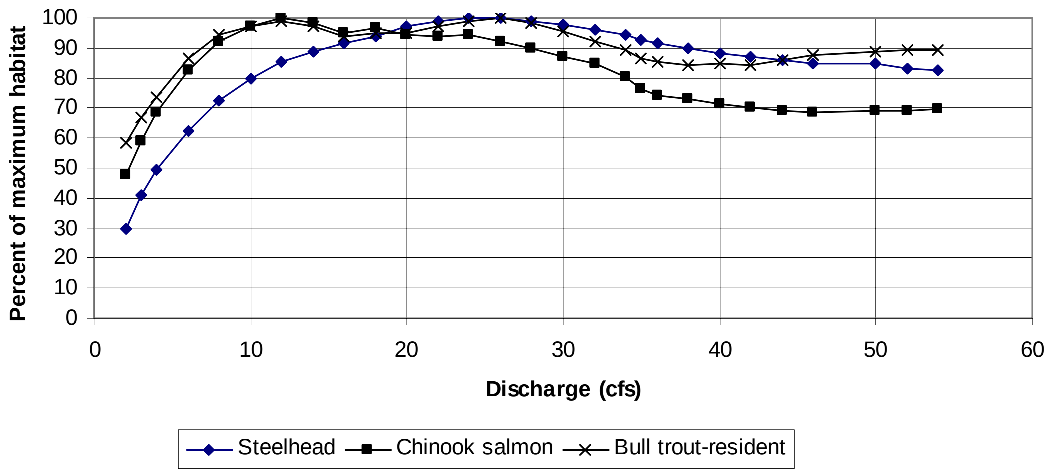


Figure 45. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles in Granite Boulder Creek.

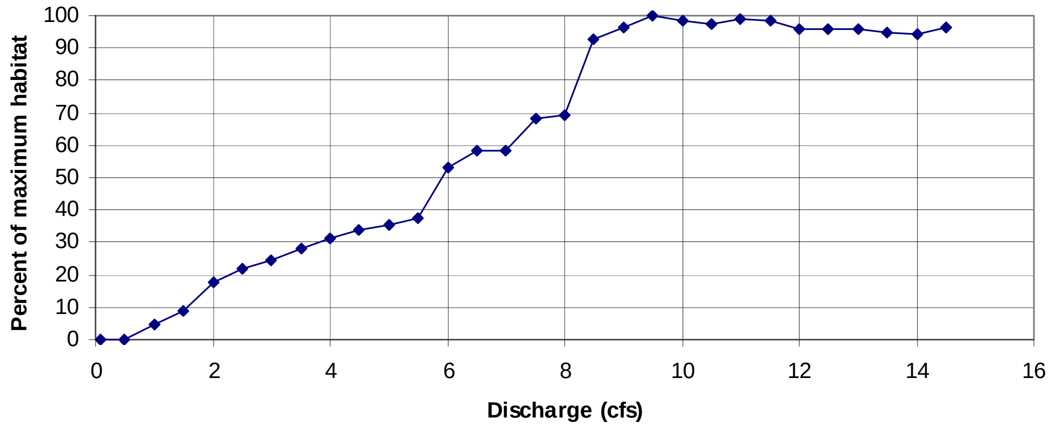


Figure 46. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for steelhead spawning in Dad's Creek.

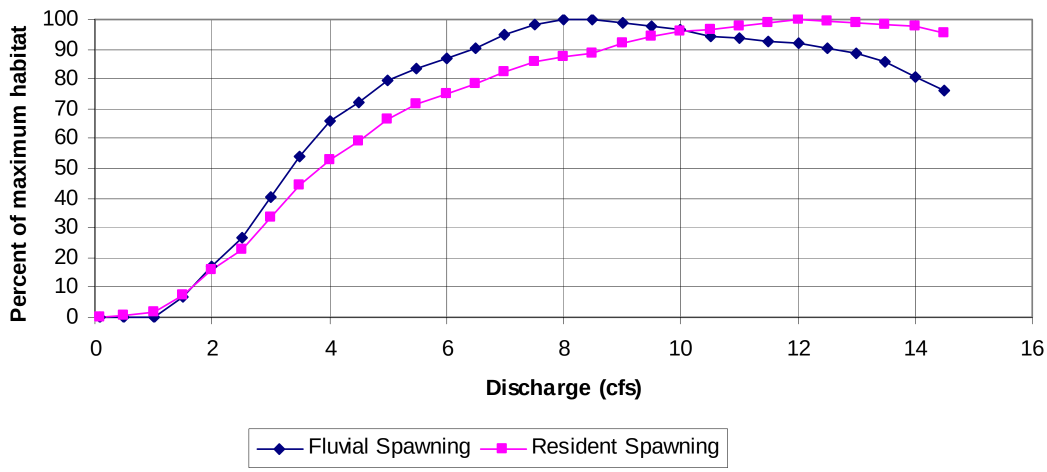


Figure 47. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout spawning in Dad's Creek.

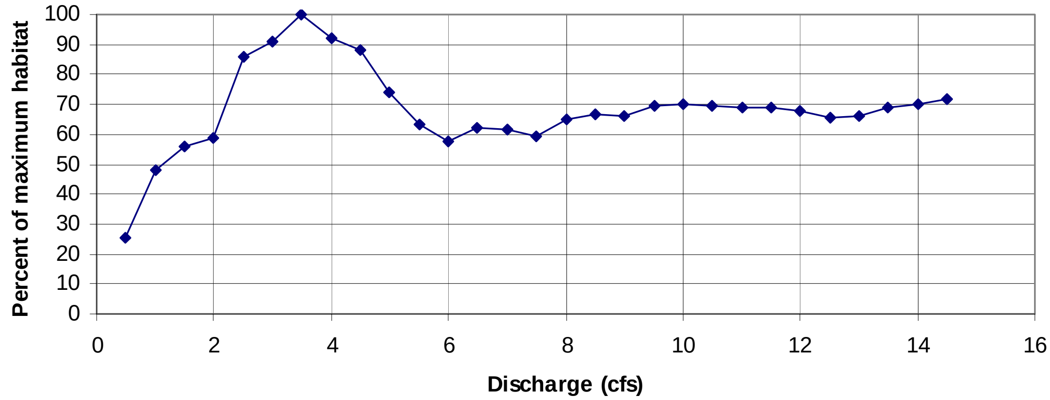


Figure 48. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for bull trout fluvial adult rearing in Dad's Creek.

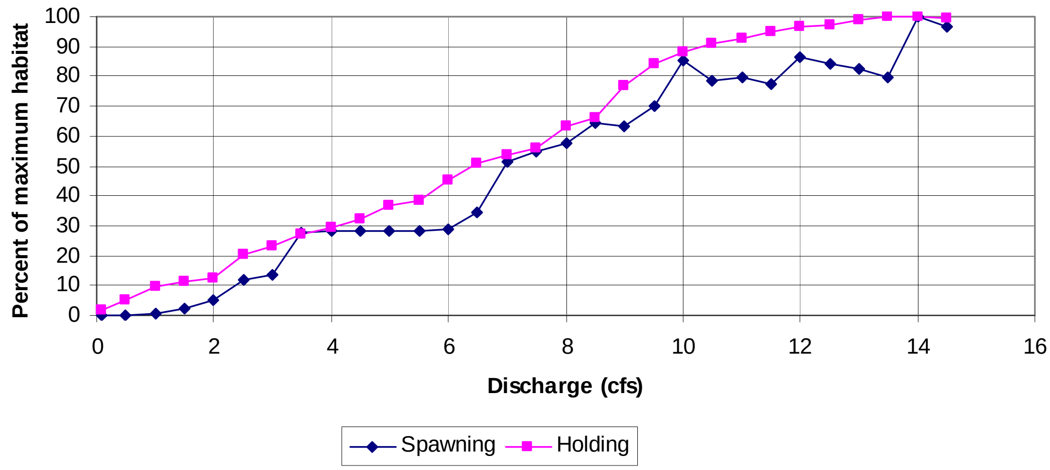


Figure 49. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon spawning and holding in Dad's Creek.

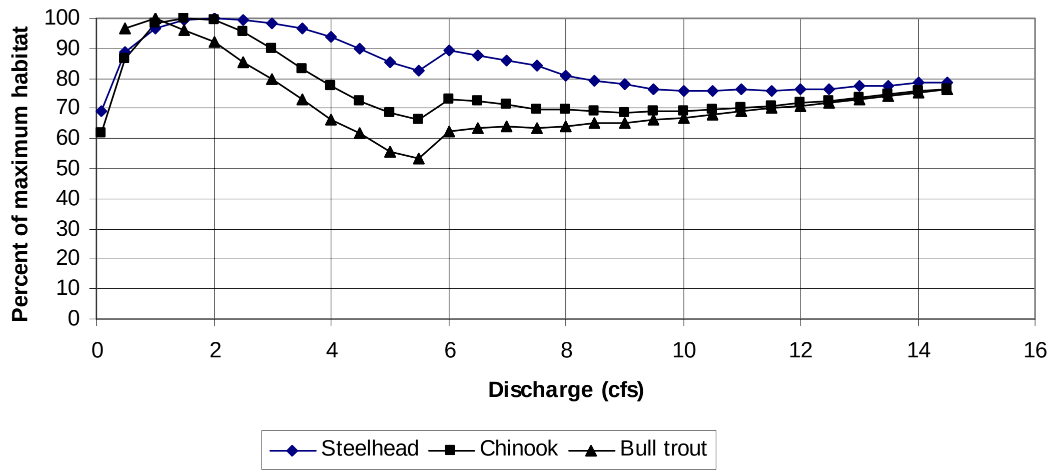


Figure 50. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry in Dad's Creek.

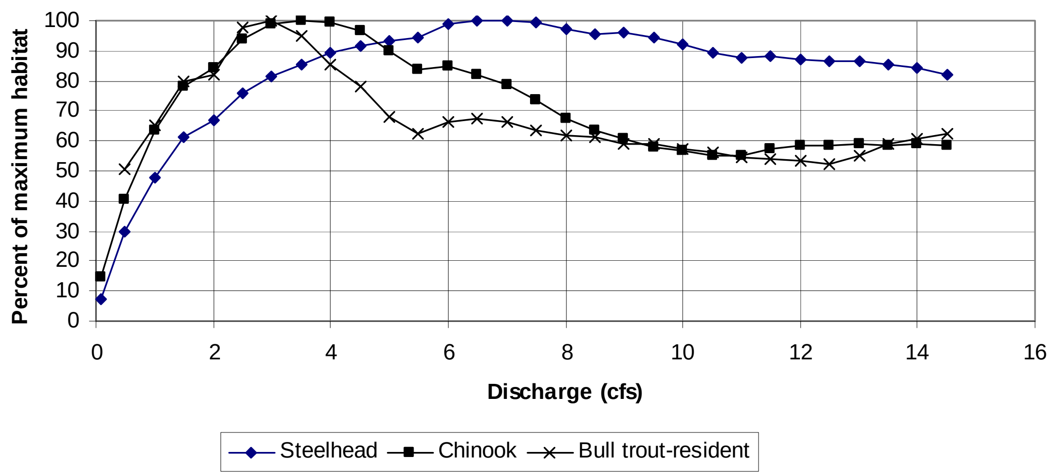


Figure 51. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles in Dad's Creek.

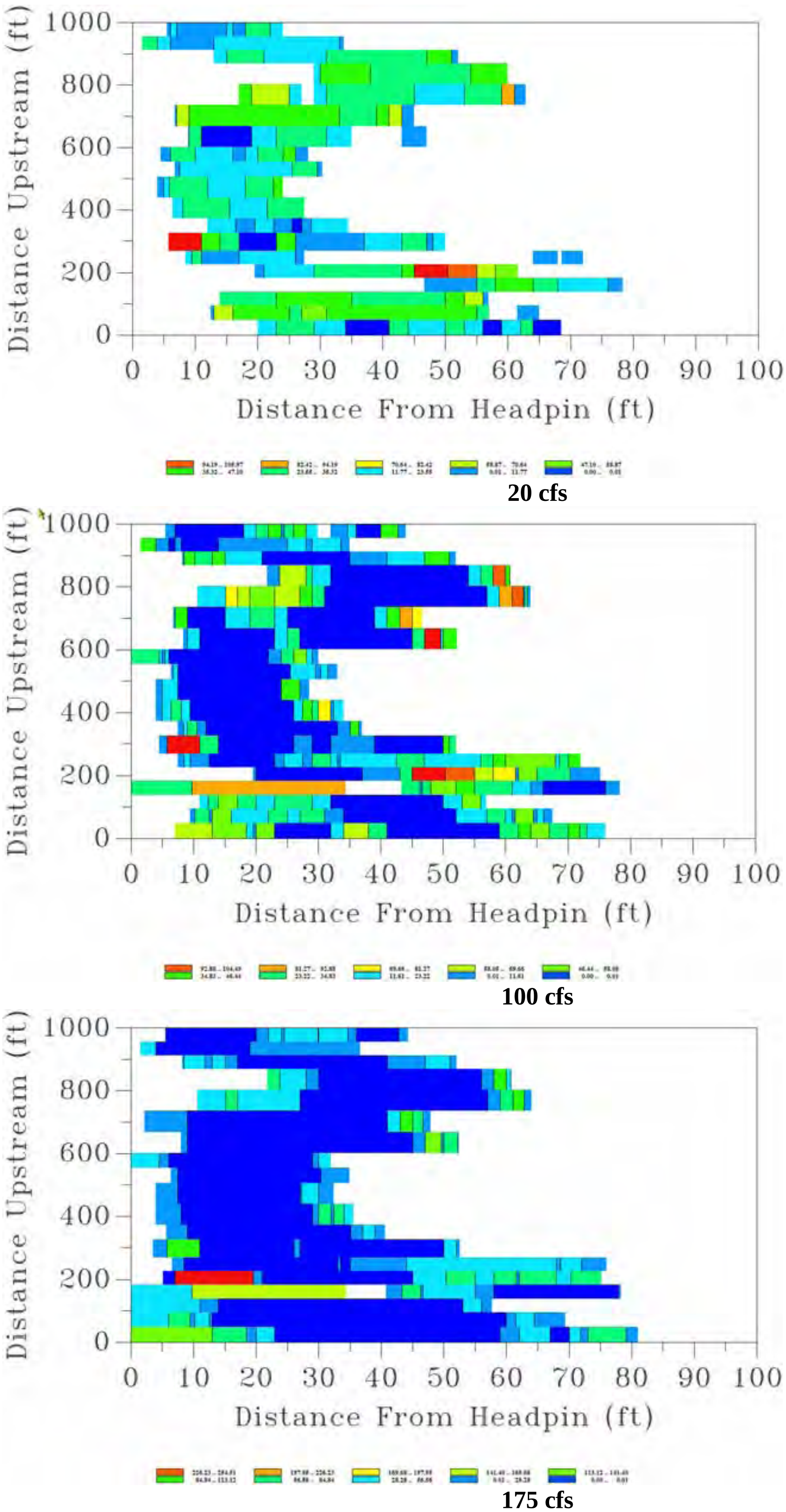


Figure 52. WUA maps (weighted cells) for steelhead fry in upper John Day River Cottonwood Galley at three different flows. Red cells provide highest WUA, yellow cells provide intermediate WUA, and blue cells provide lowest WUA.

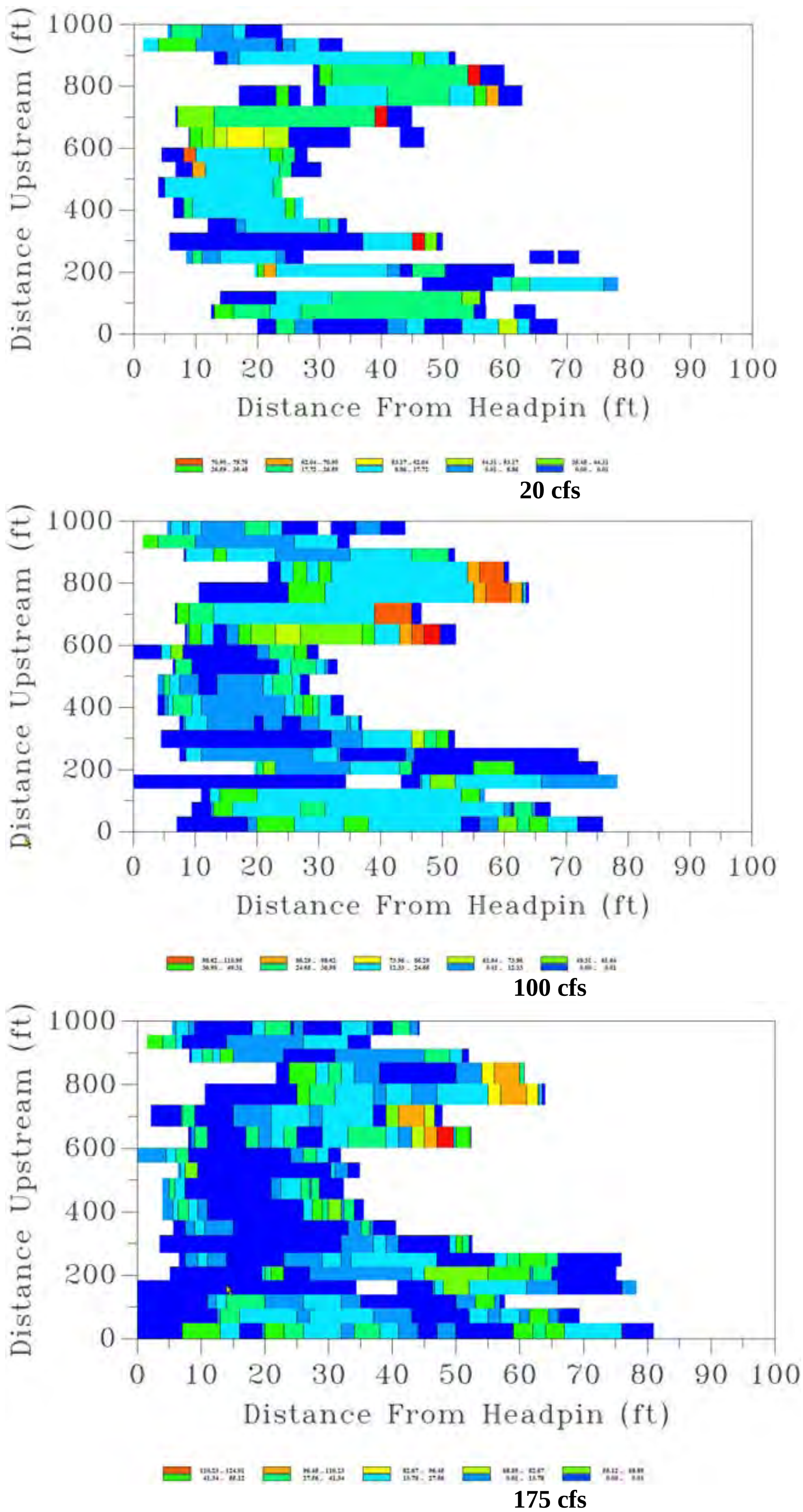
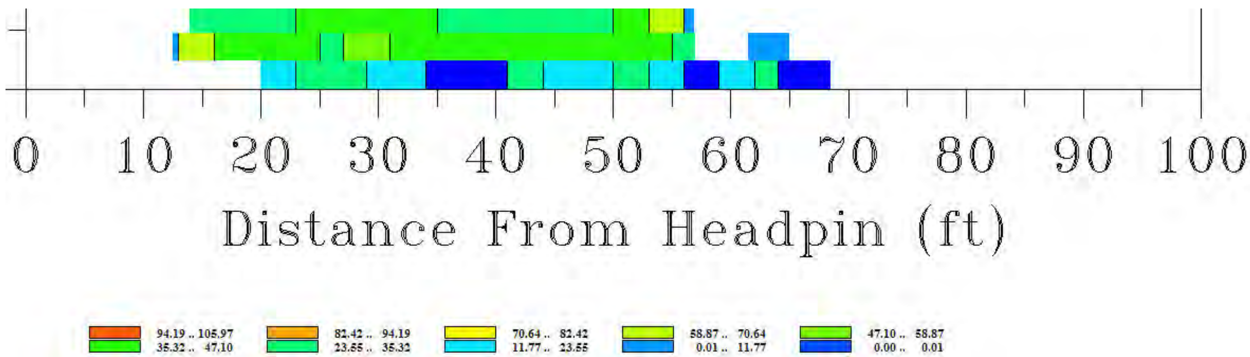
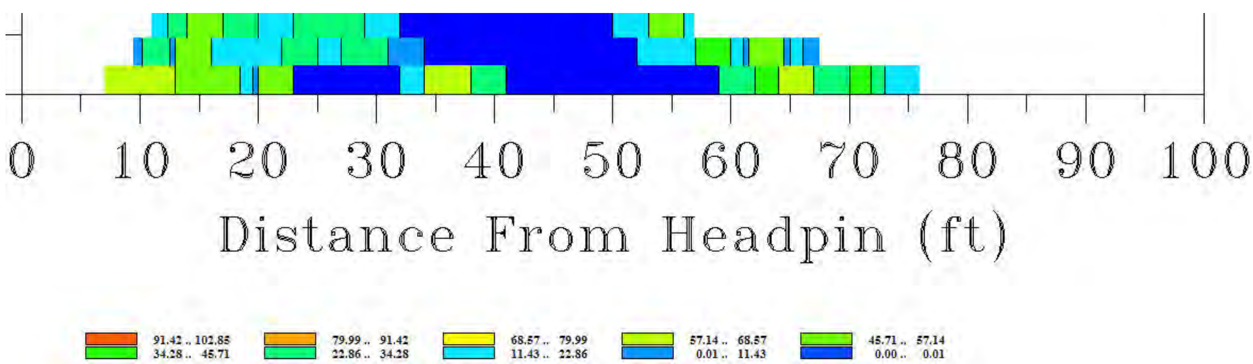


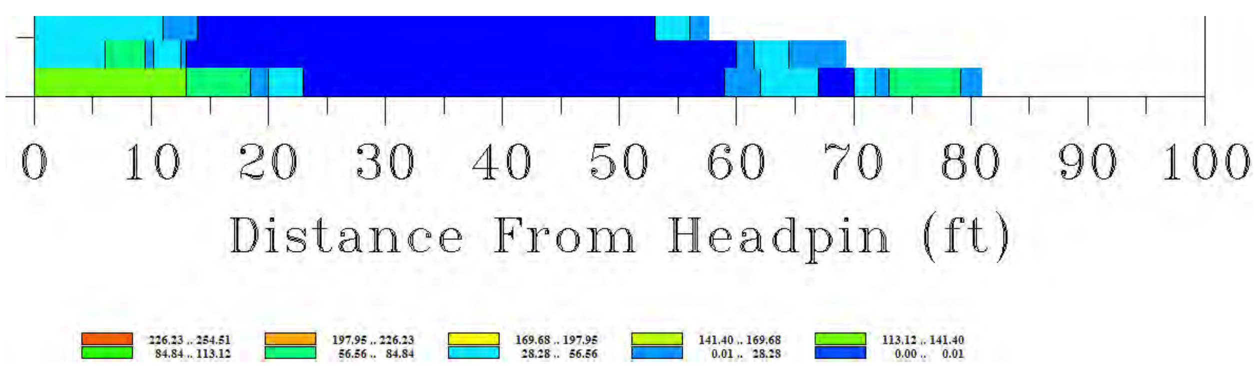
Figure 53. WUA maps (weighted cells) for steelhead juvenile in upper John Day River Cottonwood Galley at three different flows. Red cells provide highest WUA, yellow cells provide intermediate WUA, and blue cells provide lowest WUA.



20 cfs



100 cfs



175 cfs

Figure 54. WUA maps (weighted cells) for steelhead fry in upper John Day River Cottonwood Galley, transects 1-3, at three different flows. Red cells provide highest WUA, yellow cells provide intermediate WUA, and blue cells provide lowest WUA.

5.3 Escape Cover

Complete WUA results for fry and juveniles using the Klamath River escape cover coding system are located in Appendix E. For discussion purposes, an example is presented here that compares habitat modeling results using the December, 2005 escape cover coding and the Klamath coding with an explanation of why the results differ.

Figure 55 overlays WUA results for Chinook salmon juveniles in upper John Day River, Cottonwood Galley using the escape cover coding for John Day and Klamath. The results are substantially different. Optimal habitat using the John Day coding peaks at 60 cfs compared to the Klamath coding peaking at 150 cfs. The reason for this difference is best illustrated using the habitat mapping results (Figures 56 and 57). The blue, or dark shade, indicates little or no habitat. Again, color-coded legends are misleading and need to be examined closely. Figure 56 shows WUA for all transects using the John Day coding at three different flows. At low flow, most of the channel has some amount of juvenile habitat because the very large gravel, which dominates the center of the channel, has an escape cover SI of 0.2 and grass, which occurs along the edges, has an SI of 0.4 for juvenile Chinook salmon (Table 6). Habitat peaks at 60 cfs and.decreases at higher flows, mainly due to increased velocities. In Figure 57, WUA is mapped using the Klamath codes. Most habitat occurs at the higher flows because the dominate substrate, very large gravel, has an escape cover SI of 0.03 and grass has an SI of 1.0 (Table 7). This results in very low quality habitat in the center of the stream channel and high quality habitat occurring along the bank edges where water inundates grass at higher flows. From a different perspective, Figure 58 illustrates the same results for just the first three transects with a side-by-side comparison using John Day and Klamath escape cover codes at the three flows. Thus, the results are controlled by relative SI differences between grass and very large gravel. Higher SI values for rock substrates compared to grass tend to reduce flows corresponding to optimal WUA for fry and juveniles. Likewise, lower SI values for large substrates and relatively higher values for grass tend to increase flows that provide optimal WUA.

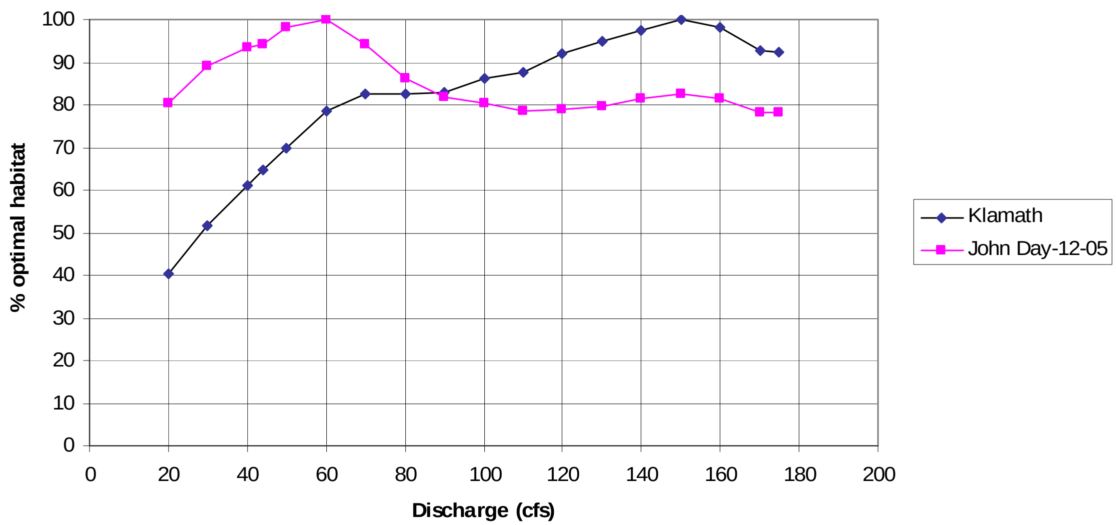


Figure 55. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for Chinook salmon juveniles in upper John Day River – cottonwood galley.

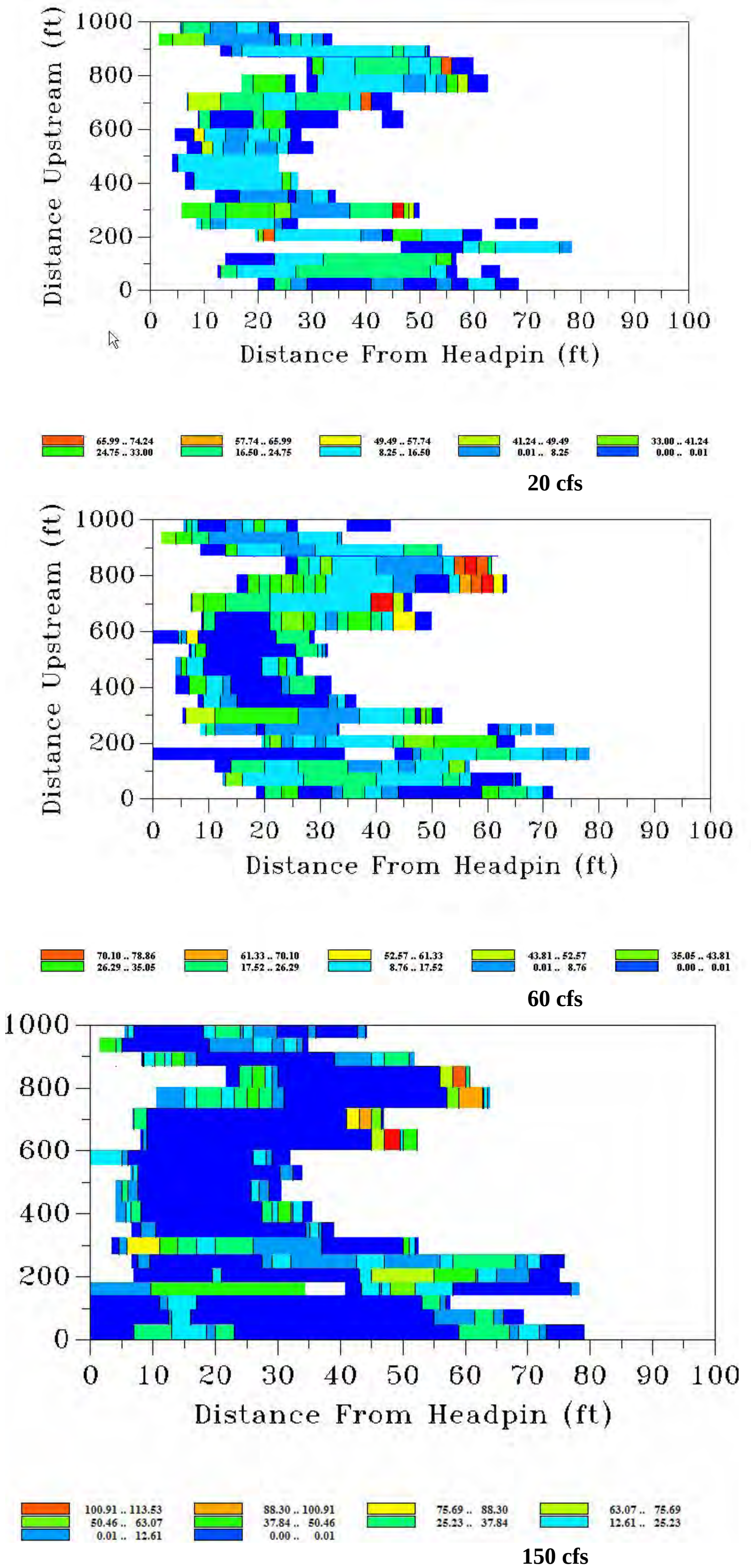
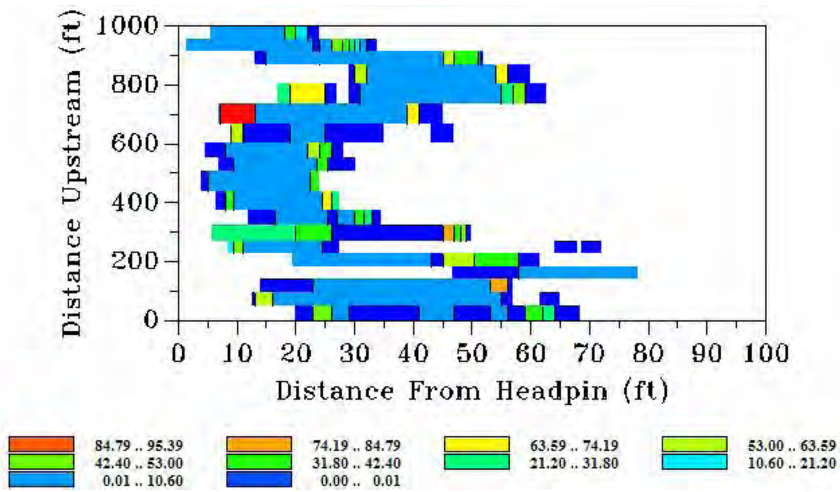
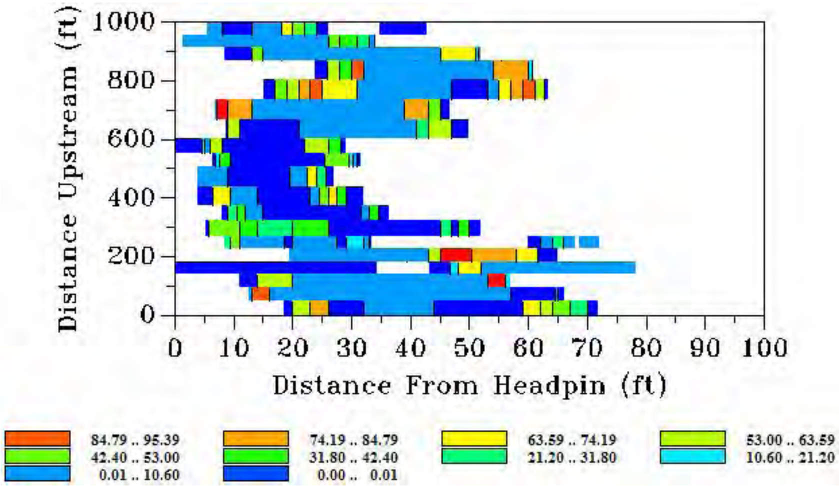


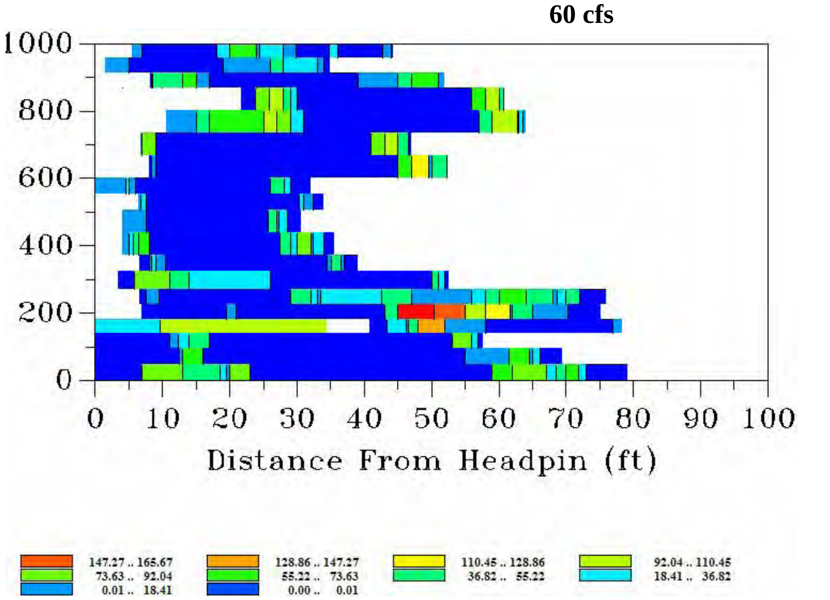
Figure 56. WUA maps (weighted cells) for juvenile Chinook salmon in John Day River, cottonwood galley using December, 2005 escape cover codes at three different flows. Red cells provide highest WUA, yellow cells provide intermediate WUA, and blue cells provide lowest WUA.



20 cfs



60 cfs



150 cfs

Figure 57. WUA maps (weighted cells) for juvenile Chinook salmon in John Day River, cottonwood galley using Klamath escape cover codes at three different flows. Red cells provide highest WUA, yellow cells provide intermediate WUA, and blue cells provide lowest WUA.

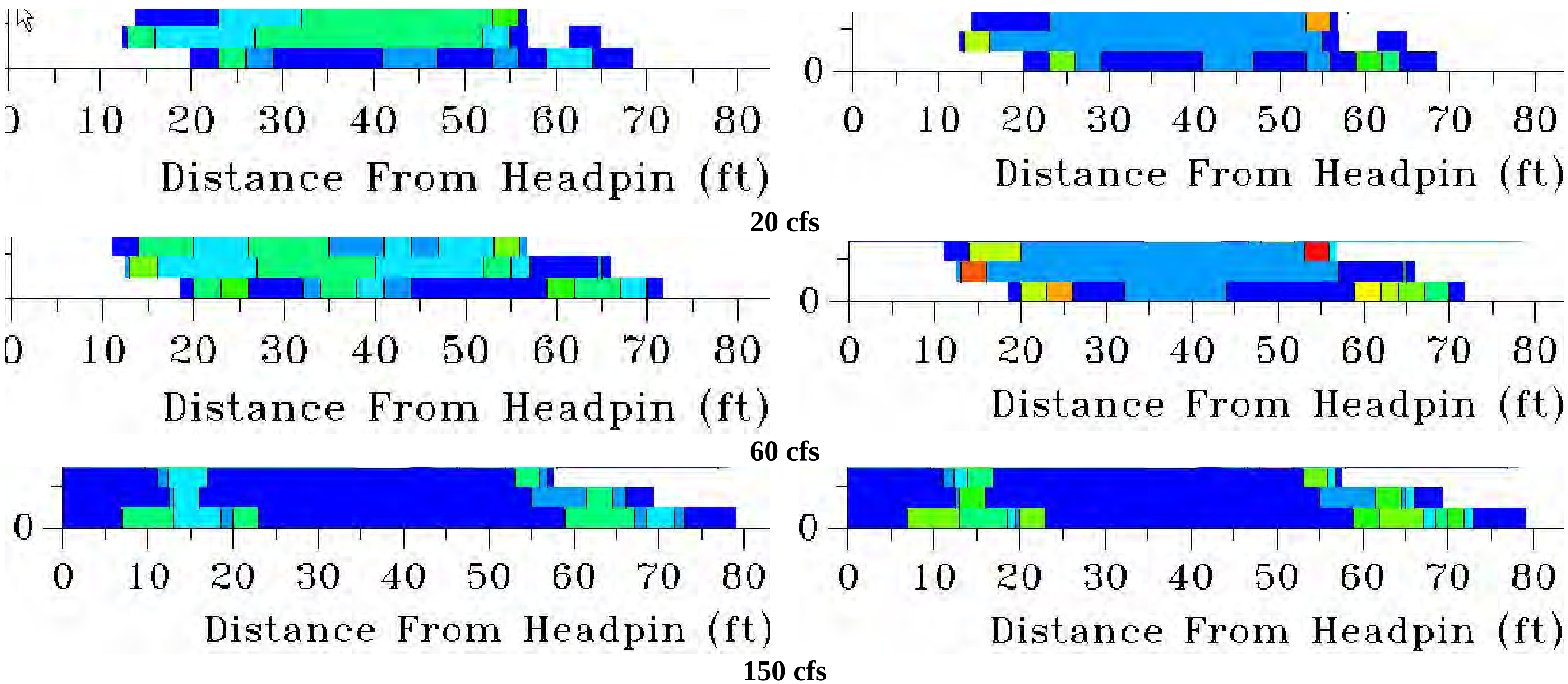


Figure 58. Maps of WUA (weighted cells) for juvenile Chinook salmon in John Day River, cottonwood galley transects 1-2 (riffles) and transect 3 (pool) using December, 2005 escape cover codes (left column) and Klamath escape cover codes (right column). Red cells provide highest WUA, yellow cells provide intermediate WUA, and blue cells provide lowest WUA.

Selection of an appropriate escape cover HSC coding system for fry and juvenile salmonids will continue to be a matter of professional opinion until there is a better understanding of fish behavior in the John Day River sub-basin. Although site-specific fish observations would help determine an appropriate escape cover HSC, a well designed site-specific HSC study for fry and juvenile salmonids could be complicated by the mobile nature of these life stages and rapidly changing use of habitat over time and space. For example, during daylight on November 15, 2005, local biologists Tim Unterwegner (ODFW) and Brent Smith (CTWSRO) snorkeled a short reach of the Middle Fork John Day River between Caribou Creek and Vincent Creek in an attempt to identify microhabitat use by juvenile Chinook salmon and steelhead and help validate the PHABSIM modeling results. No salmonids were observed, even in habitat where they would be expected to occur (near riprap in a deep pool). Tim Unterwegner speculated that the fish may have moved downstream to overwinter. Another possibility is that the fish were concealed in the substrate during the daylight and moved into open water during night. Regardless, the effort highlighted the complex behavior of juvenile salmonids in terms of microhabitat use.

Seasonal and diel shifts in habitat use by young salmonids are well documented (Everest & Chapman 1972; Hillman and Griffith 1987; Blatz et al. 1991; Roper et al. 1994; Thurow 1997; Spangler and Scarnechhia 2001; Kahler et al. 2001). Habitat selection also depends on variables such as temperature, food, stream flow, cover, predators, and population densities (Bjornn 1971; Bugert et al. 1991; Nielsen and Lisle 1994; Shirvell 1994). For models to be useful, they must include all the factors that regulate standing crop (Bjornn & Reiser 1991). Ignoring the spatial positioning of habitats and the dispersal capabilities of fish between them affects estimates of habitat quality and production (Kocik & Ferreri 1998). In summary, habitat modeling of fry and juvenile salmonids is a highly complex science involving many interacting variables. Further exploration is needed.

5.4 Adult Fish Passage

Passage results are shown in Tables 12-15 and Figures 59 and 60 for upper John Day River and Middle Fork John Day River. Cross-sectional profiles of shallow riffles used in the analysis are shown in Figures 61 and 62. At a shallow riffle transect on the upper John Day River in the Cottonwood Galley near Prairie City, discharge greater than 58 cfs satisfied both criteria. For a shallow riffle in the Middle Fork John Day River between Caribou Creek and Vincent Creek, results show that discharges greater than 32 cfs satisfied both continuous width and total width criteria.

Table 12. Summary of adult fish passage results on upper John Day River and Middle Fork John Day River.

% of width	0.4 ft depth		0.6 ft depth		Both satisfied	
River Segment	Upper John Day River nr Prairie City (cfs)	Middle Fork John Day River between Caribou Cr and Vincent Cr (cfs)	Upper John Day River nr Prairie City (cfs)	Middle Fork John Day River between Caribou Cr and Vincent Cr(cfs)	Upper John Day River nr Prairie City (cfs)	Middle Fork John Day River between Caribou Cr and Vincent Cr (cfs)
Continuous (10%)	<20.0	11.5	20.0	28.0	20.0	28.0
Total (25%)	28.4	15.0	58	32.0	58.0	32.0

Table 13. Discharge versus depth and width relationships at one shallow transect on John Day River – Cottonwood Galley (transect 1- riffle)

Discharge (cfs)	Stream width (ft)	0.4 ft depth (ft)	% of total width	0.4 ft depth continuous	Continuous % of width	0.6 ft depth (ft)	% of total width	0.6 ft depth continuous	Continuous % of width
20	33	8	24	8	23	3	10	3	10
30	48	12	26	9	18	7	14	7	14
40	51	17	32	9	18	8	15	8	15
44	52	20	39	10	19	9	18	8	15
50	52	26	49	10	19	11	21	8	16
60	53	30	56	21	41	14	26	9	17
70	54	34	63	22	41	18	33	9	17
80	56	42	75	22	40	24	44	10	18
83	57	44	78	23	40	26	46	10	18
90	62	48	78	43	69	29	46	21	34
100	66	50	76	44	66	31	47	22	33
110	68	51	75	51	75	35	51	22	32
120	70	52	74	52	74	41	59	22	32
130	72	52	73	52	73	48	66	43	60
140	74	53	71	53	71	49	66	43	58
150	76	53	70	53	70	50	66	44	58
160	78	54	70	54	70	51	66	51	66
170	79	56	71	56	71	52	66	52	66
175	79	56	71	56	71	52	66	52	66

Table 14. Discharge versus depth and width relationships at one shallow transect on Middle Fork John Day River – Caribou Creek to Vincent Creek (transect 7 – riffle)

Discharge (cfs)	Stream width (ft)	0.4 ft depth (ft)	% of total width	0.4 ft depth continuous	Continuous % of width	0.6 ft depth (ft)	% of total width	0.6 ft depth continuous	Continuous % of width
6	53	1	2	1	2	0	0	0	0
10	54	6	11	4	7	0	0	0	0
13	55	10	19	8	14	0	0	0	0
20	63	28	44	21	33	1	2	1	2
30	66	41	62	26	40	10	16	8	12
31	66	51	78	51	78	16	24	16	24
40	68	53	78	53	78	26	38	20	29
50	71	54	76	54	76	35	50	24	34
60	74	60	81	60	81	52	70	52	70
70	77	62	81	62	81	53	68	53	68
80	80	64	80	64	80	54	67	54	67
90	82	65	79	65	79	55	66	55	66
100	84	66	79	66	79	61	72	61	72
110	86	68	79	68	79	62	72	62	72
120	87	69	79	69	79	63	72	63	72
130	89	71	79	71	79	64	72	64	72
140	91	73	80	73	80	65	72	65	72
150	93	74	80	74	80	66	71	66	71
160	94	76	81	76	81	67	71	67	71
170	96	78	81	78	81	68	71	68	71
172	96	78	81	78	81	68	71	68	71
175	97	78	81	78	81	69	71	69	71

Table 15. Measured depths across passage transects at low flows.

Upper John Day River		Middle Fk John Day River	
44 cfs		13 cfs	
Vertical station (ft)	Depth (ft)	Vertical station (ft)	Depth (ft)
12.5	0	22	0.0
16	0.1	30	0.3
19	0.4	35	0.3
22	0.7	40	0.5
25	0.7	45	0.4
27	0.3	50	0.2
31	0.1	55	0.2
34	0.2	60	0.3
37	0.3	65	0.4
40	0.4	70	0.4
43	0.5	75	0.6
46	0.4	78	0.5
49	0.6	82	0.0
52	0.9		
55	0.9		
57	0.4		
60	0.1		
61.5	0		

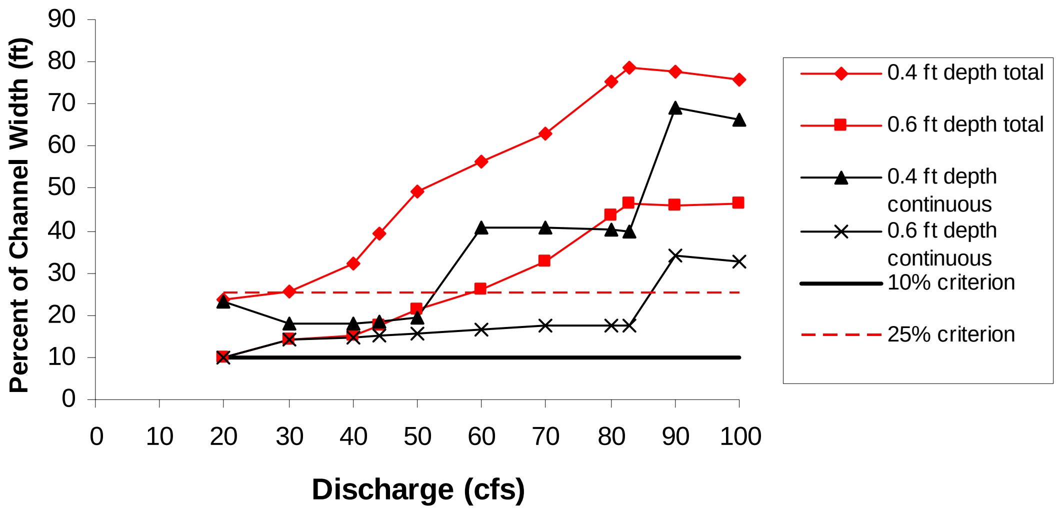


Figure 59. Percent of channel width at depths greater than passage criteria at a shallow riffle transect (38 feet longitudinal distance) on upper John Day River.

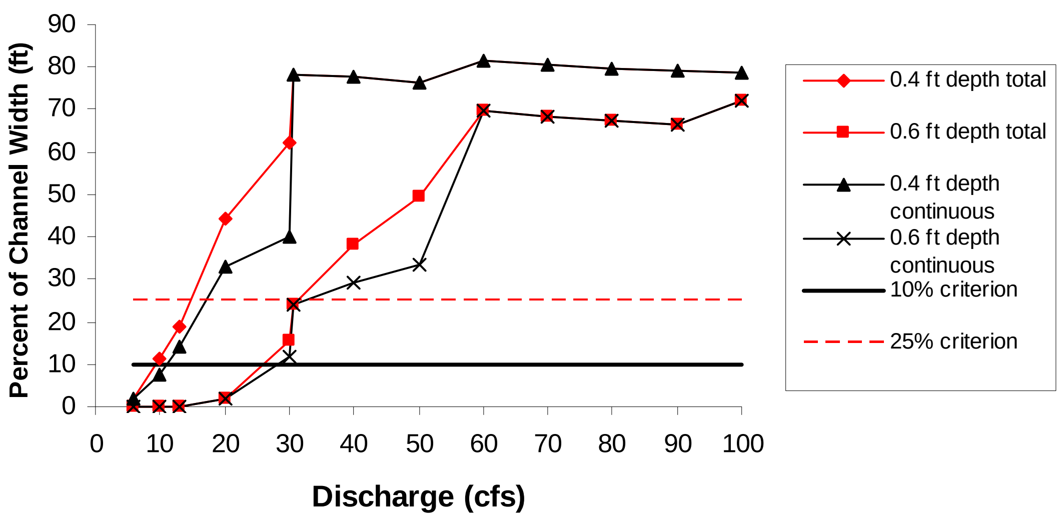


Figure 60. Percent of channel width at depths greater than passage criteria at a shallow riffle transect (36 feet longitudinal distance) on Middle Fork John Day River.

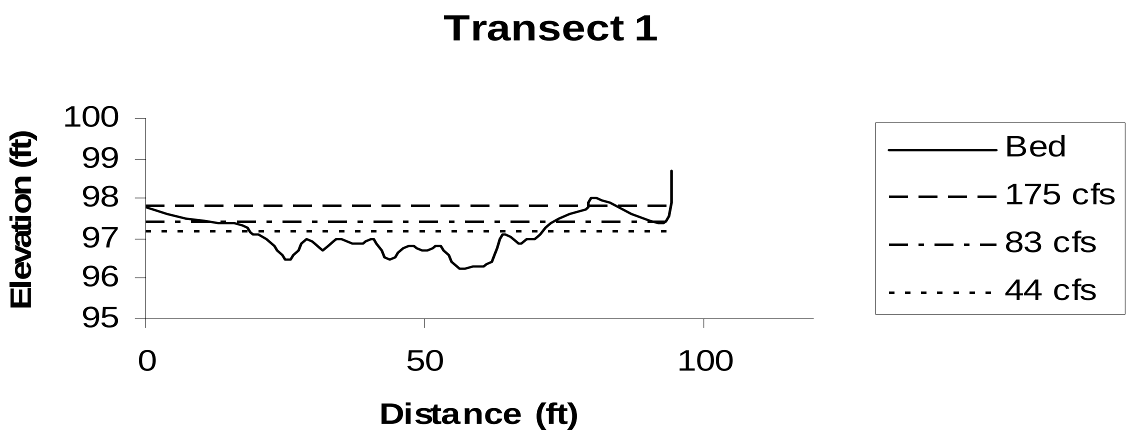


Figure 61. Cross-sectional profile of riffle transect on upper John Day used in passage analysis.

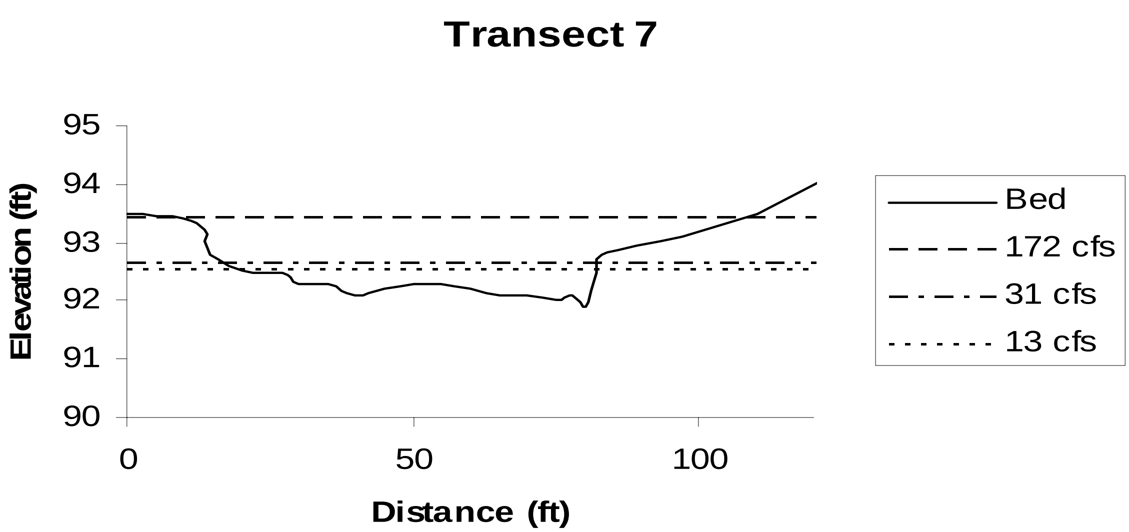


Figure 62. Cross-sectional profile of riffle transect on Middle Fork John Day used in passage analysis.

5.5 Summary Results

The upper John Day River (Cottonwood Galley) discharges required for maximum WUA ranged from 40 to 120 cfs for steelhead, 20 to 140 cfs for Chinook salmon, and 30 to 80 cfs for bull trout, depending on life stage (Table 16). Fry required least amount of water to maximize habitat among life stages. Discharges required for adult passage over a shallow riffle habitat transect were 58 and 20 cfs for the 0.6 ft depth criterion greater than 25 percent of the total channel width and greater than 10 percent of the contiguous channel width, respectively (Table 16).

The Middle Fork John Day River (Caribou Creek to Vincent Creek) discharges required for maximum WUA ranged from 50 to 100 cfs for steelhead, 6 to 175 cfs for Chinook salmon, and 6 to 70 cfs for bull trout, depending on life stage (Table 16). Fry required least amount of water to maximize habitat among life stages. Discharges required for adult passage over a shallow riffle habitat transect were 32 and 28 cfs for the 0.6 ft depth criterion greater than 25 percent of the total channel width and greater than 10 percent of the contiguous channel width, respectively (Table 16).

Higher flows were generally required for maximum WUA in the Middle Fork John Day River between Camp Creek and Big Boulder Creek than between Caribou Creek and Vincent Creek. Flows for maximum WUA ranged from 40 to 180 cfs for steelhead, 40 to 260 cfs for Chinook salmon, and 29 to 240 cfs for bull trout, depending on life stage (Table 16). Fry required least amount of water to maximize habitat among life stages. Tributary results also showed fry required least amount of water to maximize habitat among life stages.

Modeling results provided insight into the relationships between flow and habitat and how these results relate to the natural hydrograph. For example, optimal habitat for juvenile steelhead in the Middle Fork John Day River between Caribou Creek and Vincent Creek occurred at 100 cfs (Table 16). Downstream in the Middle Fork John Day River between Camp Creek and Big Boulder Creek, optimal habitat for juvenile steelhead occurred at 140 cfs. Results showed that flows greater than 32 cfs met 0.6 depth adult passage criteria at a shallow riffle in the Middle Fork John Day River between Caribou Creek and Vincent Creek. The accompanying natural hydrology report (Reclamation 2005) showed that average monthly flows in the Middle Fork John Day River between Clear Creek and Camp Creek were below 100 cfs June through November and above 200 cfs March through May (Figure 5). Thus, there is not enough available water in average water years to provide optimal flow conditions for juvenile steelhead habitat during summer and fall. However, steelhead passage conditions are met in the spring.

Table 16. Habitat modeling and estimated naturalized hydrology summary for John Day River instream flow study

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]		MAF (cfs)[2]	June flows (cfs) at exceedance levels			July flows (cfs) at exceedance levels			August flows (cfs) at exceedance levels		
	Steelhead	Chinook salmon	Bull trout Fluvial	Bull trout Resident	>25% of total channel width	>10% of contiguous channel width		20%	50%	80%	20%	50%	80%	20%	50%	80%
Upper John Day-Cottonwood					58	20	169	322	505	768	144	217	325	81	100	138
Spawning	120	110	70	80												
Adult	-	140	44	-												
Juvenile	70	60		70												
Fry	40	20		30												
Middle Fk John Day-Caribou Cr-Vincent Cr					32	28	126	55	86	123	31	35	39	26	28	31
Spawning	90	60	50	40												
Adult	-	175	40	-												
Juvenile	100	40		70												
Fry	50	6		6												
Middle Fk John Day-Camp Cr-Big Boulder Cr							126	55	86	123	31	35	39	26	28	31
Spawning	180	200	100	240												
Adult	-	260	80	-												
Juvenile	140	50		50												
Fry	40	40		29												
Reynolds Creek							19	7	13	19	4	5	6	4	4	4
Spawning	44	>46	26	>46												
Adult	-	>46	>46	-												
Juvenile	30	26		30												
Fry	16	12		14												
Granite Boulder Creek							12	5	8	12	3	3	4	3	3	3
Spawning	46	35	40	>54												
Adult	-	46	28	-												
Juvenile	24	12		26												
Fry	10	10		8												
Dad's Creek							6	3	4	6	1	2	2	1	1	1
Spawning	9.5	14	8.5	12												
Adult	-	13.5	3.5	-												
Juvenile	6.5	3.5		3												
Fry	2	1.5		1												

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

Examination of the natural discharge estimates in Table 16 shows that flow estimates for the upper John Day stream segment are much greater than the other stream segments at all exceedance levels. The only explanation for this is the differences between the hydrograph in the upper John Day River and the other stream segments and how natural flows were estimated as discussed in Section 2.0. When compared to the habitat results for juveniles, highest WUAs occur at lower flows relative to summer natural flow estimates than the other stream segments. Different WUA vs flow relationships among stream segments are caused by the differences in channel hydraulics, and do not reflect differences in natural flows. Average stream hydraulic parameters show that the channel morphology of the upper John Day River is generally intermediate in terms of widths and depths at any given flow between the two stream segments on the Middle Fork John Day River (Table 17). Thus, it is not surprising that most life stages at the upper John Day River stream segment have optimal WUAs at flows between the flows that produce optimal WUA for the two segments on the Middle Fork John Day River.

This information about hydrology and channel morphology suggests that either the upper John Day River is in the process of degrading (narrowing and deepening) or the Middle Fork John Day River is aggrading (widening and getting shallower), or a combination of both, particularly when compared to each other. This is not surprising given upstream land use disturbances (e.g., diversions, riparian clearing, livestock damage). This theory could be tested by periodically re-surveying transects as a check of channel stability.

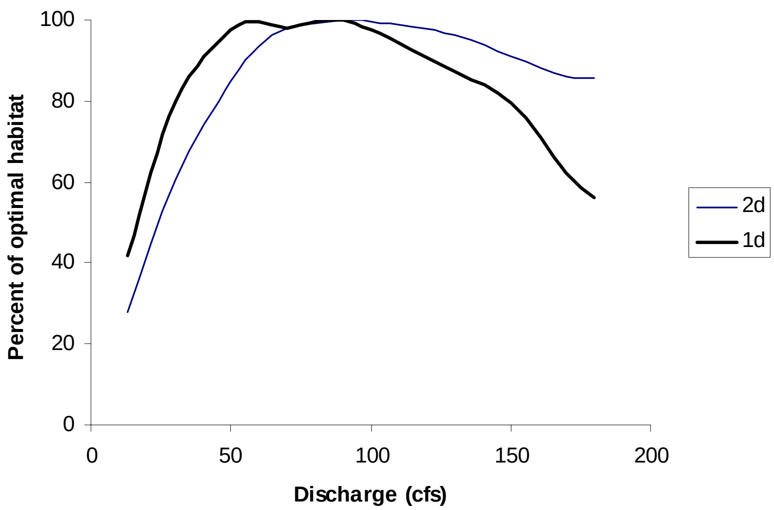
Table 17. Average stream hydraulic parameters at upper John Day River and Middle Fork John Day River stream segments.

Discharge (cfs)	Wetted Perimeter (ft)	Width (ft)	Depth (ft)	Velocity (ft/sec)
Upper John Day River-Cottonwood Galley				
20	30.7	29.9	0.7	0.9
30	33.8	32.9	0.8	1.2
40	35.5	34.6	0.8	1.4
50	36.6	35.6	0.9	1.6
60	37.4	36.3	0.9	1.8
70	38.2	37.1	1.0	1.9
80	39.0	37.8	1.0	2.1
90	40.1	38.8	1.1	2.2
100	41.8	40.5	1.1	2.3
Middle Fork John Day River-Camp Creek to Big Boulder Creek				
10	34.0	33.5	0.5	0.6
20	39.4	38.8	0.6	0.9
30	44.0	43.3	0.7	1.0
40	46.3	45.5	0.8	1.2
50	47.7	46.9	0.8	1.3
60	49.0	48.2	0.9	1.4
80	51.3	50.3	1.0	1.7
100	52.5	51.5	1.1	1.9
Middle Fork John Day River-Caribou Creek to Vincent Creek				
6	23.9	23.1	0.9	0.3
10	24.9	24.1	1.0	0.4
20	27.0	26.0	1.1	0.7
30	28.7	27.6	1.2	0.9
40	30.3	29.2	1.2	1.1
50	32.0	30.9	1.3	1.3
60	32.9	31.7	1.3	1.5
70	33.7	32.4	1.4	1.6
80	34.8	33.5	1.4	1.7
90	35.7	34.4	1.4	1.9
100	36.6	35.3	1.4	2.0

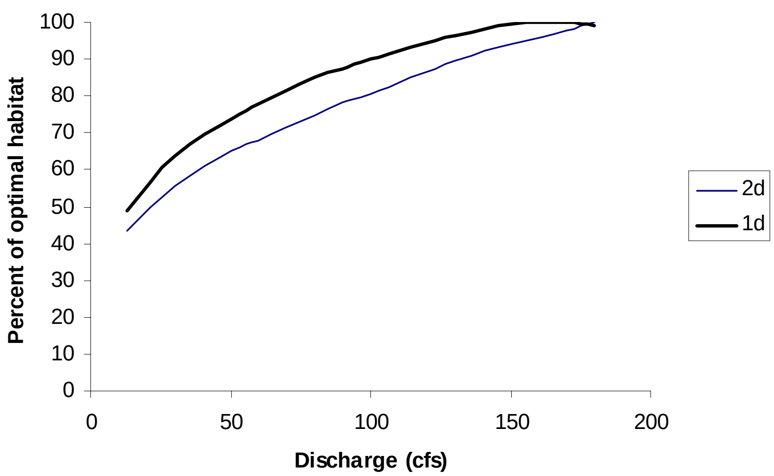
5.6 Comparison of PHABSIM with River2D Habitat Modeling

Figure 63 compares habitat analysis results for Chinook salmon spawning and adult holding between PHABSIM (one dimensional hydrodynamic model (1d)) and River2D (two dimensional hydrodynamic model (2d)) on the Middle Fork John Day River between Caribou Creek and Vincent Creek, Study Site 2 (Appendix A). These life stages were chosen because the same channel index coding system could be used. The coding system differs with other life stages. The comparison is intended to highlight both similarities and differences that arise from using different approaches to field data collection, hydraulic modeling, and the way habitat is computed. Examination of this figure based on percent of maximum habitat relationships over the same flow range shows similar overall relationships in the habitat versus discharge functions for both life stages. The differences between models reflect differing respective hydraulic modeling approaches (e.g., transect-based 1d vs topography-based 2d).

Waddle et al. (2000) reported that whether based on one-dimensional or two-dimensional flow models, the sensitivity of calculated habitat to errors in simulated depth and velocity ultimately depends on the sensitivity of target species' habitat suitability indices to depth and velocity. For this study, the major advantage of River2D modeling over PHABSIM is the attractive visual aids generated to display hydraulic and habitat results (Figure 64). However, River2D is also more labor intensive and expensive than PHABSIM. Thus, PHABSIM analysis was considered sufficient for purposes of this study since the river channels were not hydrodynamically complex enough to justify using River2D (i.e., few eddies, intermittent backwaters, transverse flows, and braided channels) and similar habitat-discharge relationships would be expected with either model. Waddle et al. (2000) suggested that in areas with generally straight or gradually bending single channels, the one-dimensional approach may suffice. This generally describes most segments of the upper John Day River and Middle Fork John Day River and their tributaries.



Chinook salmon spawning



Chinook salmon adult holding

Figure 63. Comparison of habitat modeling results between River 2D (2d) and PHABSIM (1d) at Study Site 2 on Middle Fork John Day River between Caribou Creek and Vincent Creek.

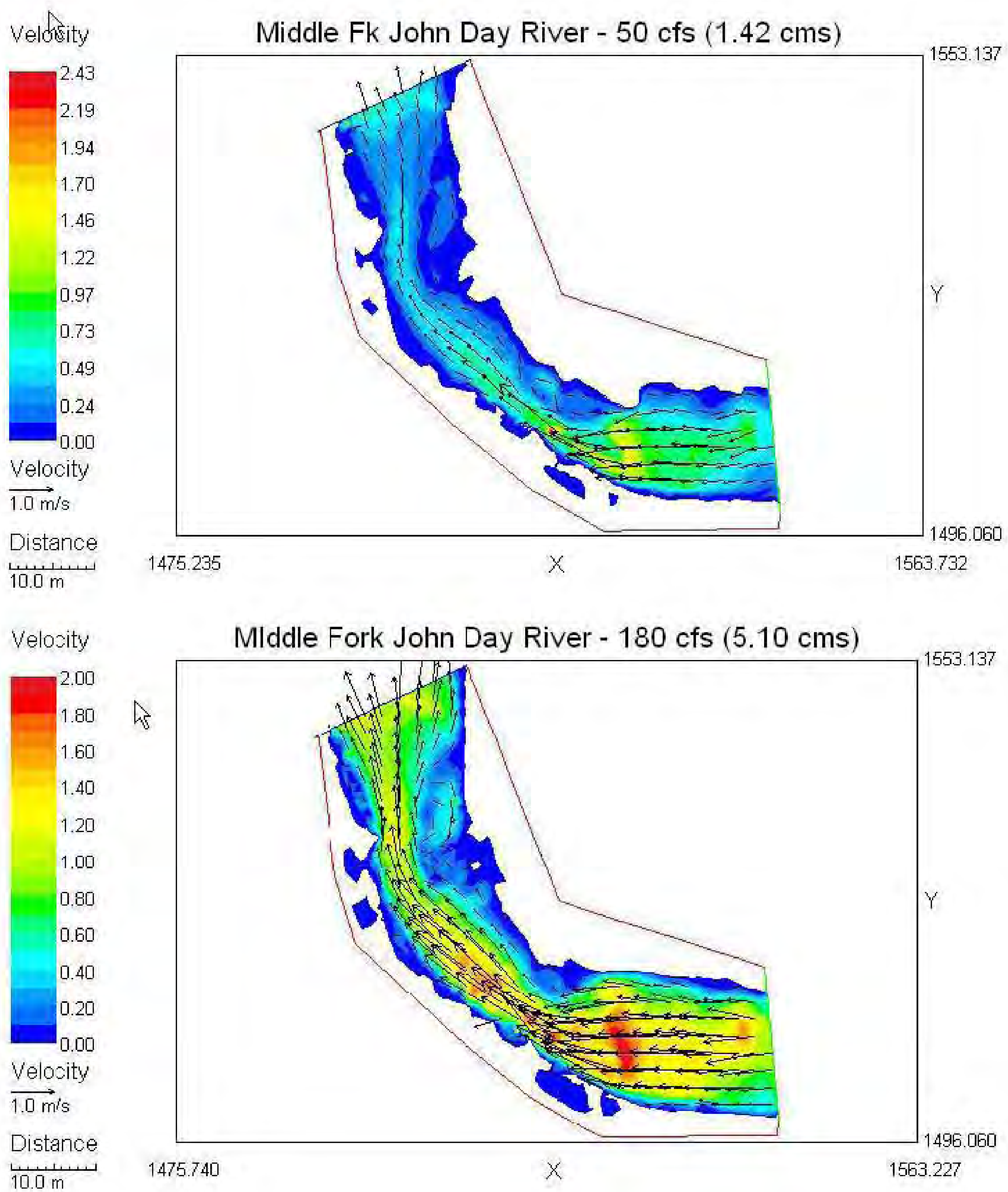


Figure 64. Velocity magnitudes at two flows in Middle Fork John Day River between Caribou Creek and Vincent Creek (Study Site 2) using River2D.

5.7 Guidelines for Using Study Results

The results summarized the hydrology, habitat, and temperature characteristics of selected stream segments within the upper John Day River and Middle Fork John Day River sub-basins. The study was based on the assumption that the results would be used to guide voluntary water acquisitions. PHABSIM analysis of the data collected and compiled for this study resulted in a series of graphs that illustrate relations between a dimensionless value called weighted usable area (WUA) and discharge (Figures 16-51). The highest point on each curve represents the discharge at which habitat is optimized for adult, spawning, fry, or juvenile life stages for the fish species analyzed in this study (salmon, steelhead, and bull trout). These optimized values rarely coincide among life stages for any one species. Furthermore, adult, spawning, and juvenile life stages for salmon, steelhead, and bull trout occur at different times of the year (Table 1). These results imply that the optimum amount of water needed for adult, spawning, and juvenile 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.

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 would seem reasonable that providing enough water for adult fish passage would be foremost in management priorities. Choice of target flows should not be reduced below the optimum discharge to the point that stream depth is reduced below the level needed for fish passage, depending on available water supply.

The selection of a target flow 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 providing for the needs of the priority life stage and species also protects other life stages and species. For example, on small tributary streams, suggested priority life stage ranking for steelhead might be (from high to low): passage > spawning > juvenile > adult (Tim Unterwegner, ODFW, personal communication, January 12, 2005). Once the priority life stage and species are ranked, then each stream segment should be examined to determine stream flow and passage conditions for the time period of concern.

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 amount of WUA available, in terms of lost or gained, can be determined by comparing WUA for a flow alternative to a reference or unregulated stream flow condition. 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 for water quality, spring runoff conditions necessary to maintain channel morphology or riparian zone functions, or of downstream migrants. Available information shows that downstream migrant survival can significantly increase with flow (Arthaud et al. 2001). Thus, high spring flows that mimic the natural hydrograph should be a consideration in managing stream flows without PHABSIM analysis.

Warm summer water temperatures are affected partly by water withdrawals, which affect stream flows. Although high summer water temperature appears to limit fish survival in late July and early August, fish populations continue to exist within available physical habitat throughout the year. In fact, steelhead and Chinook salmon redd counts have been relatively stable since the late 1950s. Although thermal modeling would help determine the benefits of additional flow, if any, to thermal regimes within the system, temperature modeling was beyond the scope of this study. However, future thermal modeling through the Oregon DEQs TMDL process may provide information on the temperature/discharge relationship and may provide an avenue to evaluate flow effects for specific flow-restoration projects.

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 RECOMMENDATIONS

This study would benefit from additional information that could be obtained from the following tasks:

1) Snorkel Middle Fork John Day in June as suggested by ODFW (Tim Unterwegner, personal communication) to document spatial-scale microhabitat use by juvenile salmonids and help validate PHABSIM model results using escape cover;

2) Verify and refine HSCs with site-specific HSC data collection;

3) Establish continuous stream gaging stations above the most upstream irrigation diversion on the mainstem rivers and tributaries in areas critical to future studies (see Reclamation (2005) for additional hydrology recommendations);

4) Temperature analysis to determine relationship between stream flows and water temperatures in the upper John Day River and Middle Fork John Day River;

5) Modify the USGS version of PHABSIM to include an algorithm for escape cover that "searches" for threshold depths and velocities at escape cover locations;

6) Modify River2D to include an escape cover function and validate it with site-specific snorkel observations; and

7) Periodically (every few years) re-survey transects to determine whether the stream channels are aggrading or degrading.

7.0 ACKNOWLEDGEMENTS

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APPENDICES

Appendix A – Study Site and Transect Descriptions, Photos, and Cross-sectional Profiles with Measured Water Surface Elevations

Appendix B – Hydraulic Calibration Results

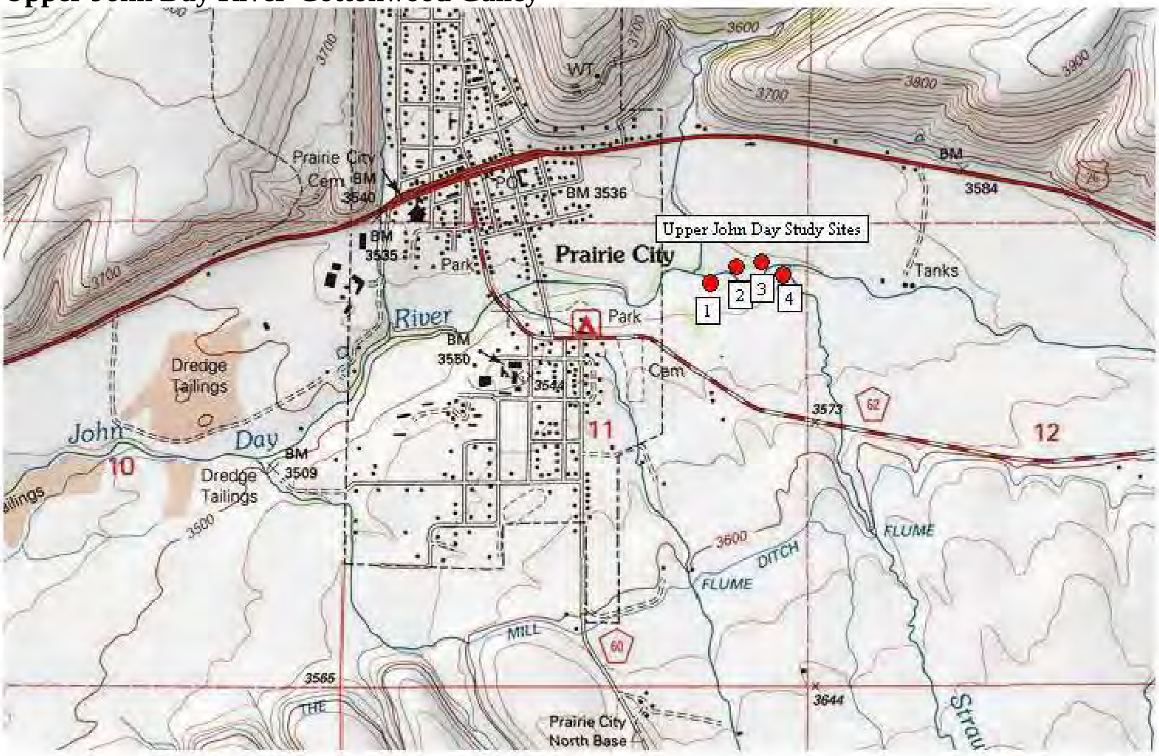
Appendix C – Habitat Suitability Criteria

Appendix D – Weighted Usable Area (WUA) Versus Discharge Relationships

Appendix E - Weighted Usable Area (WUA) Versus Discharge Relationships for Fry and Juveniles using Klamath River Escape Cover Coding System

Appendix A – Study Site and Transect Descriptions, Photos, and Cross-sectional Profiles with Measured Water Surface Elevations

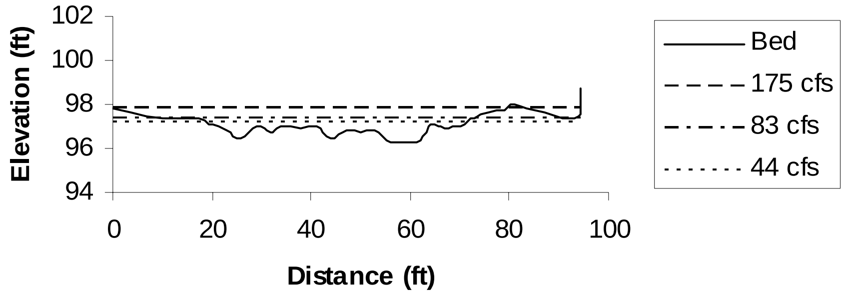
Upper John Day River-Cottonwood Galley



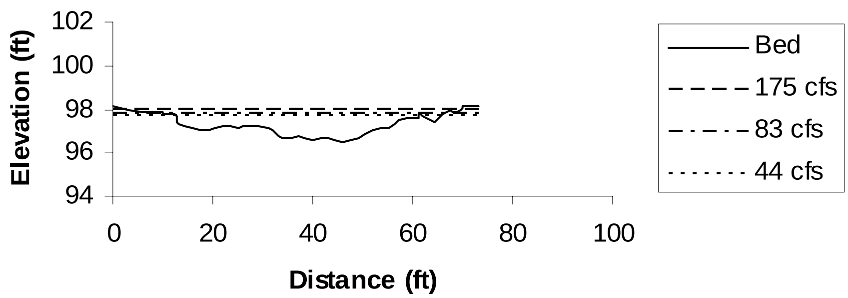
Study Site 1 (44°27.554'N; 118°41.965'W)

Transect 1 – riffle (most downstream transect)
Transect 2 – hydraulic control/riffle
Transect 3 – pool
Transect 4 – pool
Transect 5 – hydraulic control
Transect 6 – pool
Transect 7 – pool
Transect 8 – pool/backwater
Transect 9 – riffle
Transect 10 – glide (most upstream transect)

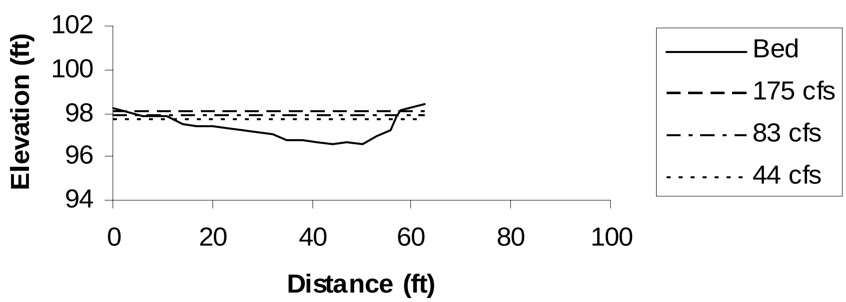
Transect 1



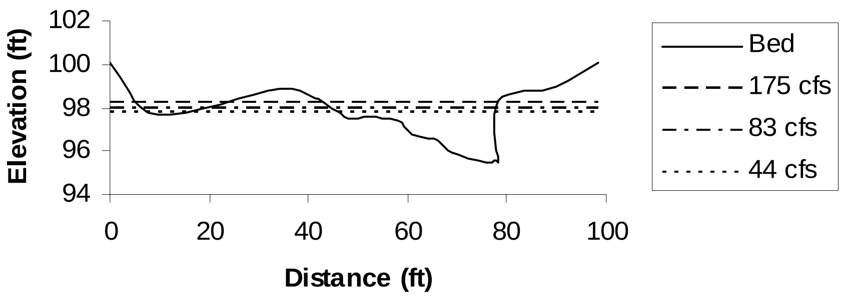
Transect 2



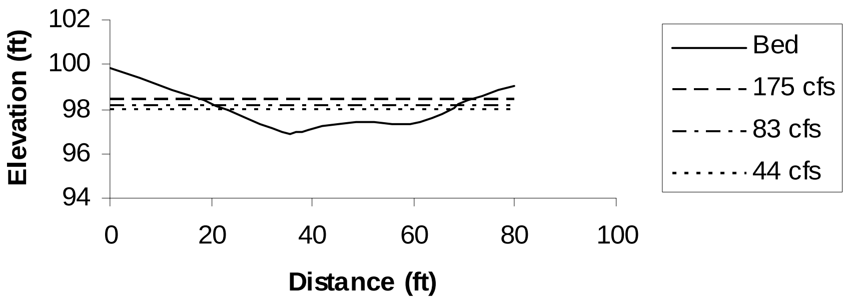
Transect 3



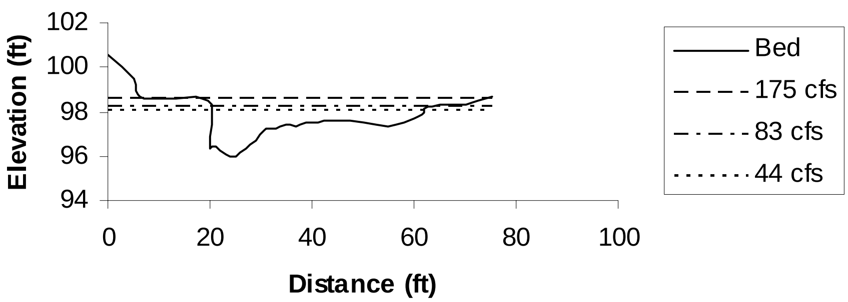
Transect 4



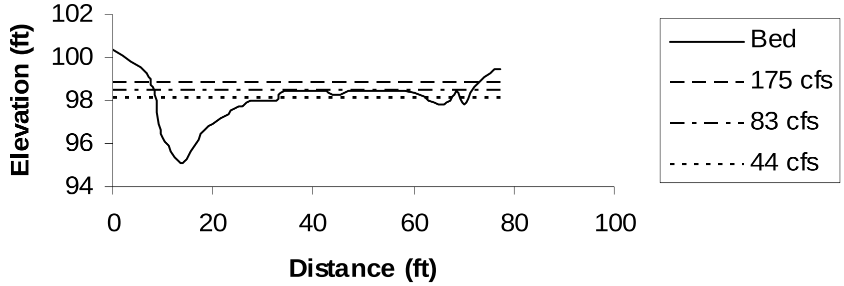
Transect 5



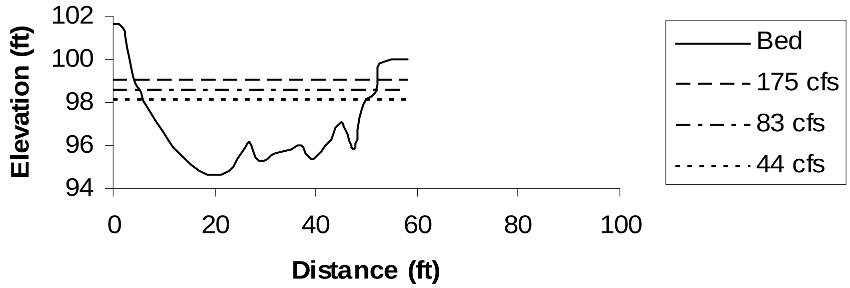
Transect 6



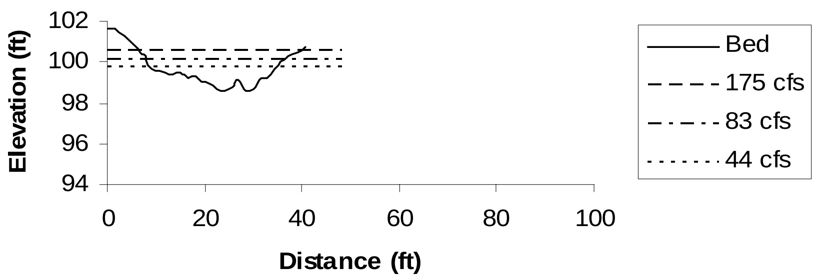
Transect 7



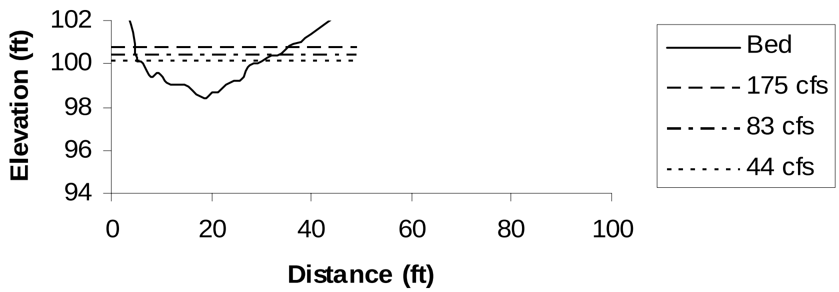
Transect 8



Transect 9

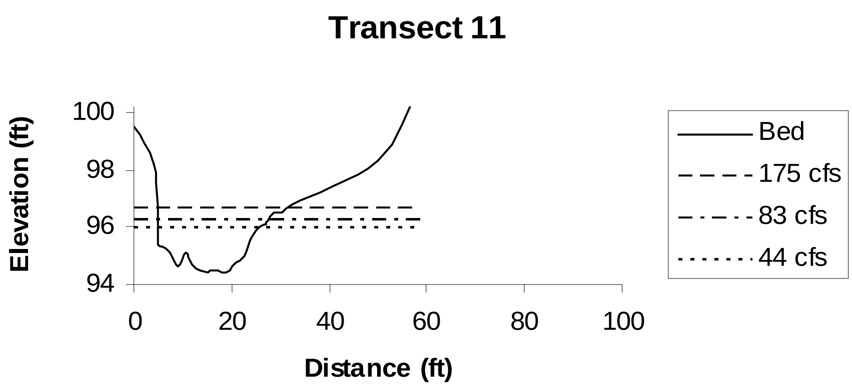


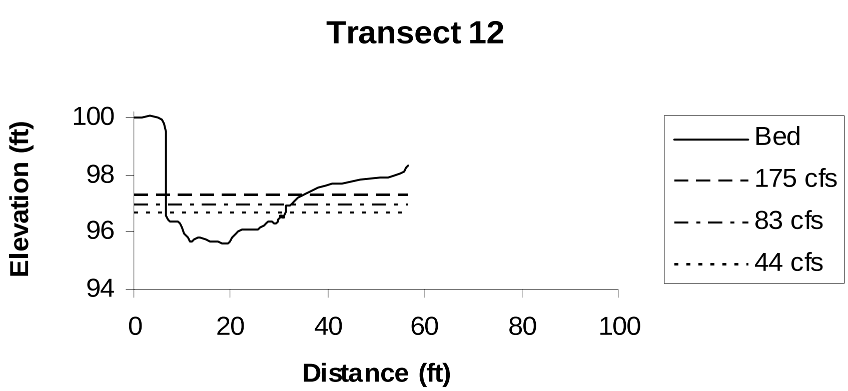
Transect 10



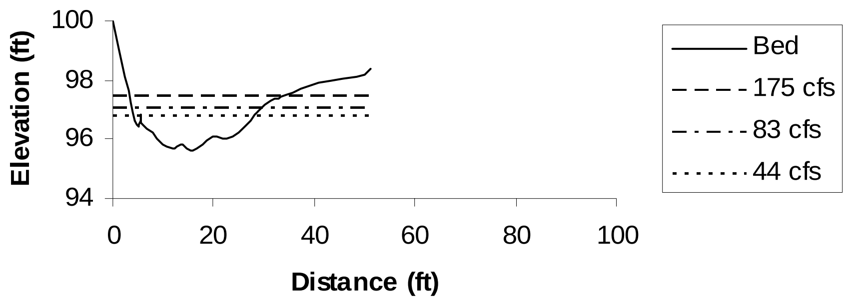
Study Site 2 (44°27.579'N; 118°41.897'W)

Transect 11 – glide (most downstream transect)
Transect 12 – riffle
Transect 13 – riffle (most upstream transect)





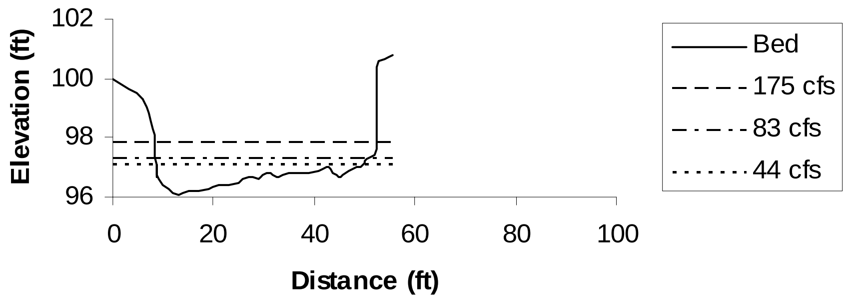
Transect 13



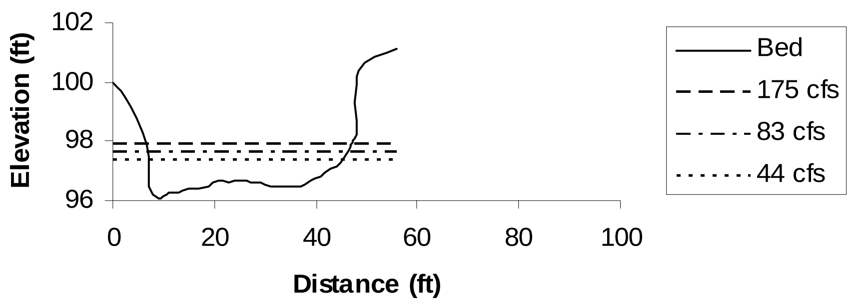
Study Site 3 (44°27.584'N; 118°41.836'W)

Transect 14 – glide (most downstream transect)
Transect 15 – glide
Transect 16 – glide
Transect 17 – glide (most upstream transect)

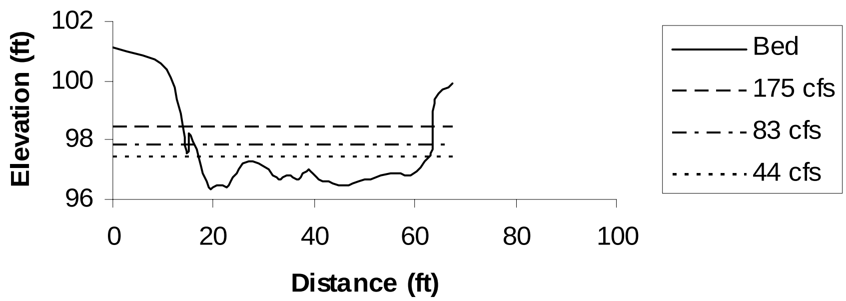
Transect 14



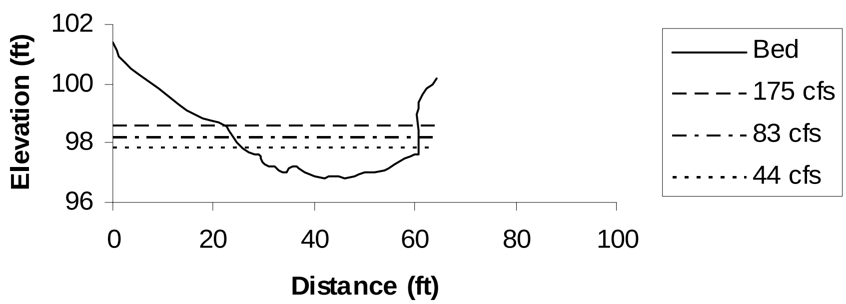
Transect 15



Transect 16

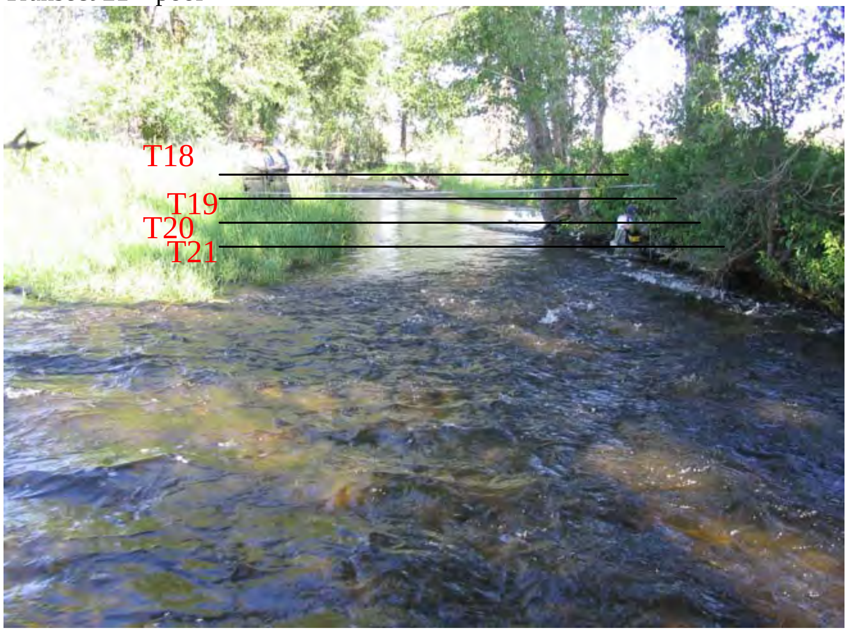


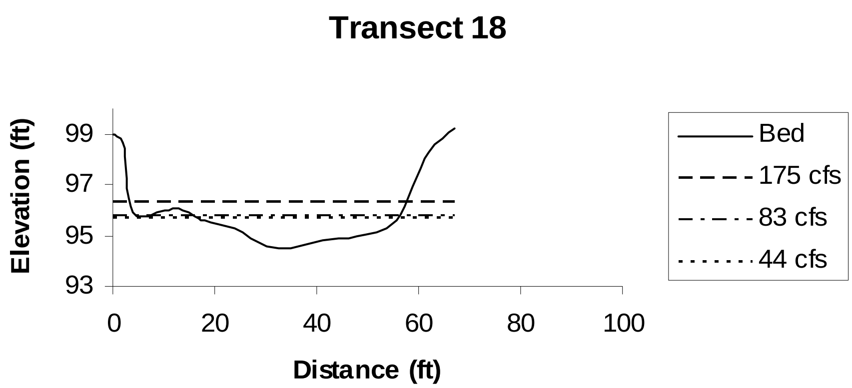
Transect 17

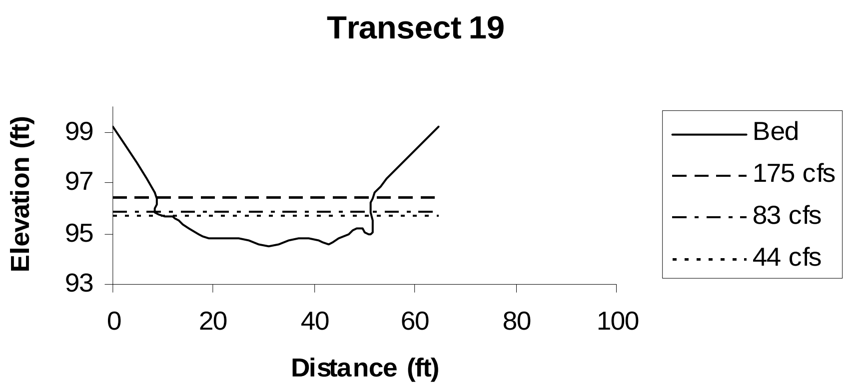


Study Site 4 (44°27.563'N; 118°41.777'W)

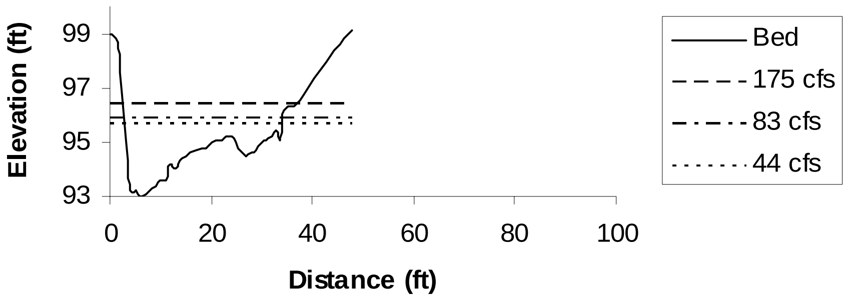
Transect 18 – hydraulic control (most downstream transect)
Transect 19 – pool
Transect 20 – pool
Transect 21 – pool



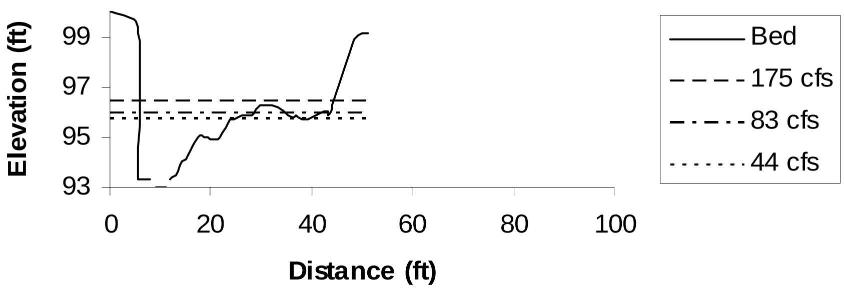




Transect 20



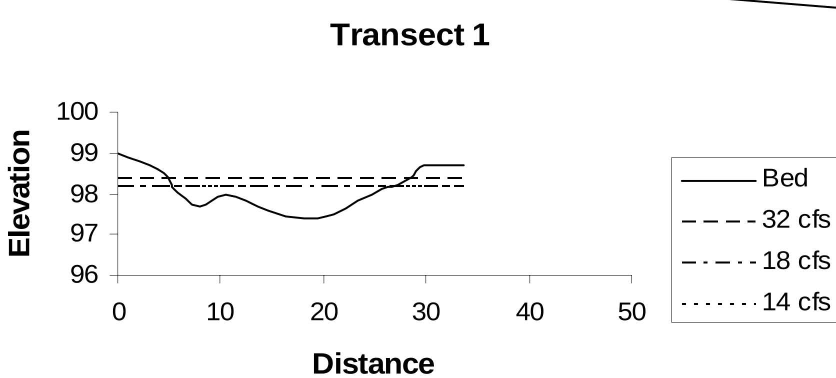
Transect 21

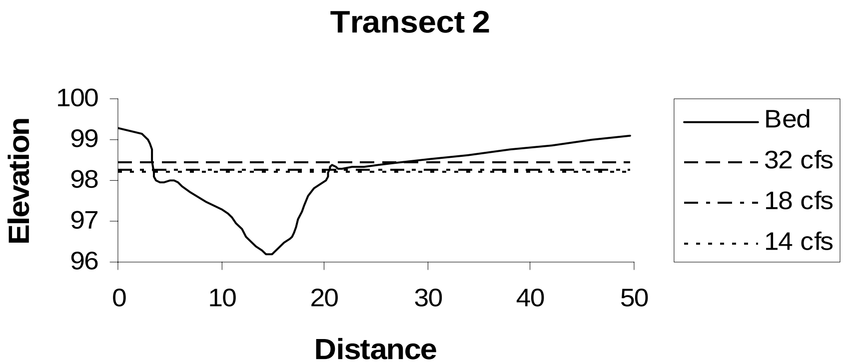


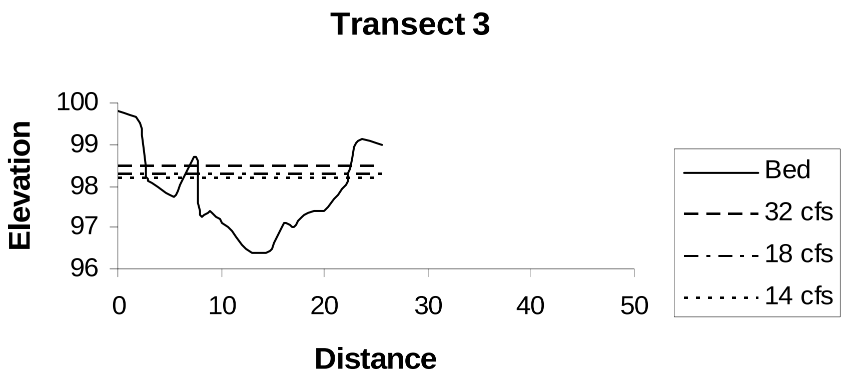
Reynolds Creek

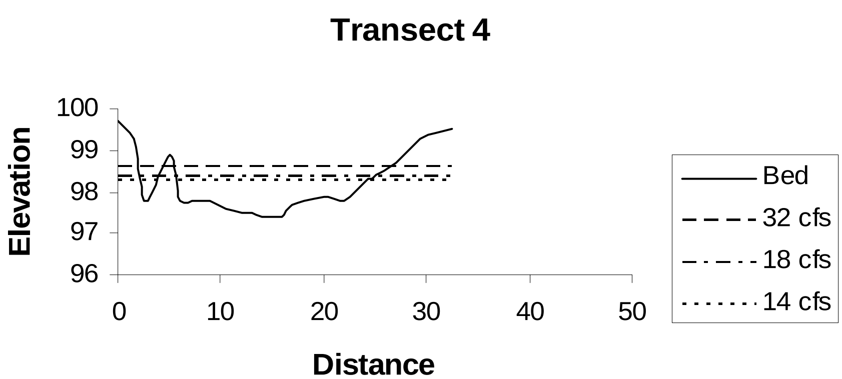
Study Site 1 (44°25.042’N; 118°32.507’W)

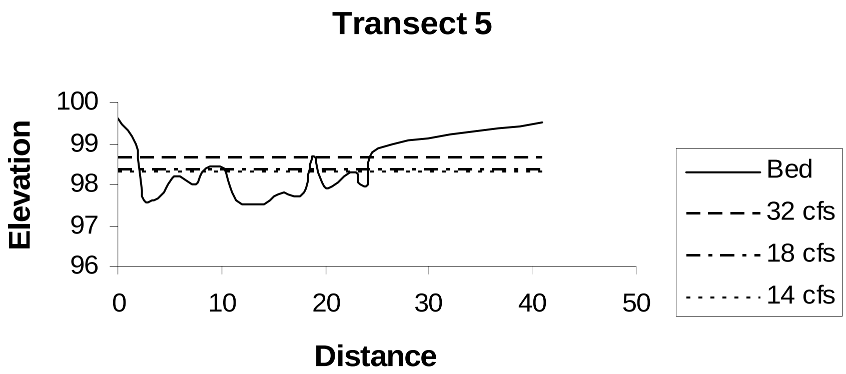
Transect 1 – hydraulic control (most downstream transect)
Transect 2 – pool
Transect 3 – pool
Transect 4 – glide
Transect 5 – glide (most upstream transect)




Transect 2
Elevation
100
99
98
97
96
0
10
20
30
40
50
Distance
Bed
32 cfs
18 cfs
14 cfs


Transect 3
Elevation
100
99
98
97
96
0
10
20
30
40
50
Distance
Bed
32 cfs
18 cfs
14 cfs

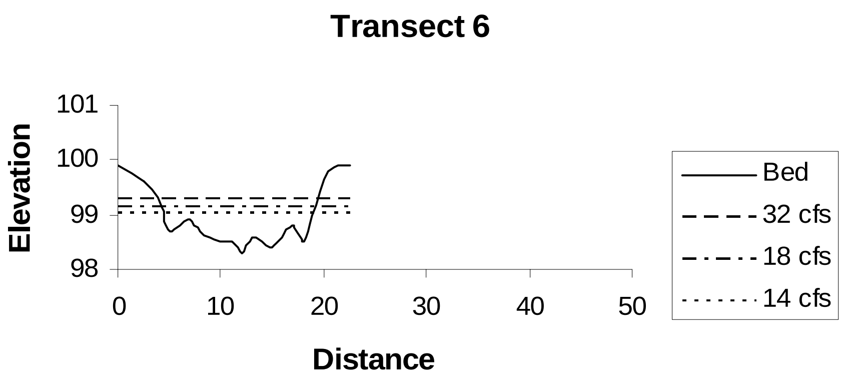

Transect 4
Elevation
100
99
98
97
96
0
10
20
30
40
50
Distance
Bed
32 cfs
18 cfs
14 cfs

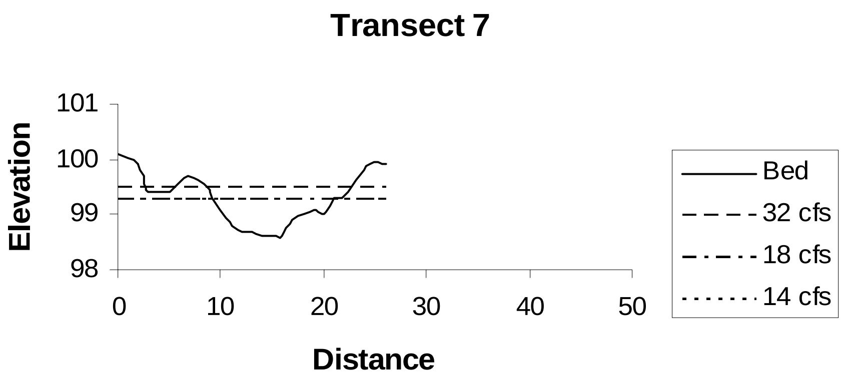


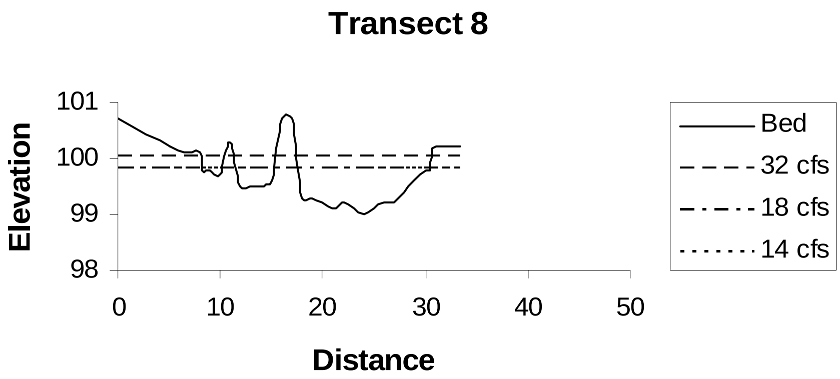
Transect 5
Elevation
100
99
98
97
96
0
10
20
30
40
50
Distance
Bed
32 cfs
18 cfs
14 cfs

Study Site 2 (44°25.018'N; 118°32.480'W)

Transect 6 – glide (most downstream transect)
Transect 7 – glide
Transect 8 – glide (most upstream transect)



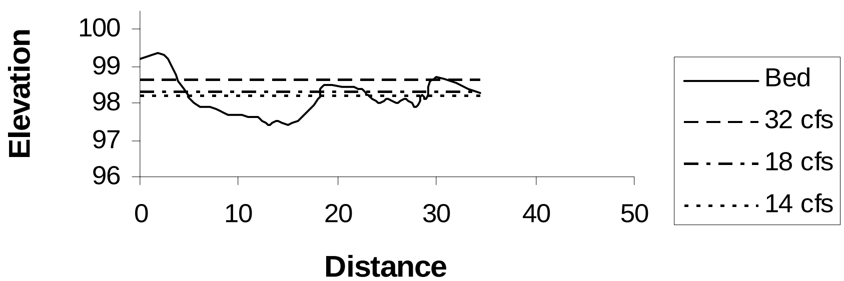




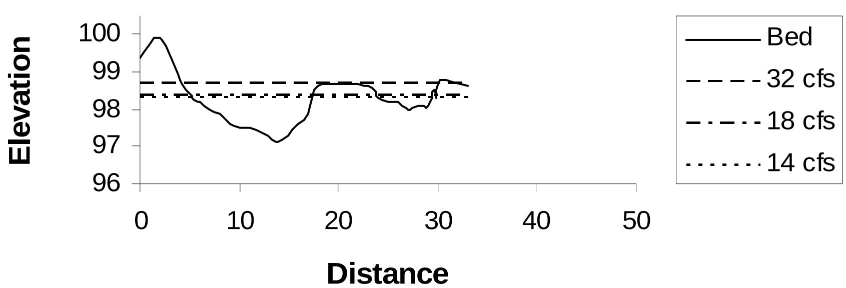
Study Site 3 (44°25.014'N; 118°32.470'W)

Transect 9 – glide (most downstream transect)
Transect 10 – glide-island
Transect 11– glide-island
Transect 12– hydraulic control
Transect 13– pool
Transect 14– pool (most upstream transect)

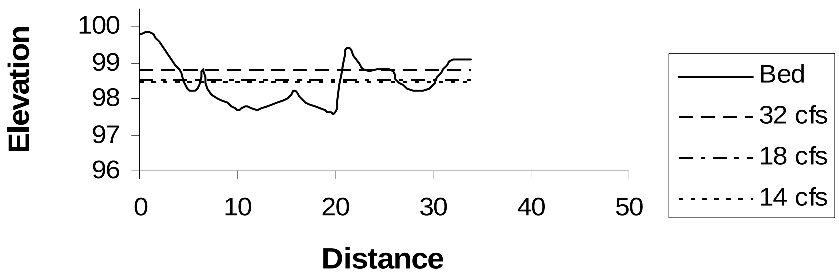
Transect 9



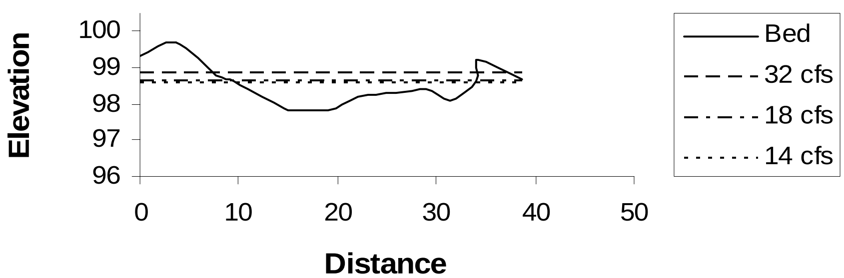
Transect 10



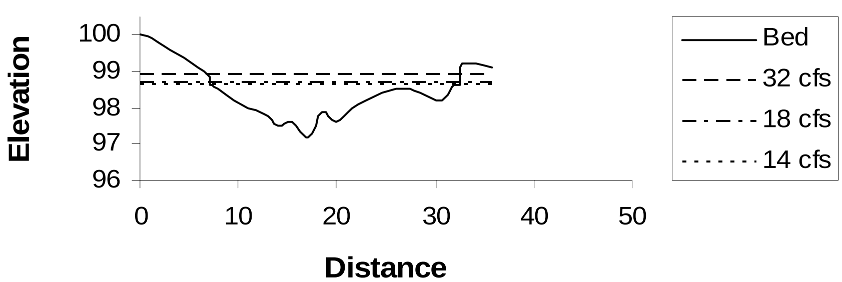
Transect 11

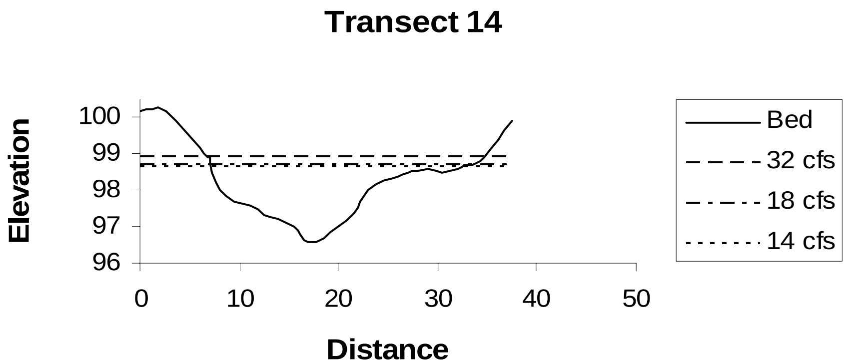


Transect 12



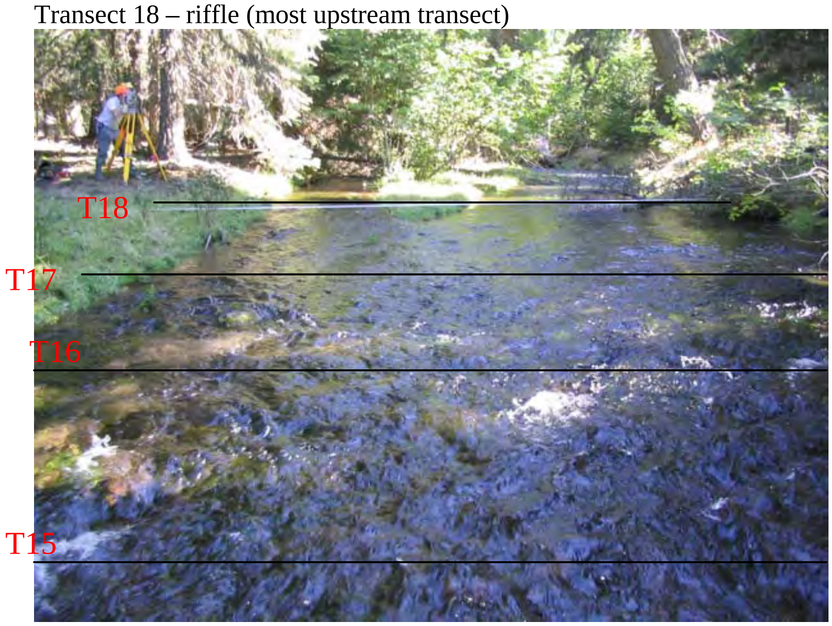
Transect 13

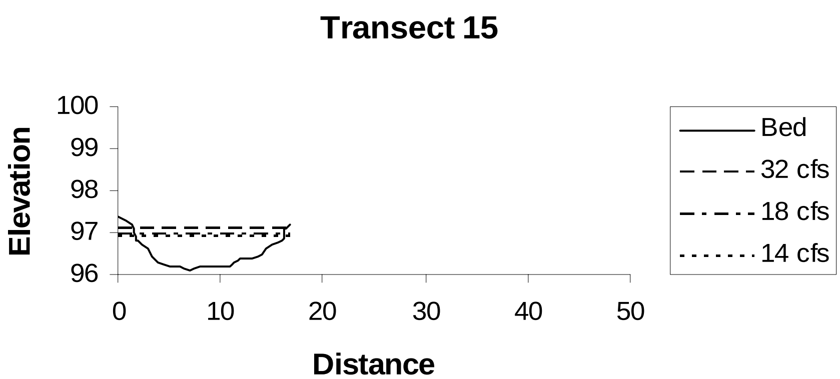


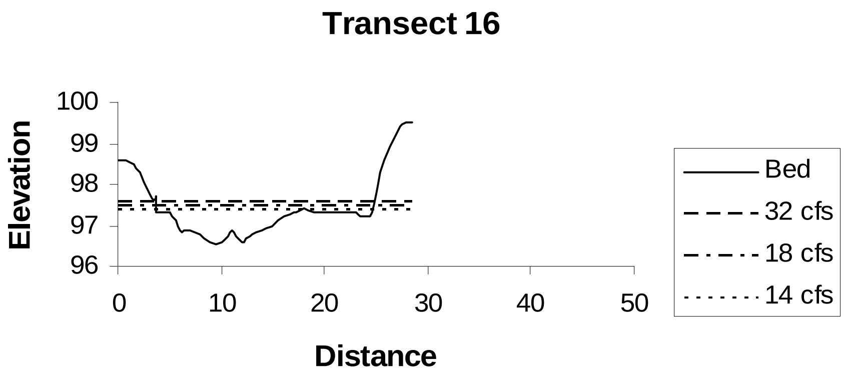


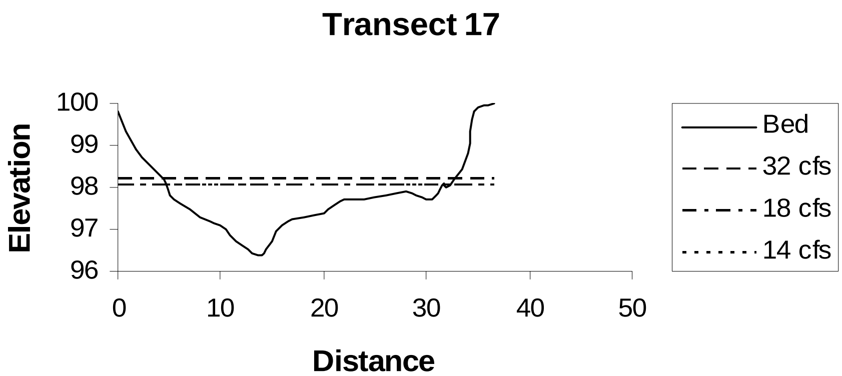
Study Site 4 (44°25.012'N; 118°32.457'W)

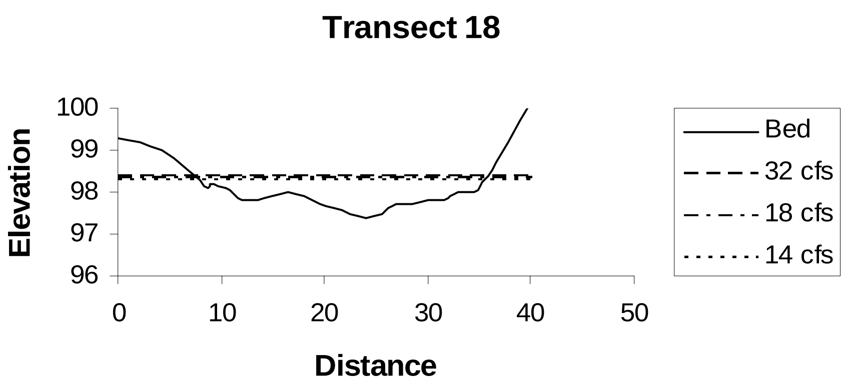
Transect 15 – glide (most downstream transect)
Transect 16 – glide
Transect 17 – riffle
Transect 18 – riffle (most upstream transect)



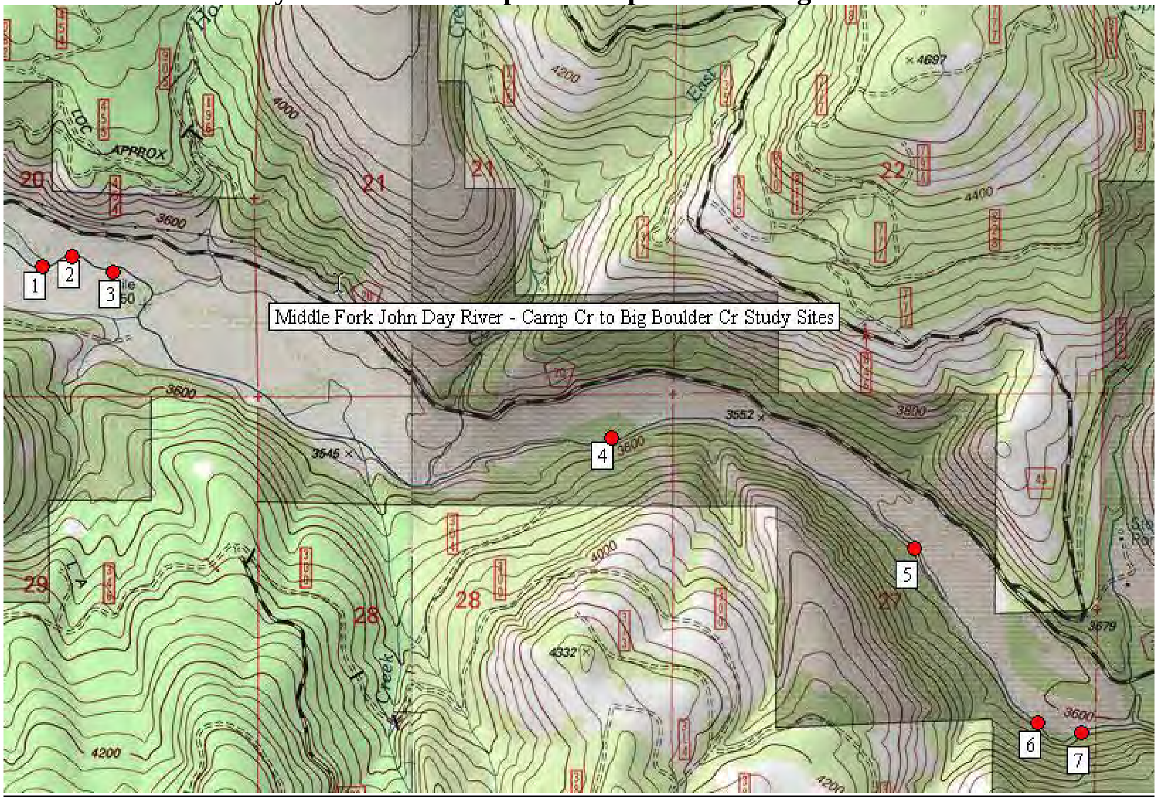



Transect 16
Elevation
Distance
100
99
98
97
96
0
10
20
30
40
50
Bed
32 cfs
18 cfs
14 cfs


Transect 17
Elevation
Distance
100
99
98
97
96
0
10
20
30
40
50
Bed
32 cfs
18 cfs
14 cfs


Transect 18
Elevation
Distance
100
99
98
97
96
0
10
20
30
40
50
Bed
32 cfs
18 cfs
14 cfs

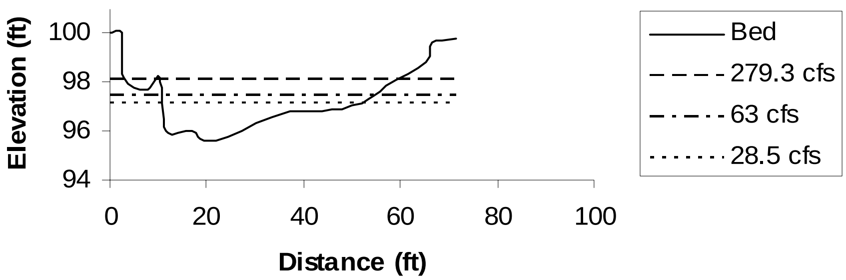
Middle Fork John Day River from Camp Creek upstream to Big Boulder Creek



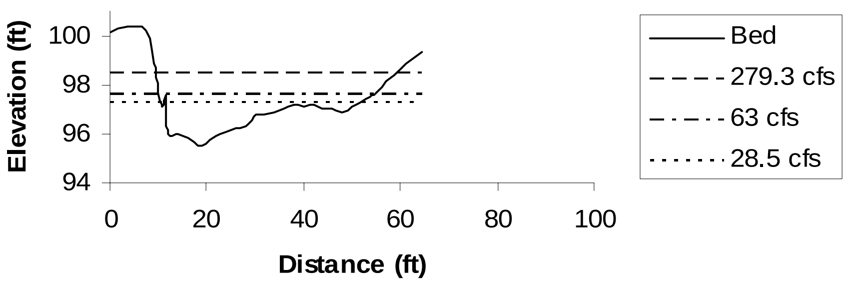
Study Site 1 – Most downstream study site (44°40.945'N; 118°46.064'W)

Transect 1 – hydraulic control (most downstream transect)
Transect 2 – pool
Transect 3 – pool
Transect 4 – pool (most upstream transect)

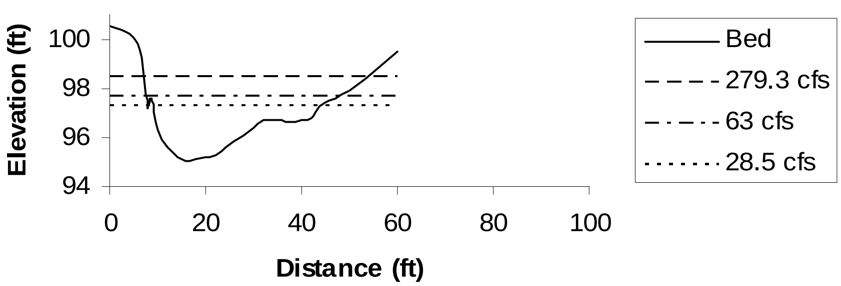
Transect 1



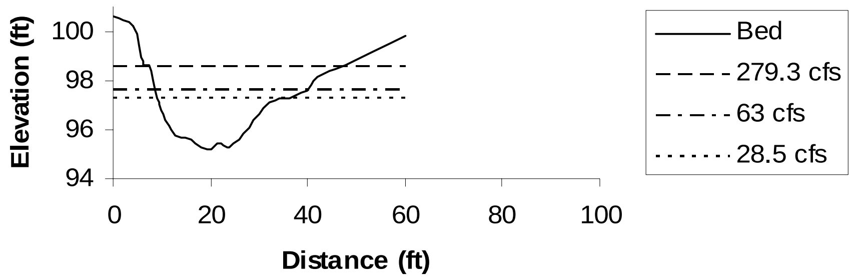
Transect 2



Transect 3



Transect 4

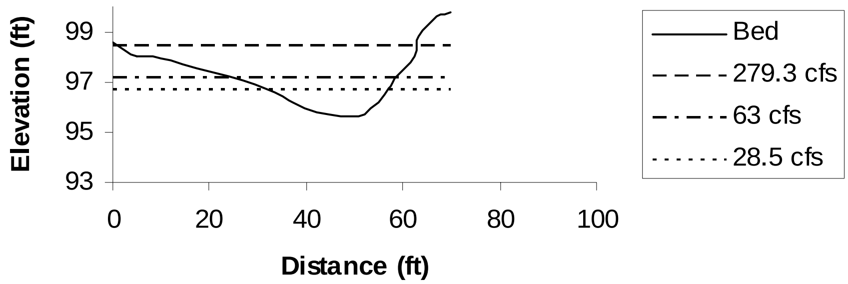


<u>Study Site 2 (44°40.905’N; 118°45.983’W)</u>

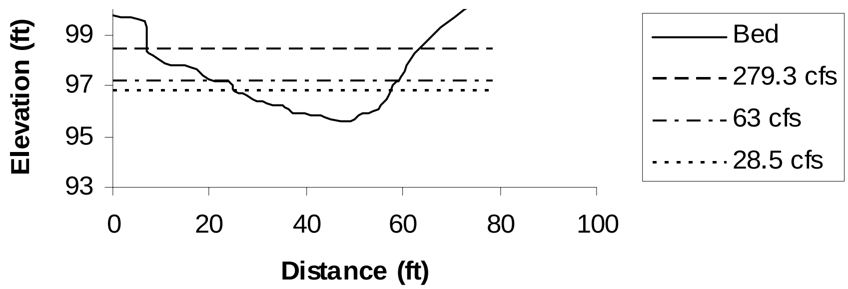
Transect 5 – hydraulic control (most downstream transect)
Transect 6 – pool
Transect 7 – pool
Transect 8 – pool (most upstream transect)

.

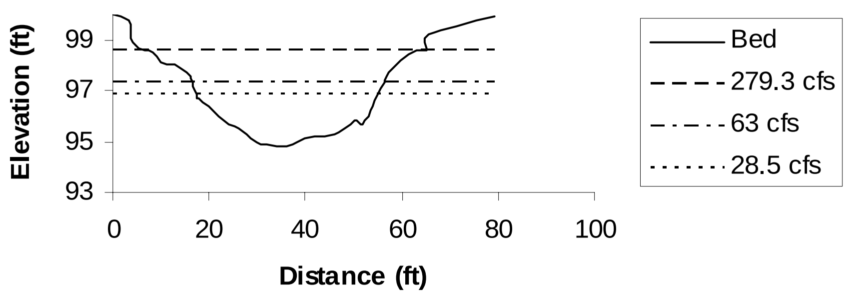
Transect 5



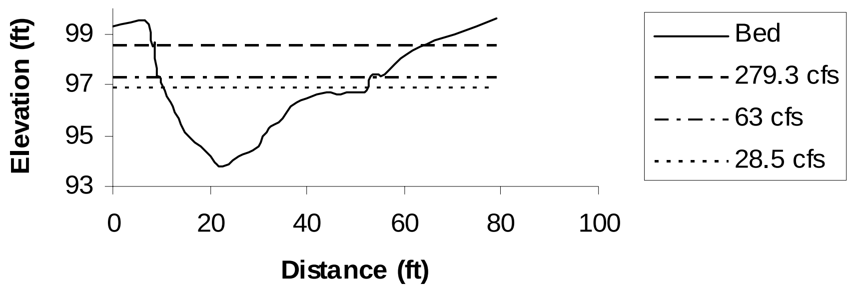
Transect 6



Transect 7



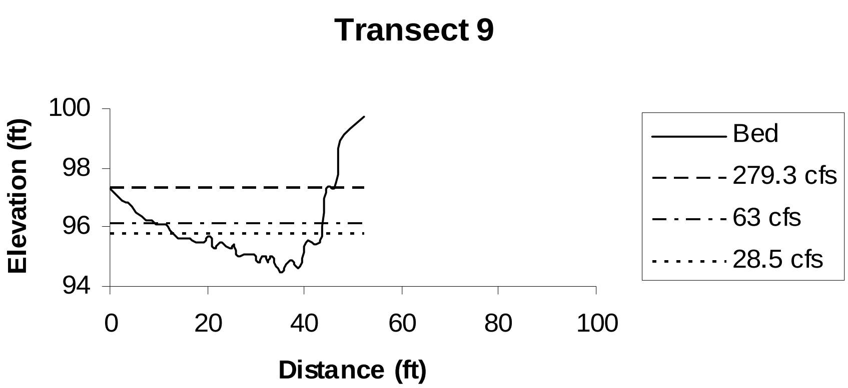
Transect 8



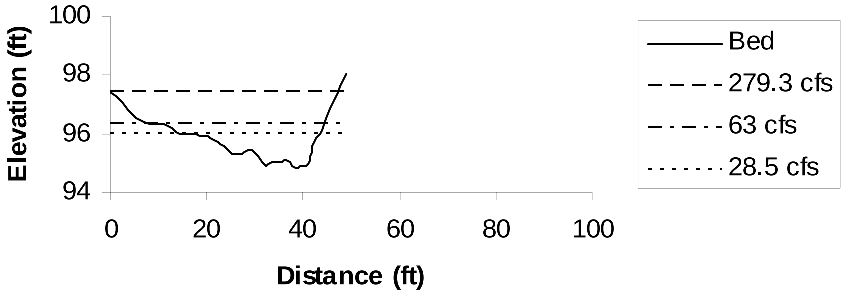
Elevation (ft)
99
97
95
93
0
20
40
60
80
100
Distance (ft)
Bed
279.3 cfs
63 cfs
28.5 cfs

Study Site 3 (44°40.898'N; 118°45.863'W)

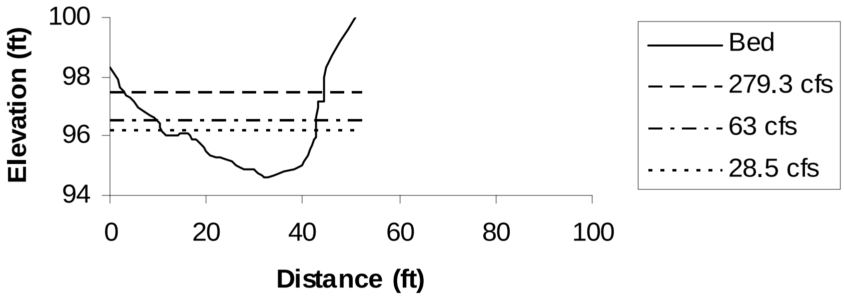
Transect 9 – riffle (most downstream transect)
Transect 10 – riffle
Transect 11 – glide
Transect 12 – glide (most upstream transect)



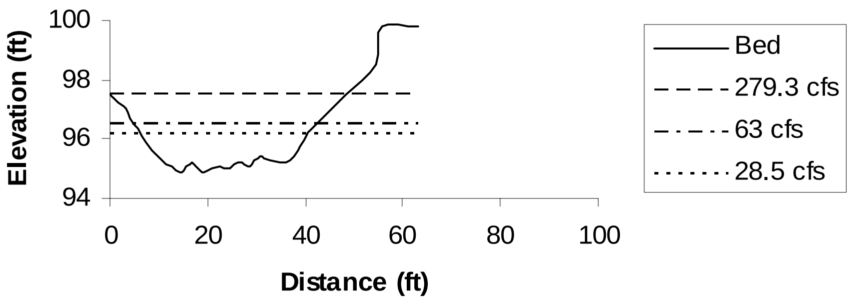
Transect 10



Transect 11

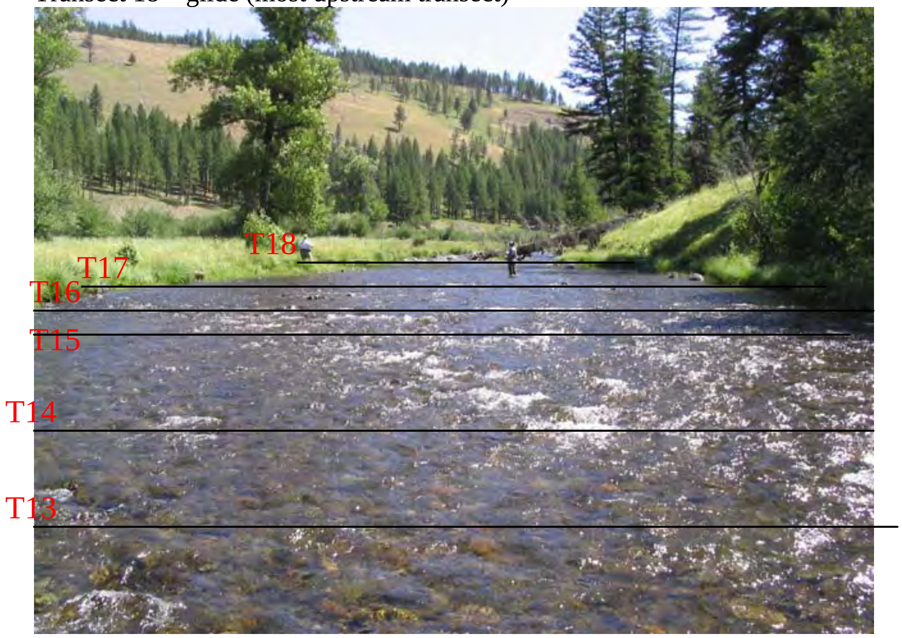


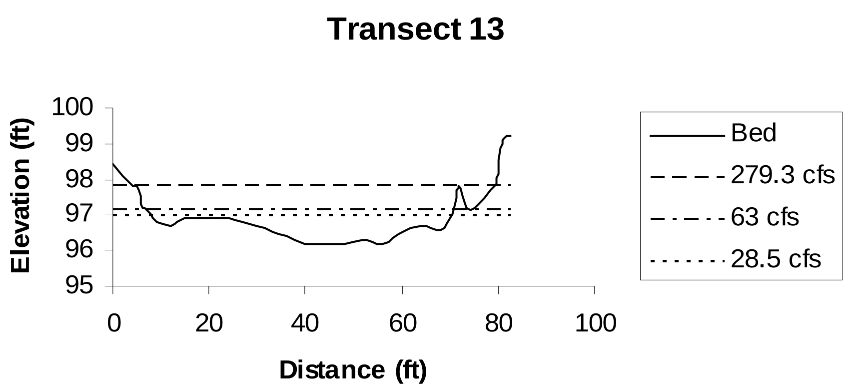
Transect 12

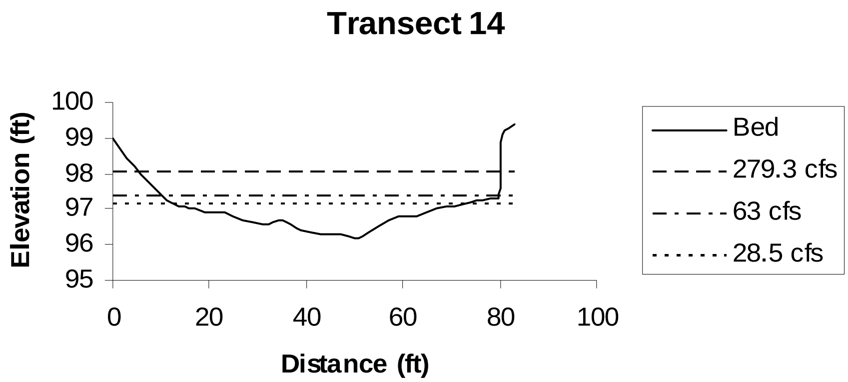


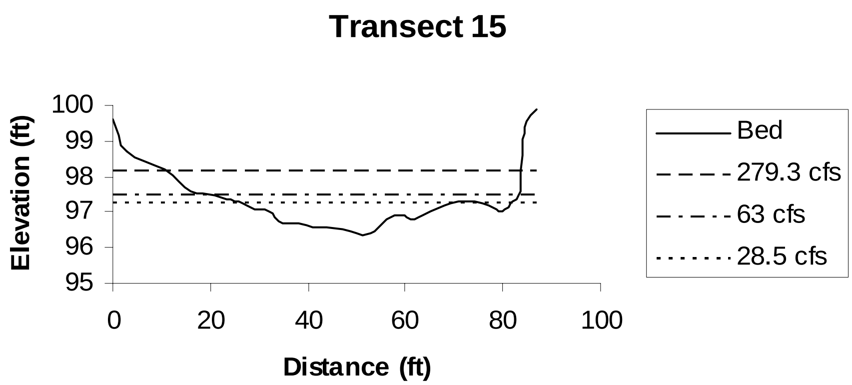
Study Site 4 (44°40.589'N; 118°44.421'W)

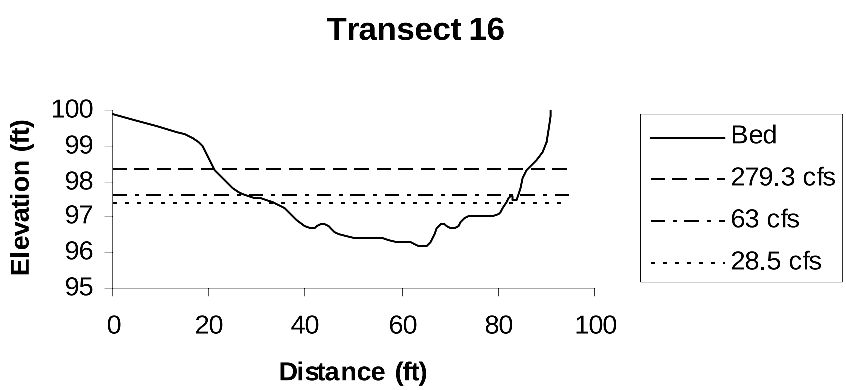
Transect 13 – riffle (most downstream transect)
Transect 14 – riffle
Transect 15 – riffle
Transect 16 – glide
Transect 17 – glide
Transect 18 – glide (most upstream transect)



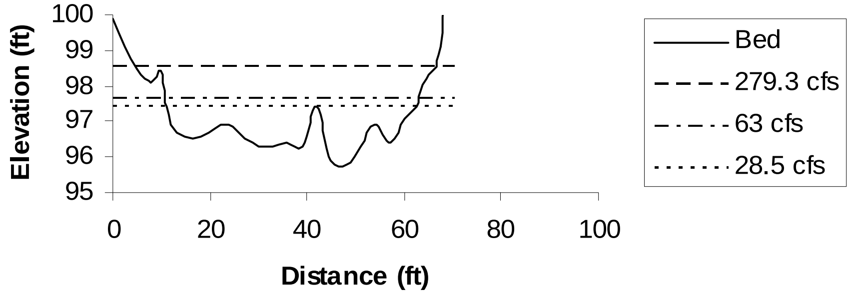



Transect 14
100
99
98
97
96
95
Elevation (ft)
0
20
40
60
80
100
Distance (ft)
Bed
279.3 cfs
63 cfs
28.5 cfs

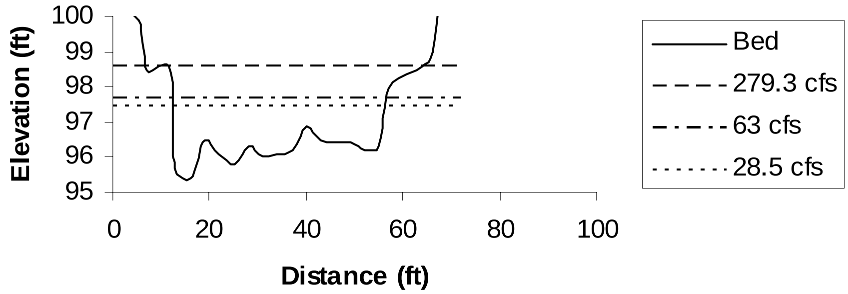

Transect 15
100
99
98
97
96
95
Elevation (ft)
0
20
40
60
80
100
Distance (ft)
Bed
279.3 cfs
63 cfs
28.5 cfs


Transect 16
100
99
98
97
96
95
Elevation (ft)
0
20
40
60
80
100
Distance (ft)
Bed
279.3 cfs
63 cfs
28.5 cfs

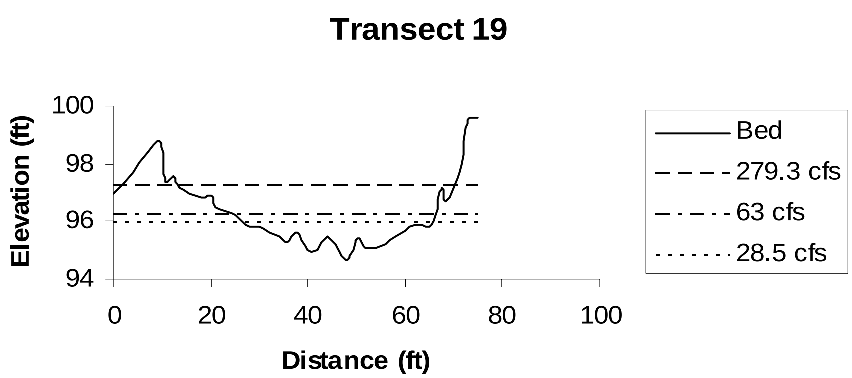
Transect 17

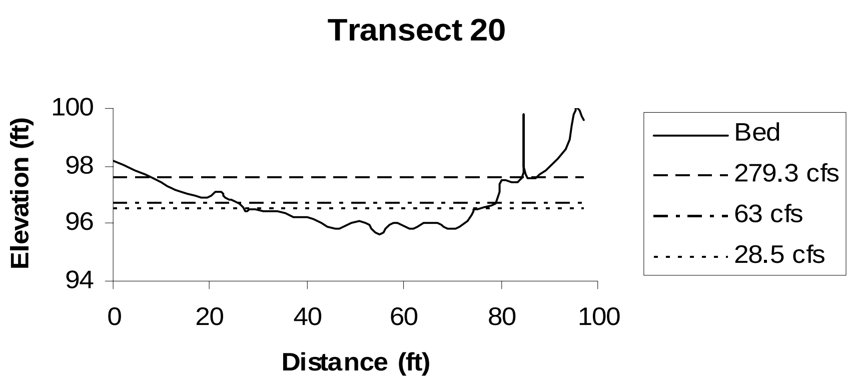


Transect 18

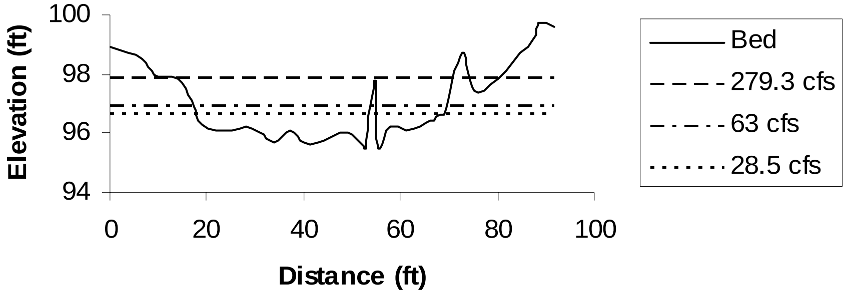


<u>Study Site 5 (44°40.306’N; 118°43.573’W)</u>
Transect 19 – riffle (most downstream transect)
Transect 20 – riffle
Transect 21 – glide
Transect 22 – glide
Transect 23 – glide (most upstream transect)

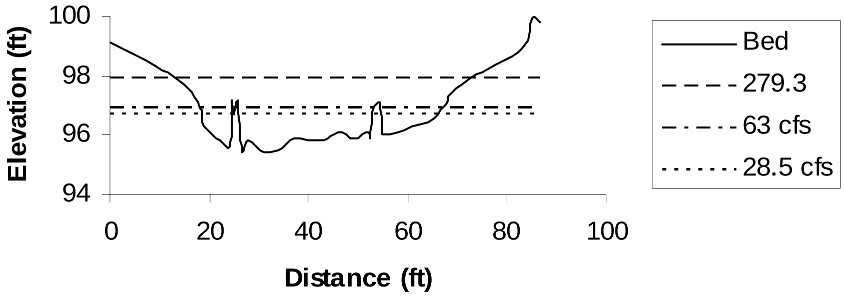




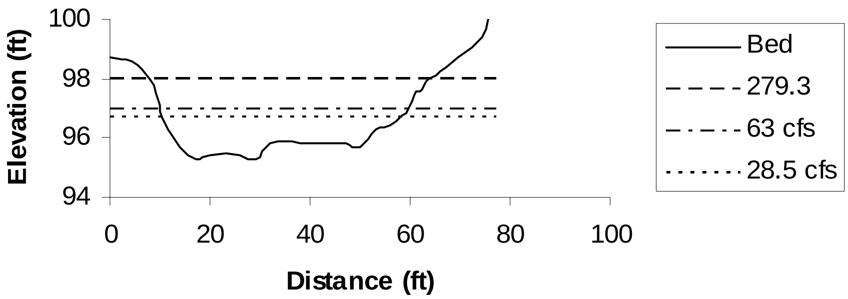
Transect 21



Transect 22

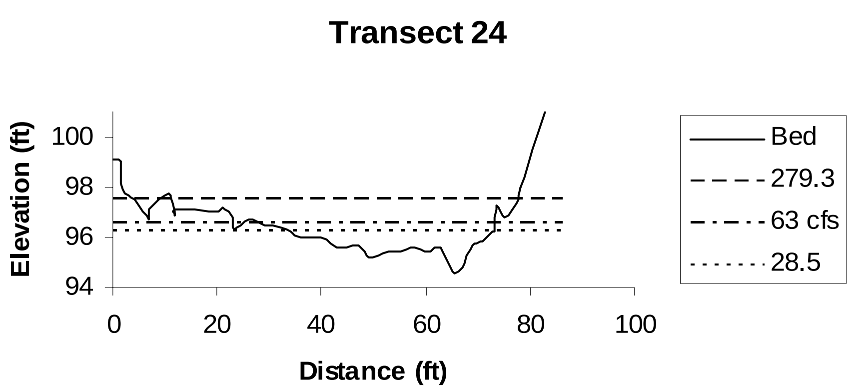


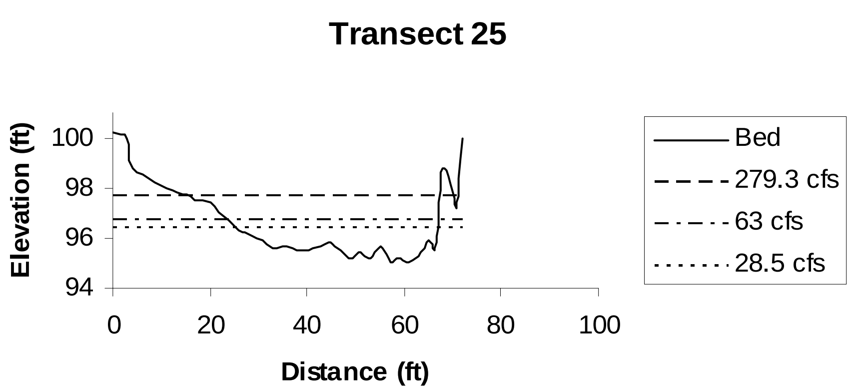
Transect 23



Study Site 6 (44°39.944'N; 118°43.199'W)

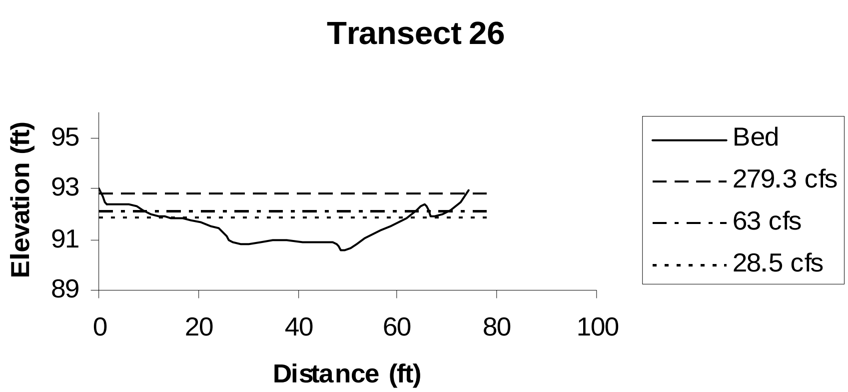
Transect 24 – glide (most downstream transect)
Transect 25 – glide (most upstream transect)



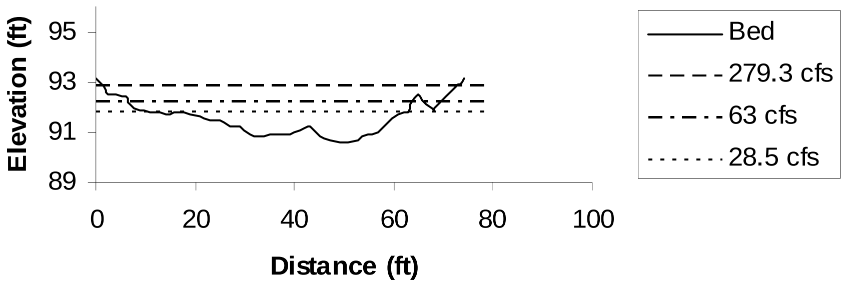


Study Site 7 (44°39.947'N; 118°43.065'W)

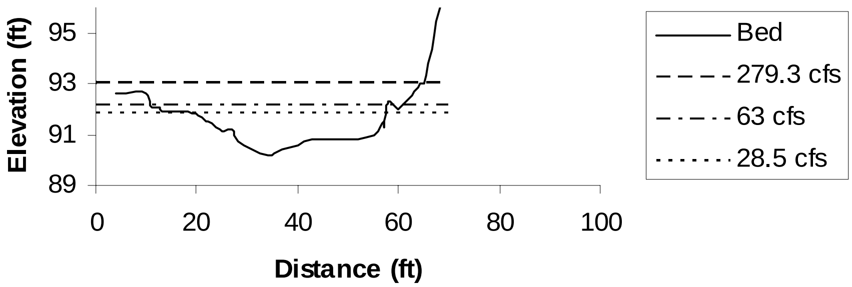
Transect 26 – hydraulic control (most downstream transect)
Transect 27 – pool
Transect 28 – pool
Transect 29 - pool (most upstream transect)



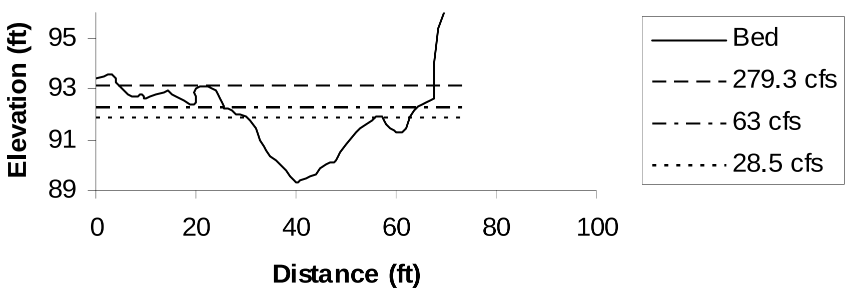
Transect 27



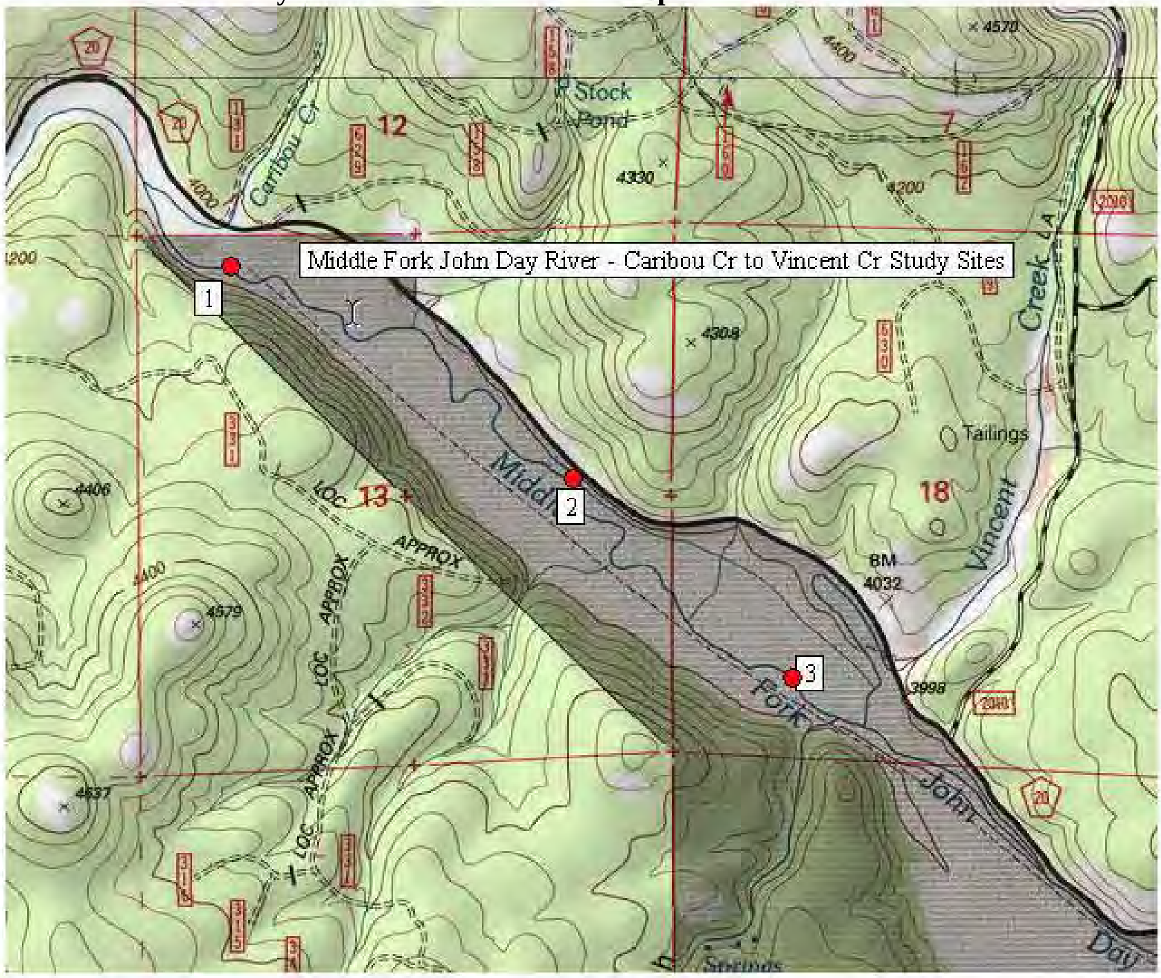
Transect 28



Transect 29



Middle Fork John Day River from Caribou Creek upstream to Vincent Creek

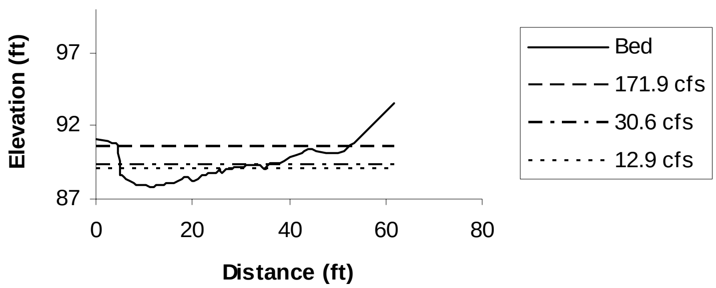


Study Site 1 (44°37.178'N; 118°34.129'W)

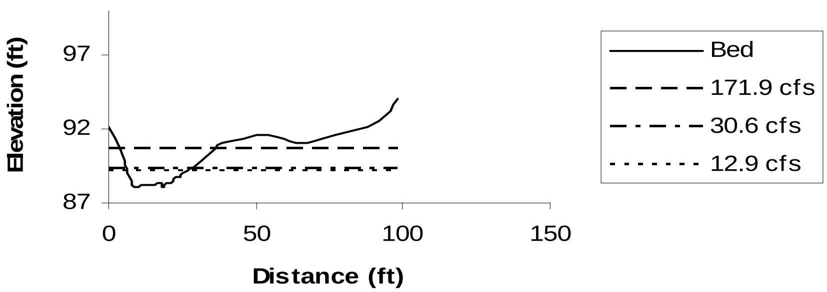
Lower transects-

Transect 1 – glide (most downstream transect)
Transect 2 – glide
Transect 3 – glide
Transect 4 – riffle
Transect 5 – riffle
Transect 6 – riffle

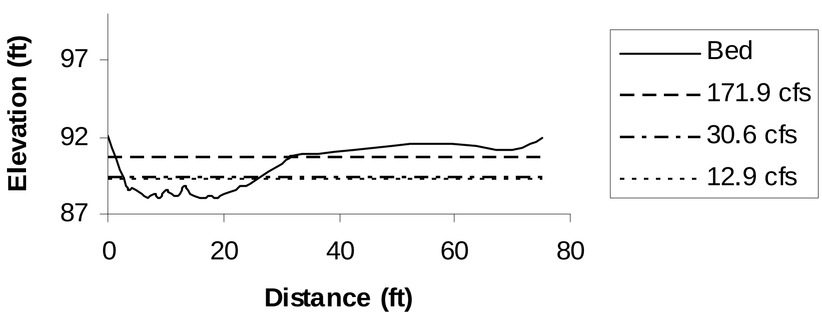
Transect 1

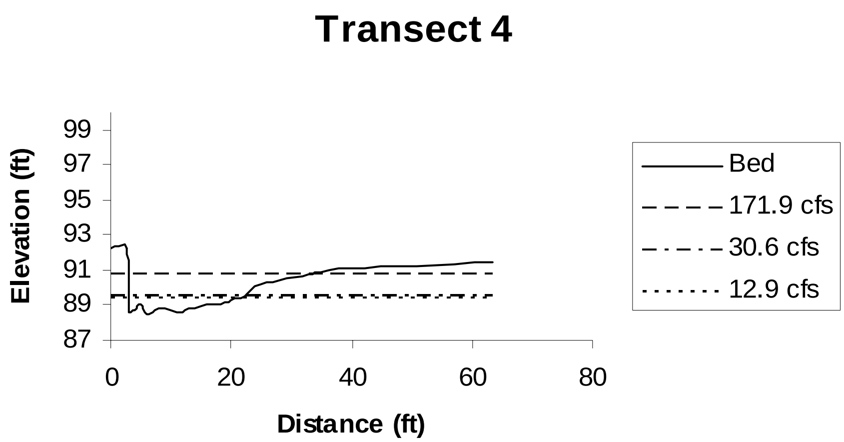


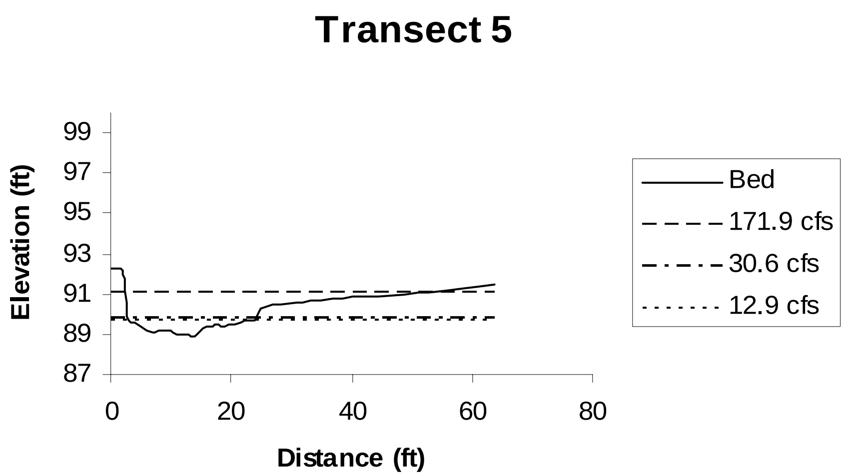
Transect 2

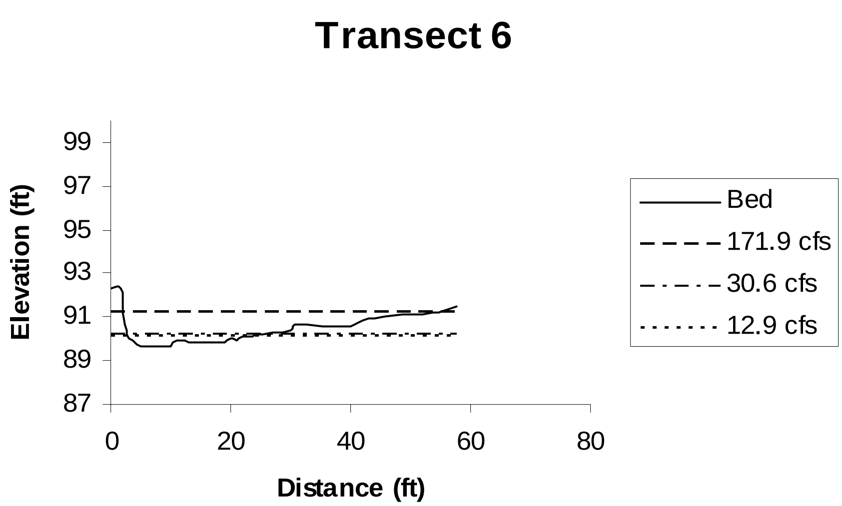


Transect 3



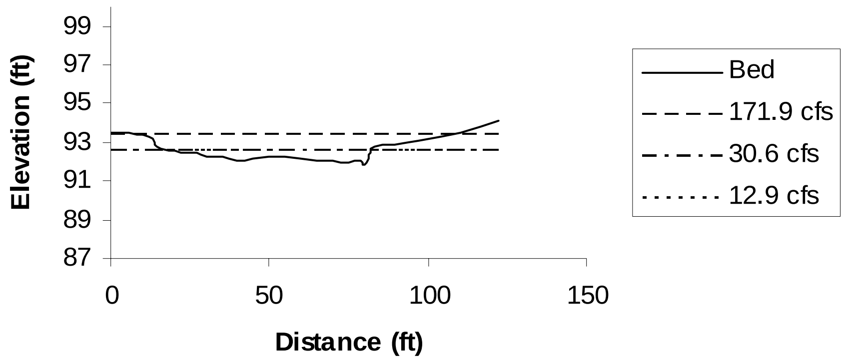

Transect 4
99
97
95
93
91
89
87
Elevation (ft)
0
20
40
60
80
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs


Transect 5
99
97
95
93
91
89
87
Elevation (ft)
0
20
40
60
80
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

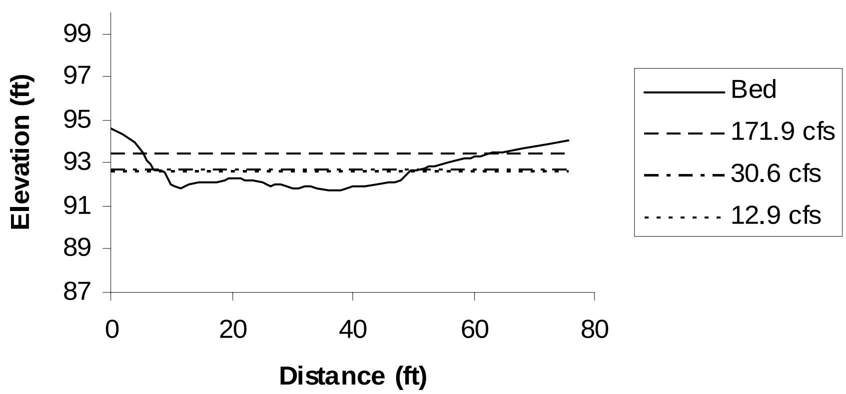

Transect 6
99
97
95
93
91
89
87
Elevation (ft)
0
20
40
60
80
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

Upper transects-
Transect 7 – hydraulic control/passage
Transect 8 – pool
Transect 9 – pool
Transect 10 – pool
Transect 11 – pool (most upstream transect)

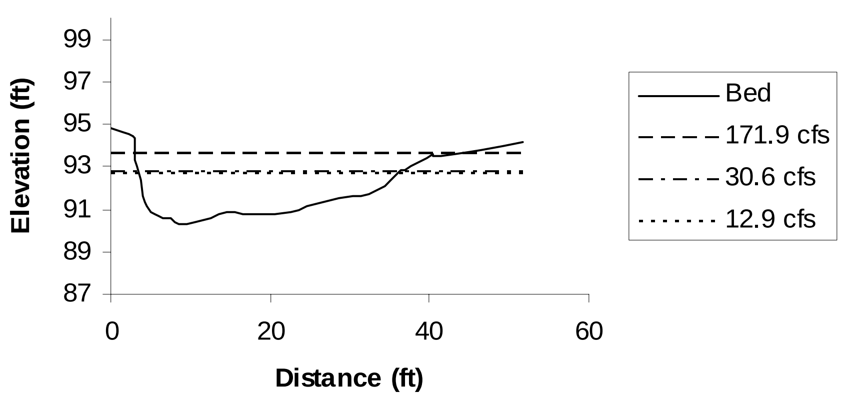
Transect 7

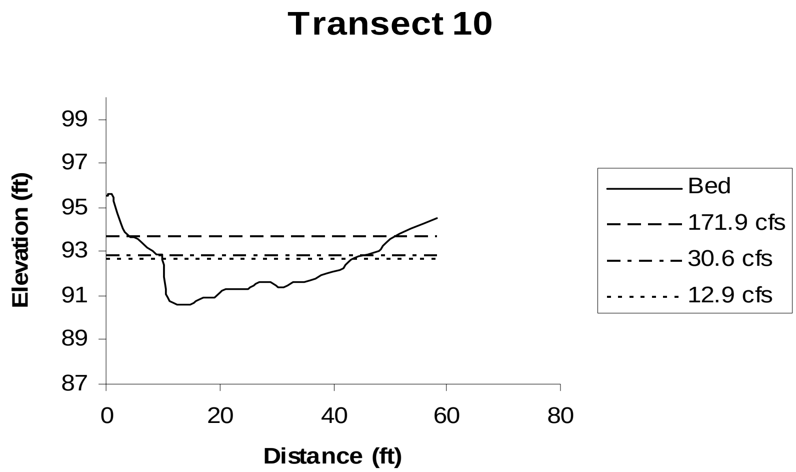


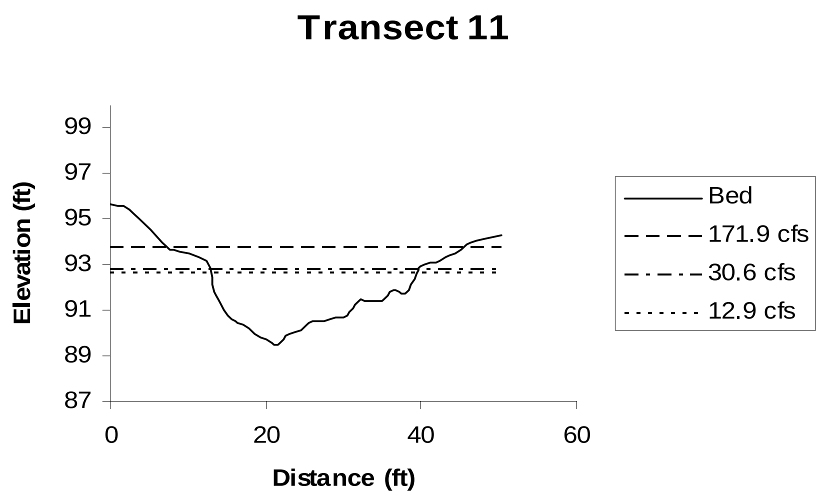
Transect 8



Transect 9



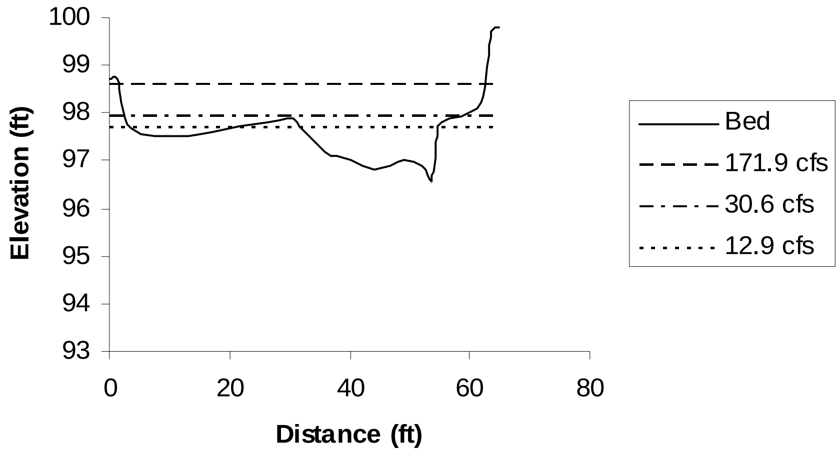

Transect 10
Elevation (ft)
99
97
95
93
91
89
87
0
20
40
60
80
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs


Transect 11
Elevation (ft)
99
97
95
93
91
89
87
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

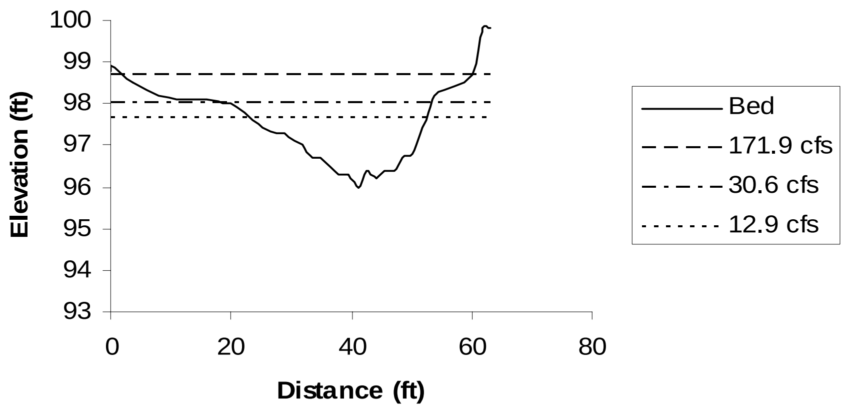
Study Site 2 (44°36.798’N; 118°33.405’W)

Transect 12 – hydraulic control (most downstream transect)
Transect 13 – pool
Transect 14 – pool
Transect 15 – pool
Transect 16 – glide
Transect 17 – glide/hydraulic control
Transect 18 – pool
Transect 19 – pool
Transect 20 – riffle
Transect 21 – riffle
Transect 22 – riffle (most upstream transect)

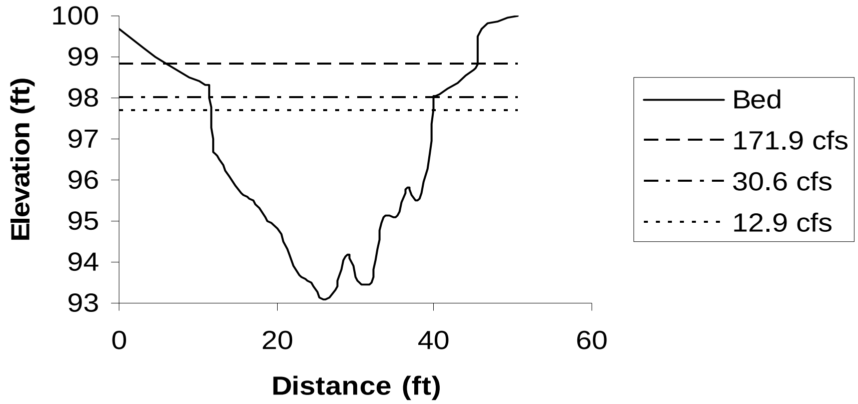
Transect 12



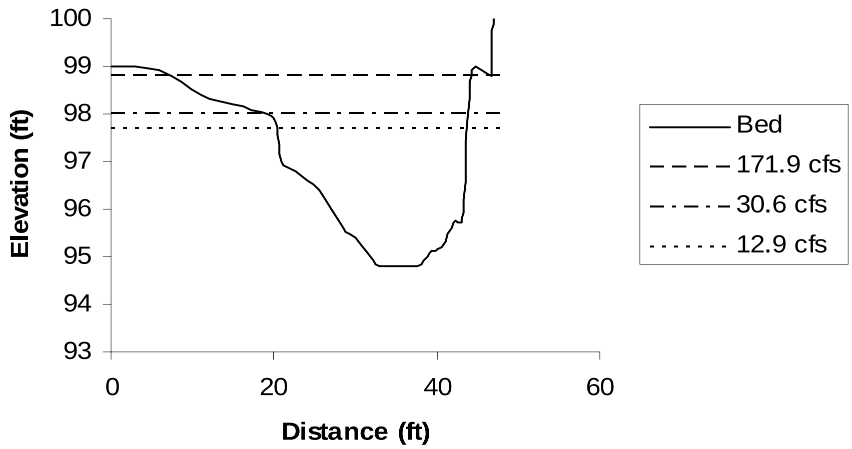
Transect 13



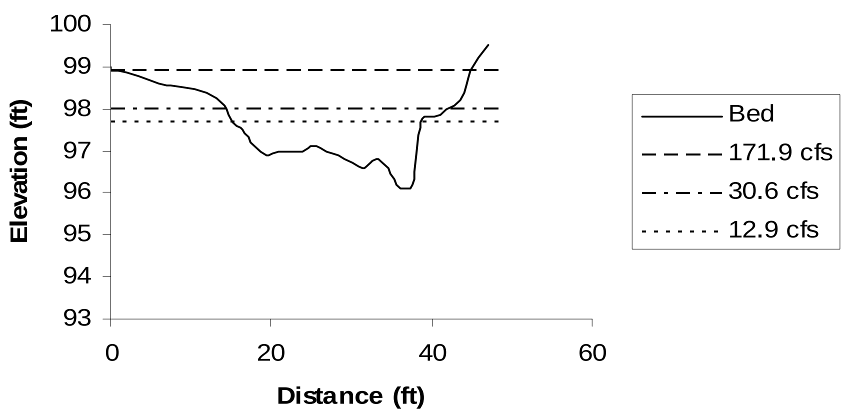
Transect 14

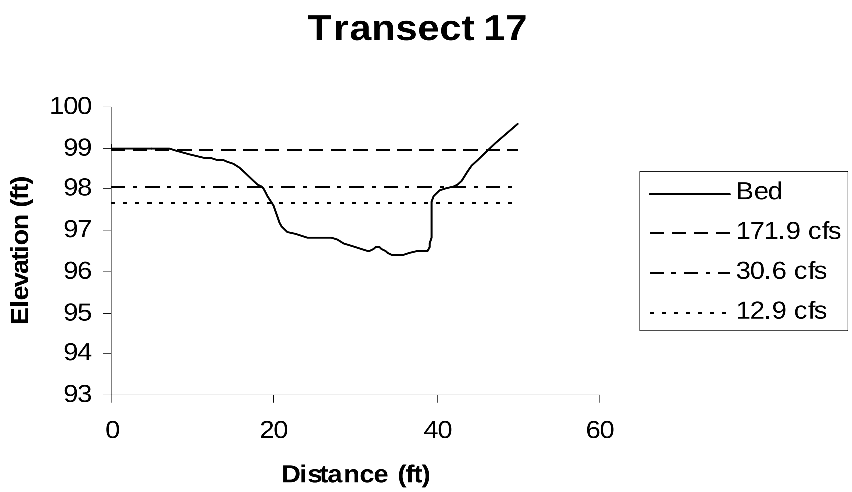


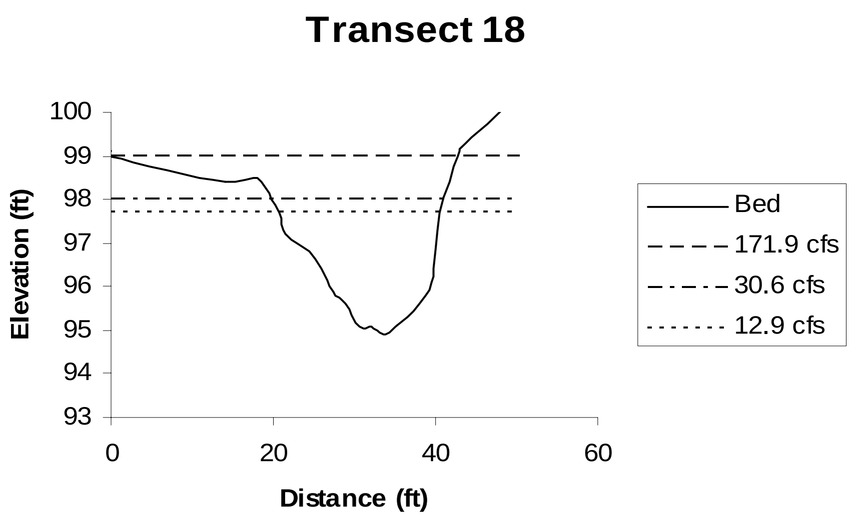
Transect 15

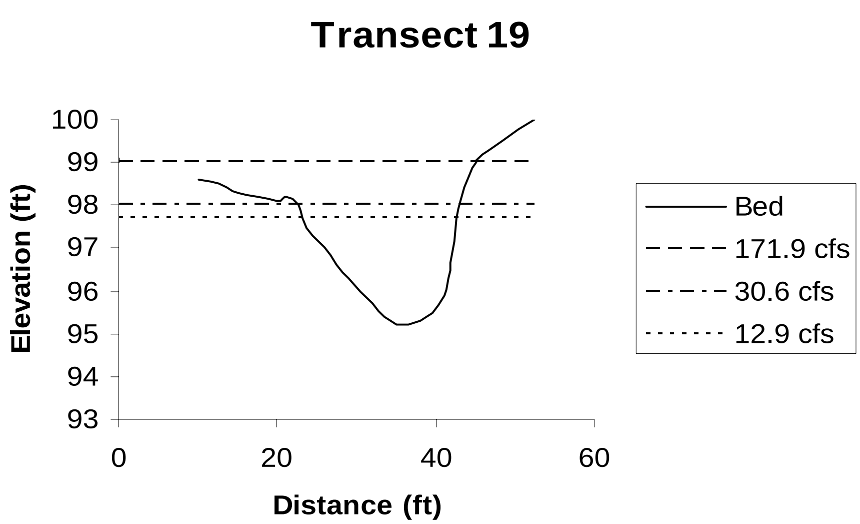


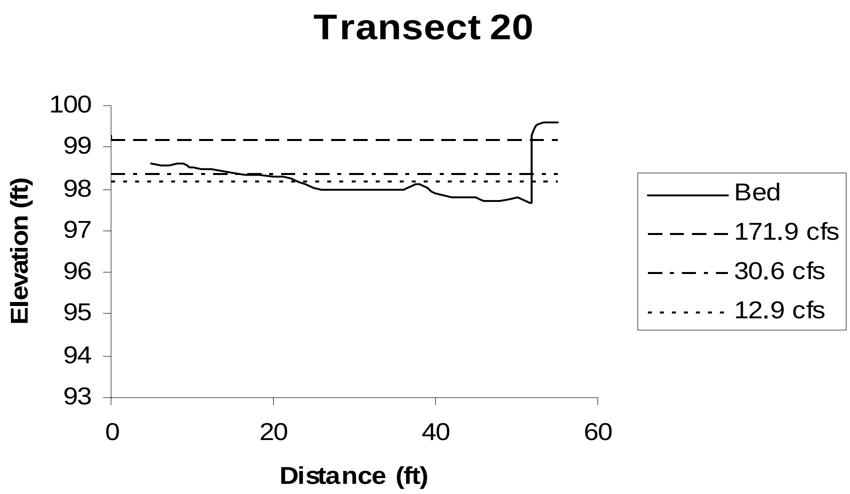
Transect 16

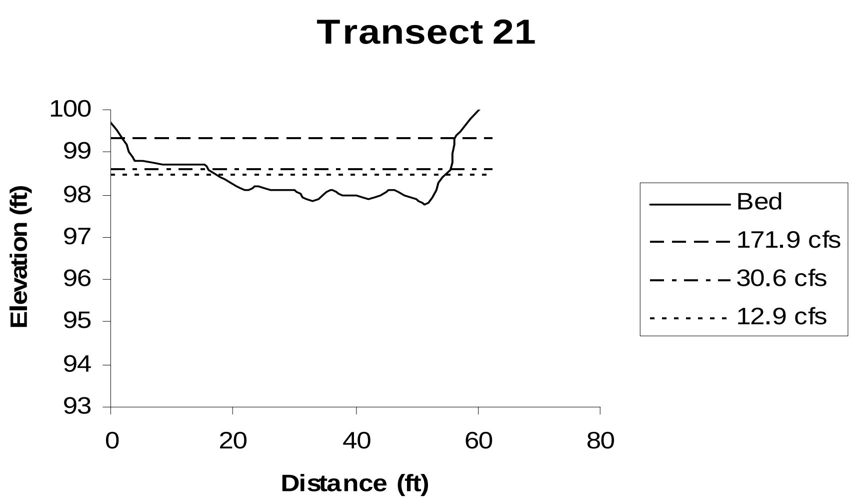


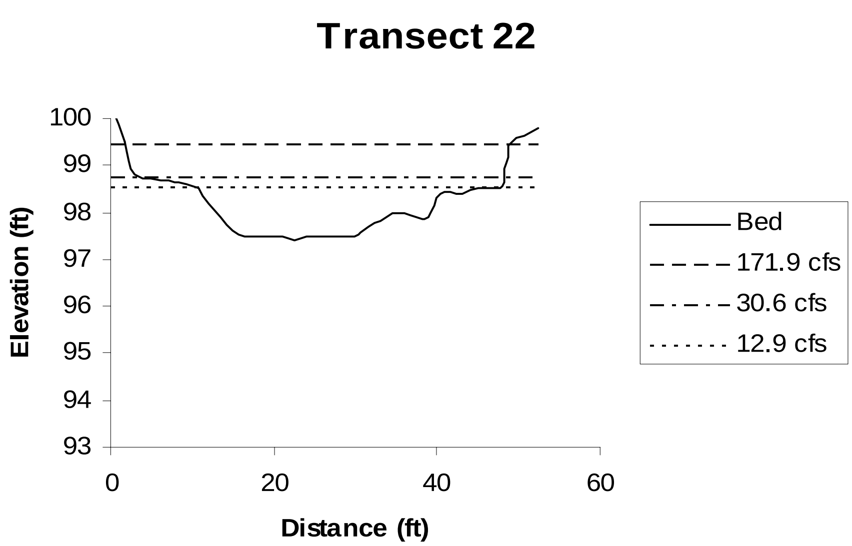

Transect 17
100
99
98
97
96
95
94
93
Elevation (ft)
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs


Transect 18
100
99
98
97
96
95
94
93
Elevation (ft)
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs


Transect 19
100
99
98
97
96
95
94
93
Elevation (ft)
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

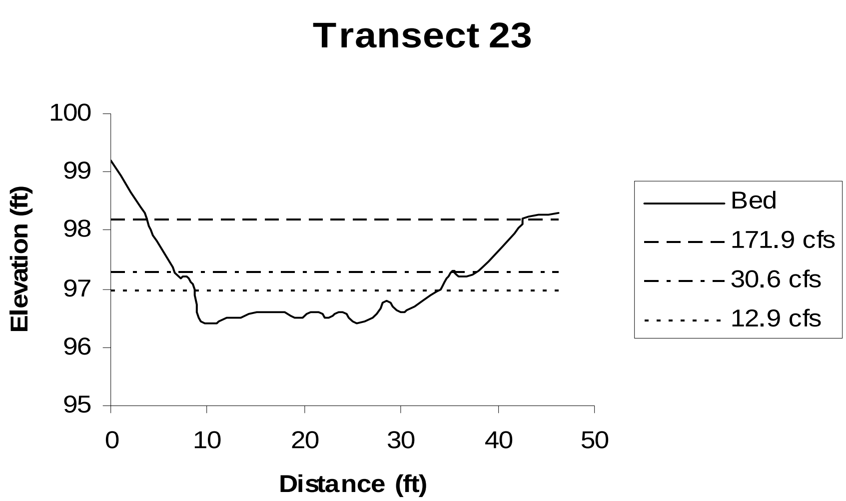

Transect 20
Elevation (ft)
100
99
98
97
96
95
94
93
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

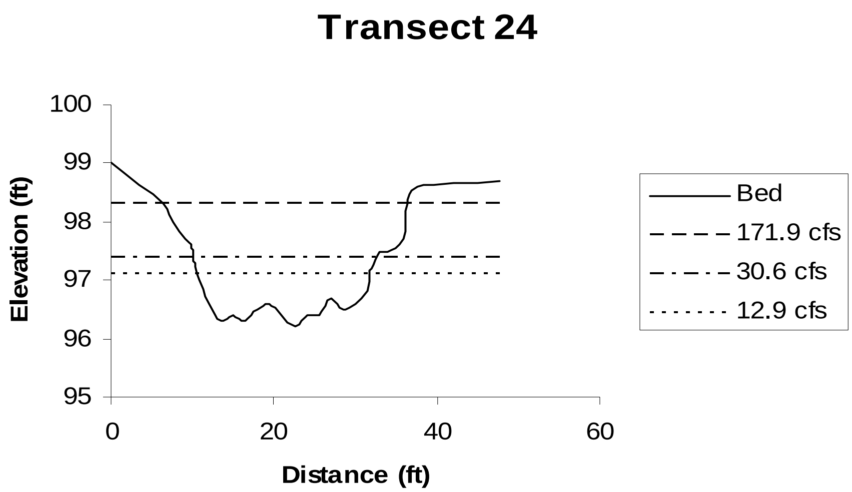

Transect 21
Elevation (ft)
100
99
98
97
96
95
94
93
0
20
40
60
80
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

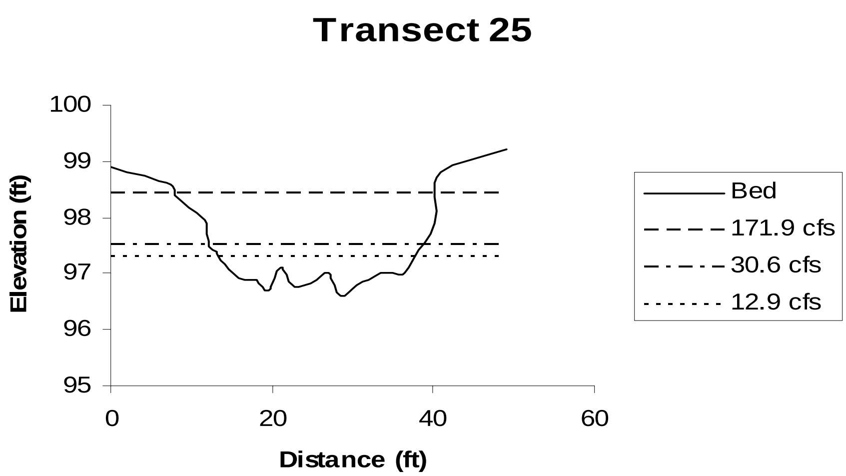

Transect 22
Elevation (ft)
100
99
98
97
96
95
94
93
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

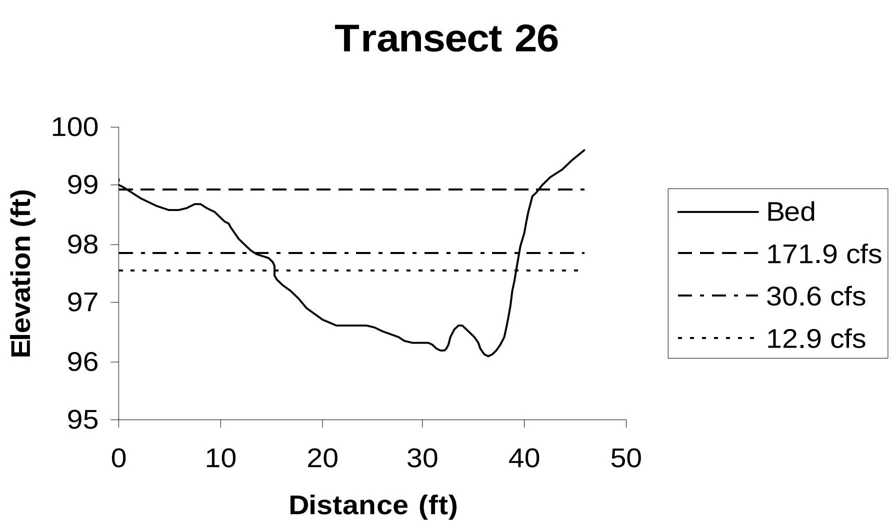
Study Site 3 (44°36.488'N; 118°32.913'W)

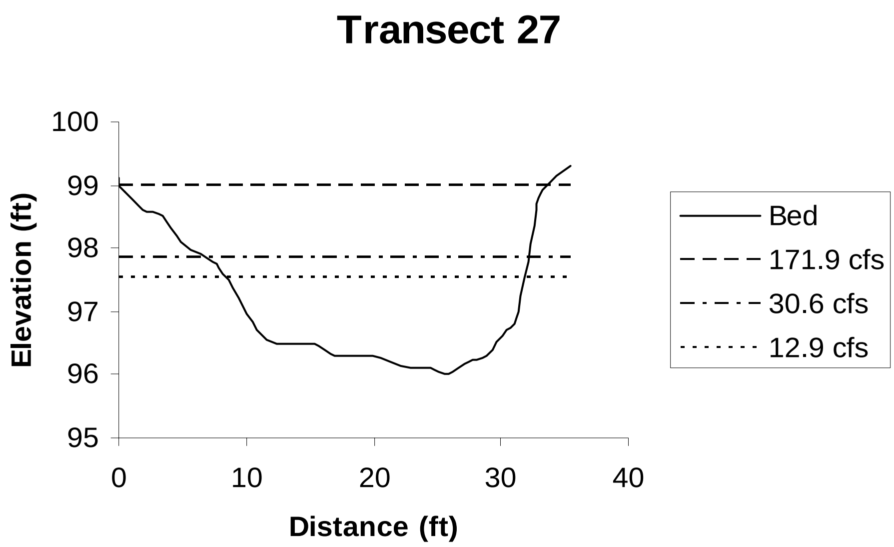
Transect 23 – riffle (most downstream transect)
Transect 24 – riffle
Transect 25 – riffle
Transect 26 – glide
Transect 27 – glide (most upstream transect)




Transect 24
100
99
98
97
96
95
Elevation (ft)
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

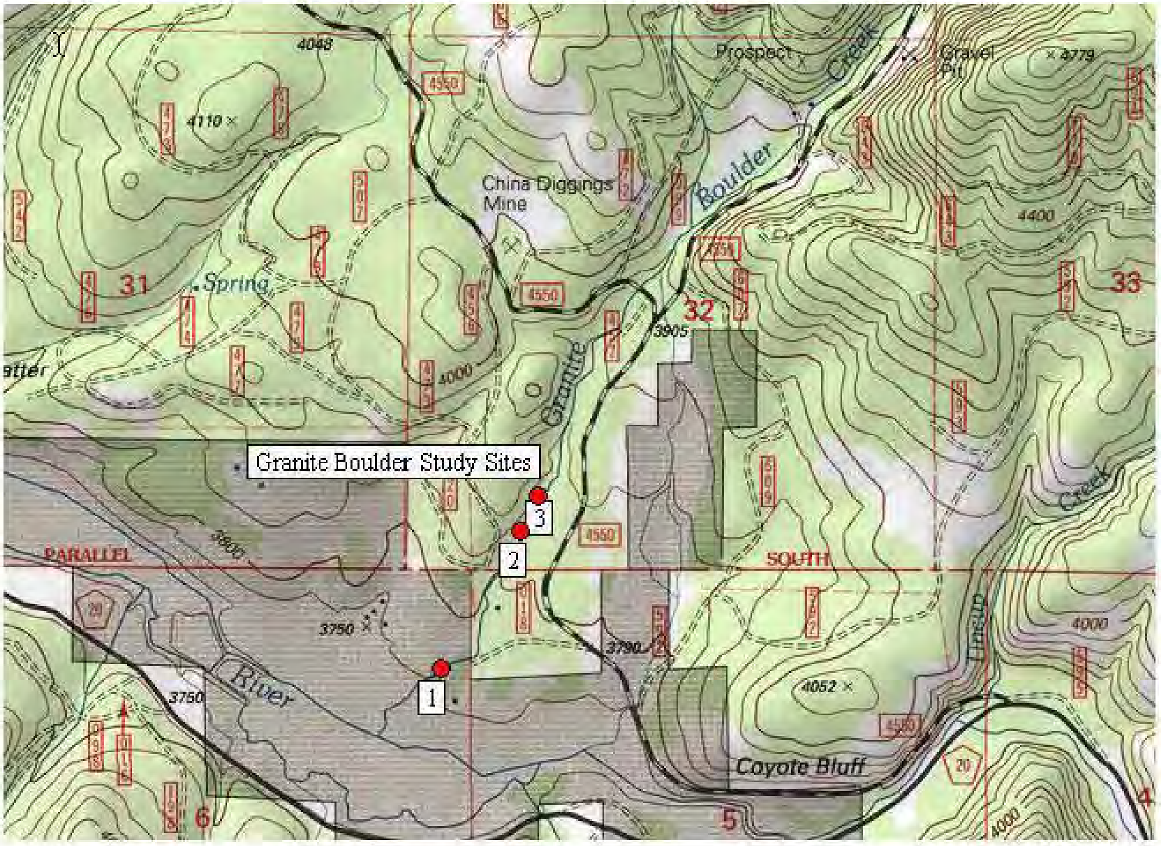

Transect 25
100
99
98
97
96
95
Elevation (ft)
0
20
40
60
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs


Transect 26
100
99
98
97
96
95
Elevation (ft)
0
10
20
30
40
50
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs



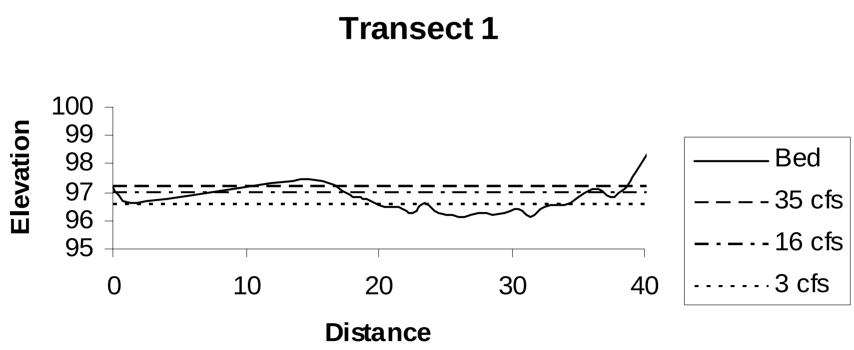
Transect 27
100
99
98
97
96
95
0
10
20
30
40
Elevation (ft)
Distance (ft)
Bed
171.9 cfs
30.6 cfs
12.9 cfs

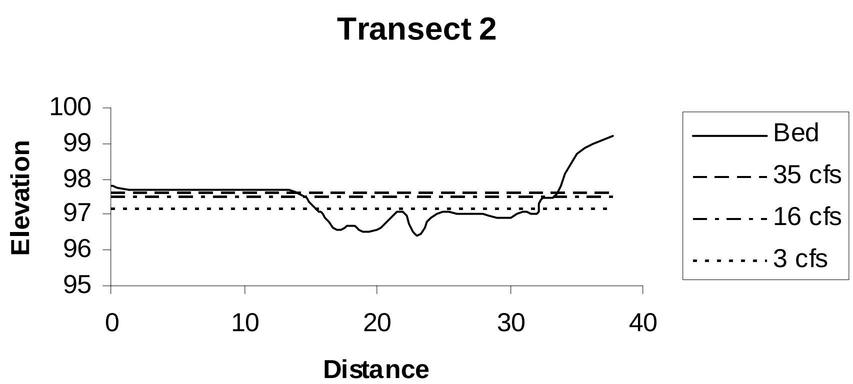
Granite Boulder Creek

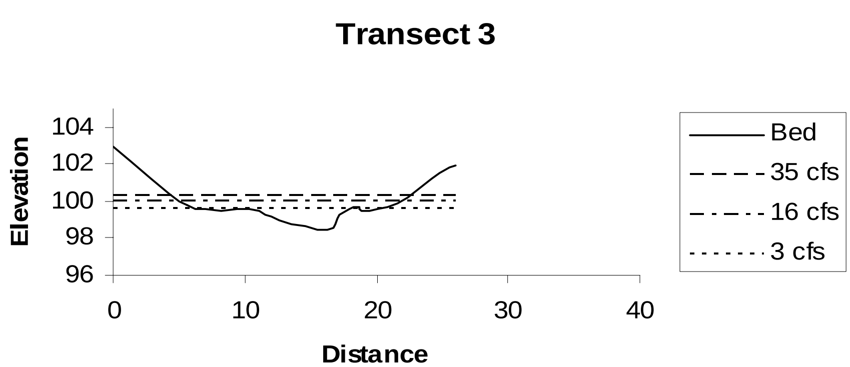


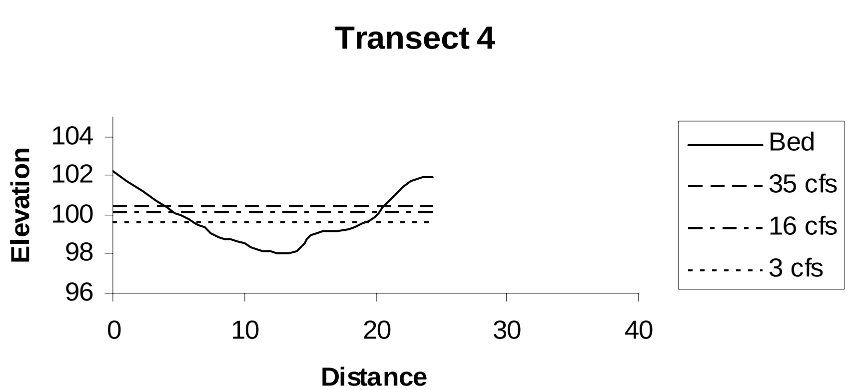
Study Site 1 (44°38.741'N; 118°39.250'W)

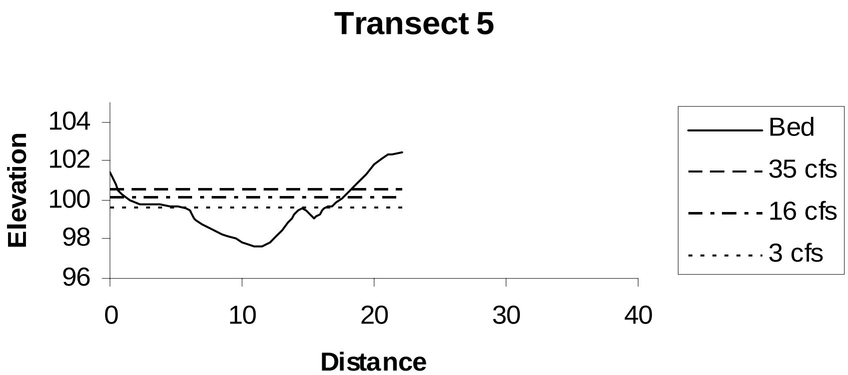
Transect 1 – riffle (most downstream transect)
Transect 2 – riffle
Transect 3 – hydraulic control
Transect 4 – pool
Transect 5 – pool
Transect 6 – pocketwater
Transect 7 – pocketwater (most upstream transect)

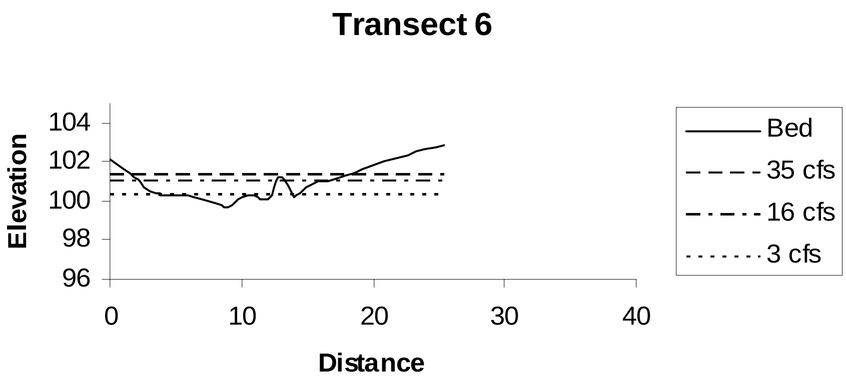

Transect 1
100
99
98
97
96
95
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

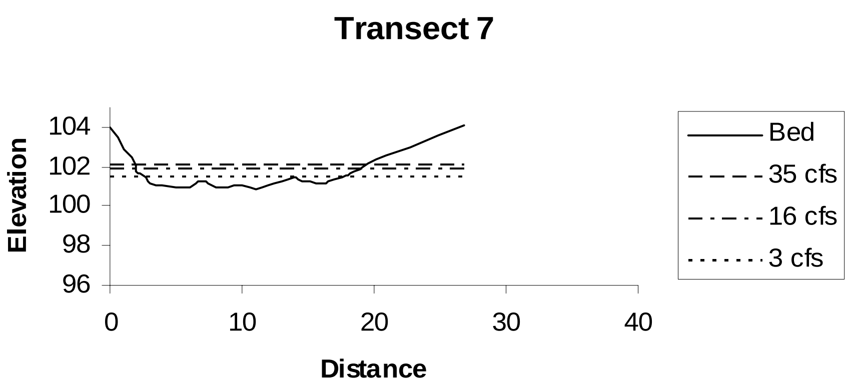

Transect 2
100
99
98
97
96
95
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs


Transect 3
104
102
100
98
96
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs


Transect 4
104
102
100
98
96
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

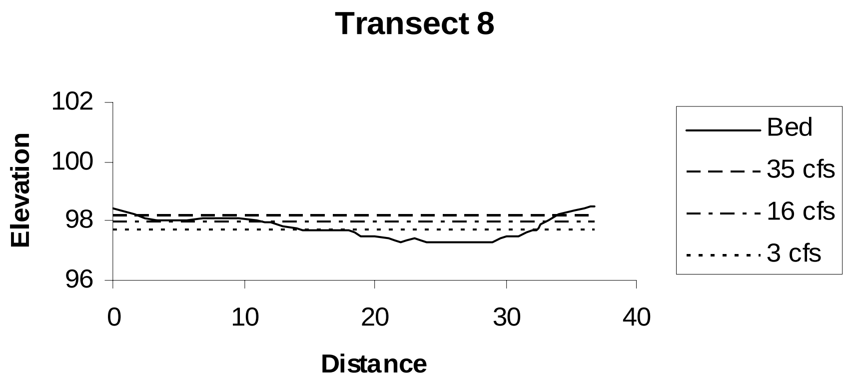

Transect 5
Elevation
104
102
100
98
96
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

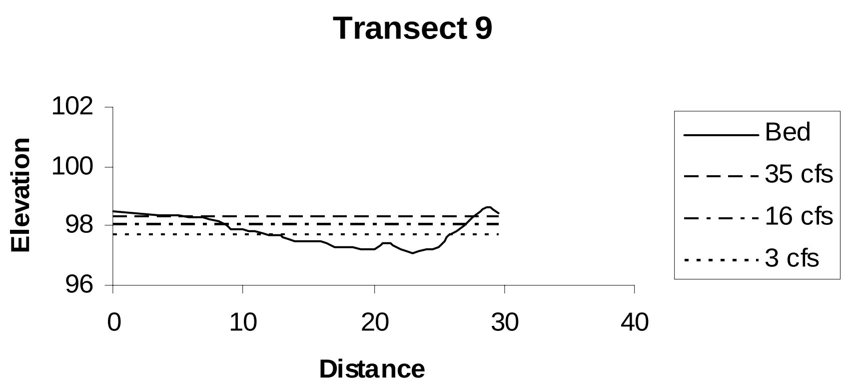

Transect 6
Elevation
104
102
100
98
96
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

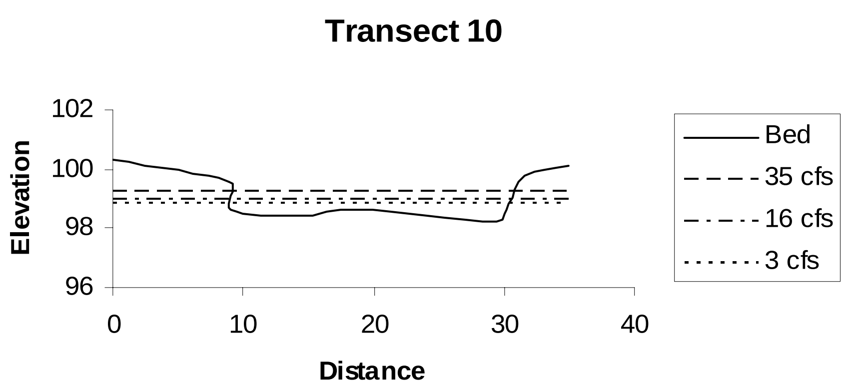

Transect 7
Elevation
104
102
100
98
96
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

Study Site 2 (44°38.968'N; 118°39.113'W)

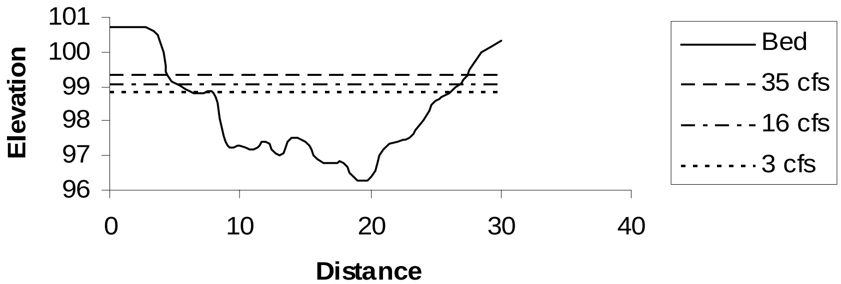
Transect 8 – glide (most downstream transect)
Transect 9 – glide
Transect 10 – hydraulic control
Transect 11 – pool
Transect 12 – pool
Transect 13 – riffle
Transect 14 – riffle (most upstream transect)


Transect 8
102
100
98
96
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

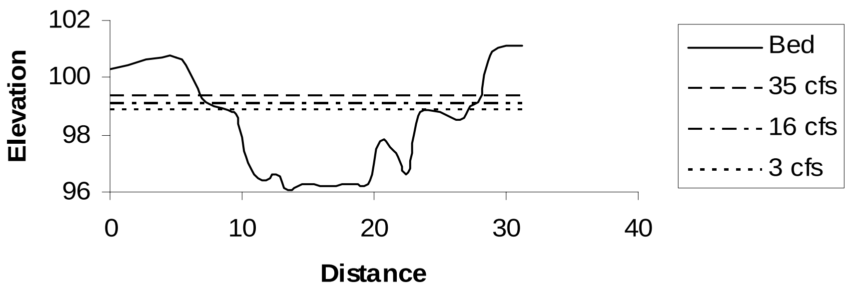

Transect 9
102
100
98
96
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs


Transect 10
102
100
98
96
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

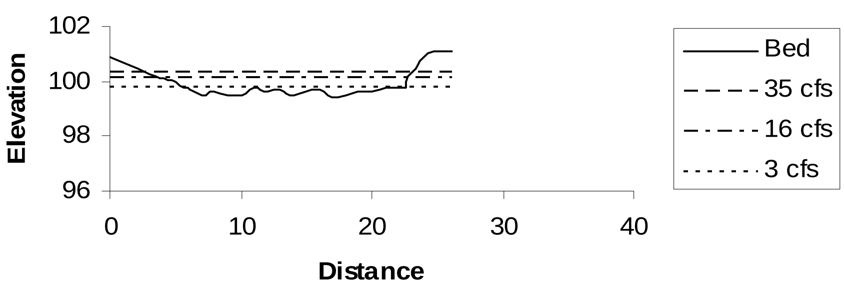
Transect 11

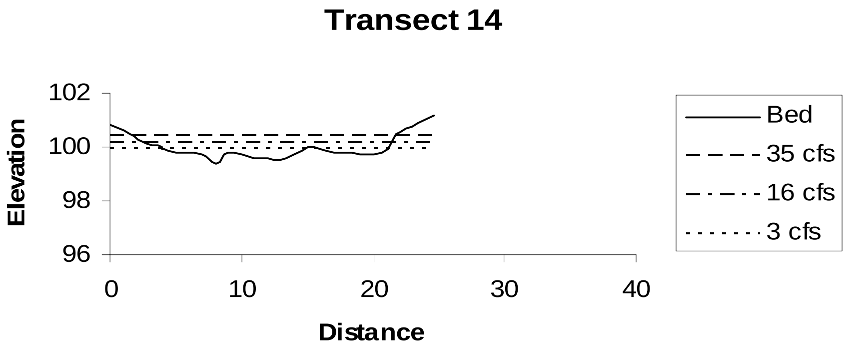


Transect 12



Transect 13

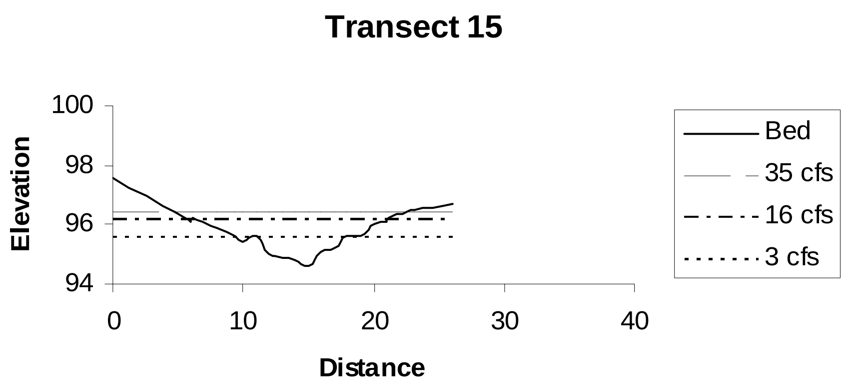




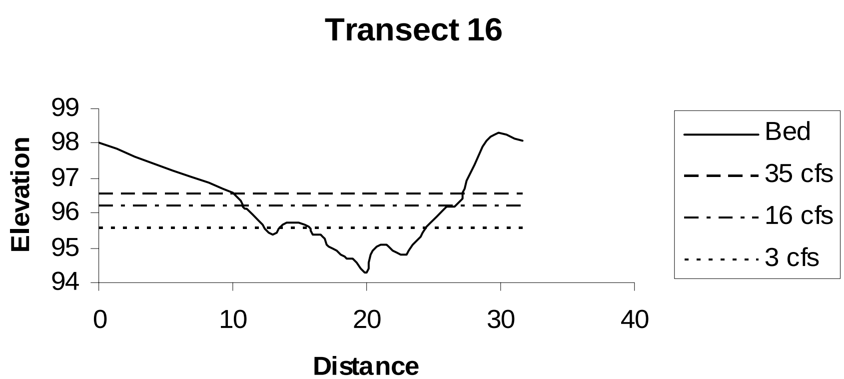
<u>Study Site 3 (44°39.017'N; 118°39.085'W)</u>

Transect 15 – hydraulic control/pool (most downstream transect)
Transect 16 – pool
Transect 17 – riffle
Transect 18 – riffle
Transect 19 – riffle (most upstream transect)

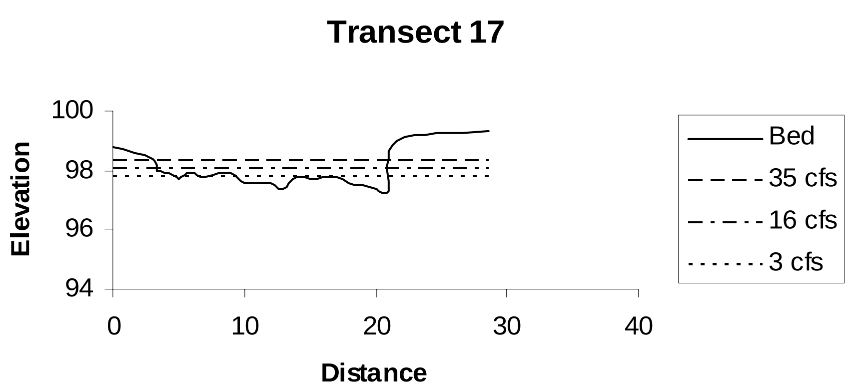

T17
T18
T19



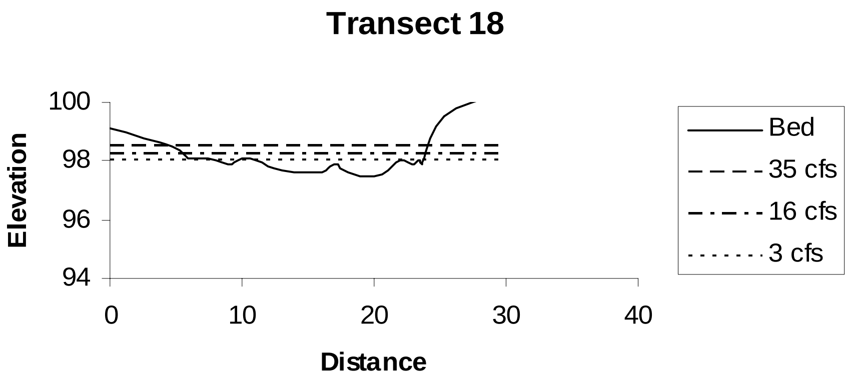
Transect 15
100
98
96
94
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

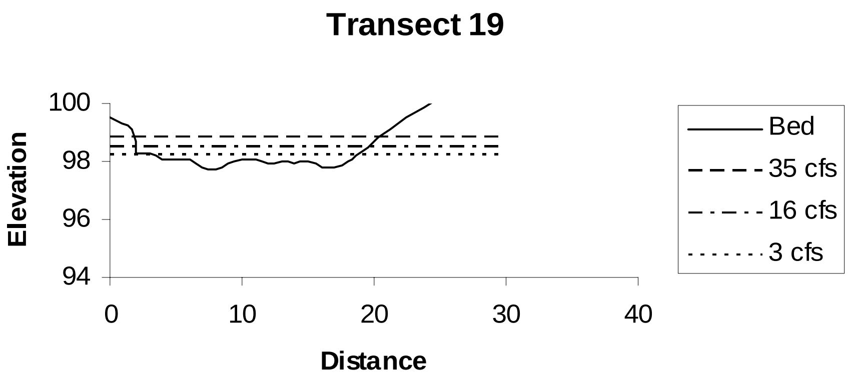


Transect 16
99
98
97
96
95
94
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

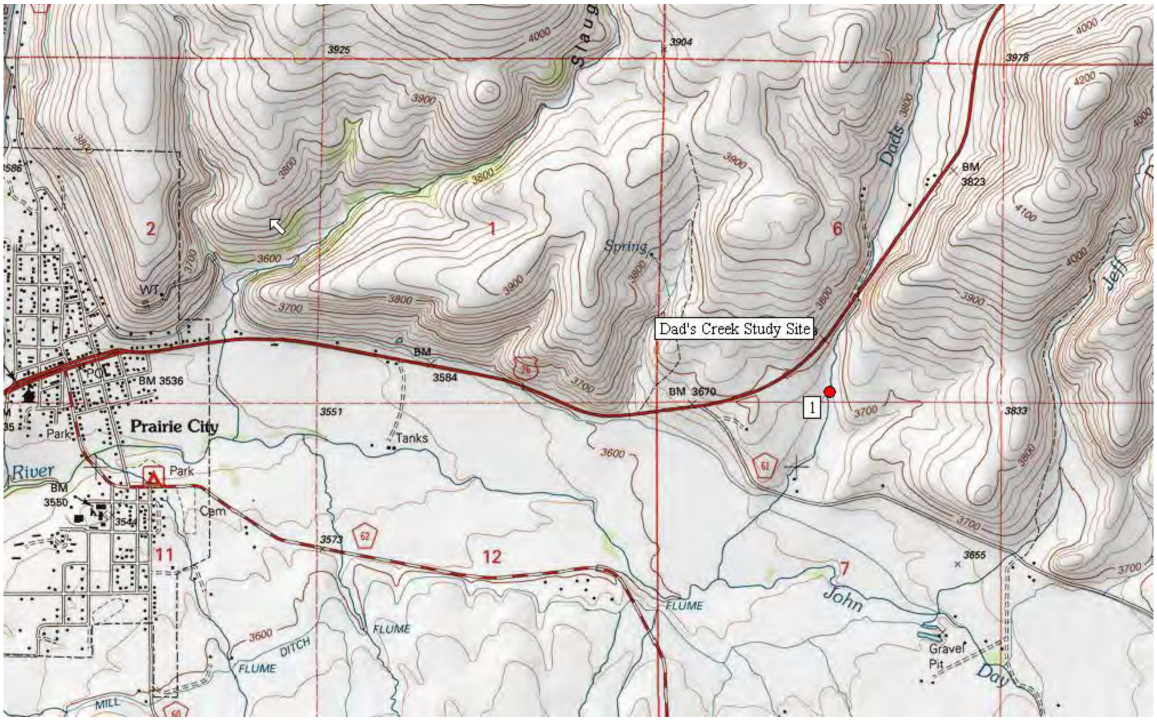


Transect 17
100
98
96
94
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs


Transcect 18
100
98
96
94
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs


Transect 19
100
98
96
94
Elevation
0
10
20
30
40
Distance
Bed
35 cfs
16 cfs
3 cfs

Dad's Creek



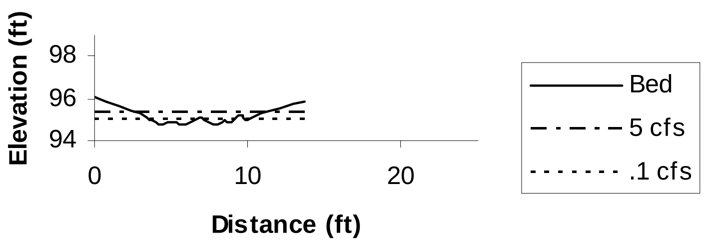
<u>Study Site 1 (44°27.668'N; 118°39.968'W)</u>

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

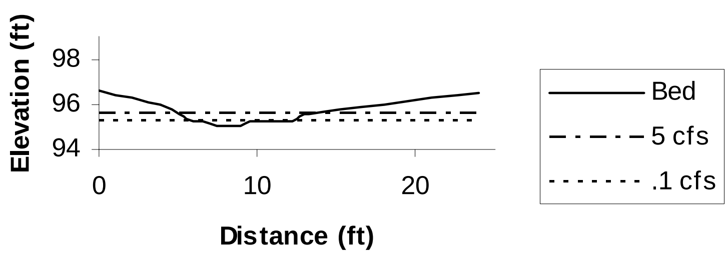

T4
T3


T5
T6

Transect 1

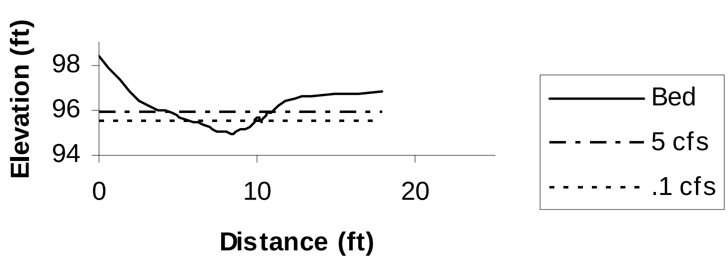


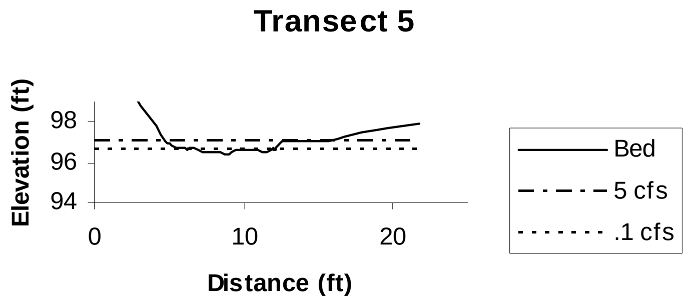
Transect 2

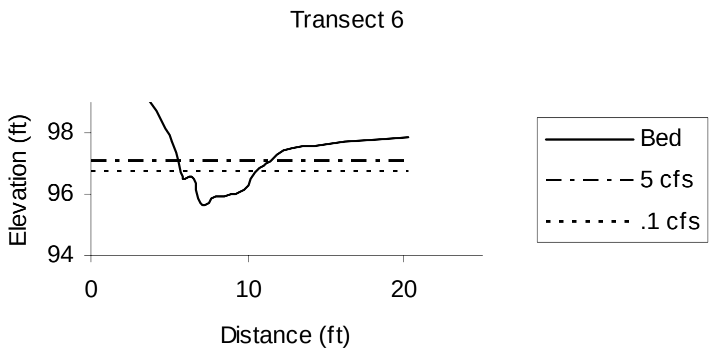


Transect 3

Transect 4




Transect 5
Elevation (ft)
98
96
94
0
10
20
Distance (ft)
Bed
5 cfs
.1 cfs


Transect 6
Elevation (ft)
98
96
94
0
10
20
Distance (ft)
Bed
5 cfs
.1 cfs

Appendix B – Hydraulic Calibration Results

Table B-1. Water surface elevation calibration results (ft) for John Day River Study Site "P4" using the STGQ model (transects 1, 9, and 10) and WSP (transects 2-8).

Transect	Distance from next downstream transect (ft)	44 cfs			83 cfs			175 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	97.15	97.14	-0.02	97.36	97.39	0.03	97.80	97.78	-0.02
2	26	97.64	97.65	0.01	97.78	97.78	0.00	98.00	98.00	0.00
3	10.5	97.71	97.67	-0.04	97.85	97.83	-0.02	98.09	98.04	-0.05
4	38	97.74	97.73	-0.01	97.94	97.95	0.01	98.21	98.23	0.02
5	68	97.97	97.97	0.00	98.12	98.12	0.00	98.43	98.43	0.00
6	5	98.02	98.02	0.00	98.20	98.22	0.02	98.60	98.61	0.01
7	41.5	98.08	98.12	0.04	98.47	98.42	-0.05	98.80	98.81	0.01
8	51.5	98.12	98.17	0.05	98.54	98.52	-0.02	99.00	99.00	0.00
9	190	99.78	99.79	0.01	100.12	100.09	-0.03	100.53	100.55	0.02
10	32.5	100.07	100.07	0.00	100.37	100.36	-0.01	100.78	100.78	0.00

Table B-2. Water surface elevation calibration results (ft) for John Day River Study Site "G5" using the STGQ model.

Transect	Distance from next downstream transect (ft)	44 cfs			83 cfs			175 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
11	0	95.96	95.91	-0.04	96.25	96.21	-0.04	96.66	96.67	0.01
12	101	96.62	96.66	0.04	96.93	96.88	-0.05	97.26	97.27	0.01
13	15	96.79	96.76	-0.03	97.01	97.00	-0.01	97.44	97.39	-0.05

Table B-3. Water surface elevation calibration results (ft) for John Day River Study Site "G8" using the STGQ model.

Transect	Distance from next downstream transect (ft)	44 cfs			83 cfs			175 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
14	0	97.06	97.04	-0.02	97.27	97.32	0.05	97.79	97.77	-0.02
15	28	97.34	97.35	0.01	97.62	97.58	-0.04	97.90	97.92	0.02
16	46	97.42	97.42	0.00	97.80	97.79	-0.01	98.40	98.41	0.01
17	59	97.83	97.85	0.01	98.17	98.13	-0.04	98.55	98.57	0.02

Table B-4. Water surface elevation calibration results (ft) for John Day River Study Site “P7” using the WSP model.

Transect	Distance from next downstream transect (ft)	44 cfs			83 cfs			175 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
18	0	95.64	95.64	0.00	95.79	95.79	0.00	96.29	96.29	0.00
19	10	95.70	95.68	-0.02	95.84	95.89	0.05	96.38	96.38	0.00
20	19	95.68	95.70	0.02	95.88	95.90	0.02	96.38	96.40	0.02
21	24	95.71	95.70	-0.01	95.91	95.92	0.01	96.46	96.42	-0.03

Table B-5. Water surface elevation calibration results (ft) for Reynolds Creek Study Site “P1” using the WSP (transects 1-3) and STGQ and MANSQ (transects 4,5) models.

Transect	Distance from next downstream transect (ft)	13.1 cfs			16.8 cfs			31.0 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	98.15	98.16	0.01	98.17	98.17	0.00	98.36	98.36	0.00
2	12	98.18	98.20	0.02	98.23	98.23	0.00	98.43	98.44	0.01
3	5	98.18	98.20	0.02	98.25	98.23	-0.02	98.46	98.45	-0.01
4	10	98.27	98.26	-0.01	98.34	98.36	0.02	98.61	98.61	0.00
5	12	98.29	98.27	-0.02	98.36	98.35	-0.01	98.63	98.63	0.00

Table B-6. Water surface elevation calibration results (ft) for Reynolds Creek Study Site “G3” using the STGQ model.

Transect	Distance from next downstream transect (ft)	13.7 cfs			16.5 cfs			32.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
6	0	99.03	99.05	0.02	99.15	99.10	-0.05	99.29	99.32	0.03
7	12	99.26	99.24	-0.02	99.27	99.29	0.02	99.50	99.50	0.00
8	18	99.82	99.80	-0.02	99.83	99.85	0.02	100.05	100.05	0.00

Table B-7. Water surface elevation calibration results (ft) for Reynolds Creek Study Site “IS” using the STGQ (transects 9-11) and WSP (transects 12-14) models.

Transect	Distance from next downstream transect (ft)	14.4 cfs			17.6 cfs			32.1 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
9	0	98.18	98.17	-0.01	98.26	98.27	0.01	98.62	98.62	0.00
10	7	98.30	98.29	-0.01	98.35	98.36	0.01	98.57	98.57	0.00
11	12	98.45	98.45	0.00	98.52	98.52	0.00	98.74	98.74	0.00
12	6	98.59	98.59	0.00	98.65	98.65	0.00	98.84	98.84	0.00
13	6	98.63	98.62	-0.01	98.68	98.68	0.00	98.90	98.88	-0.02
14	9	98.64	98.64	0.00	98.69	98.70	0.01	98.92	98.91	-0.01

Table B-8. Water surface elevation calibration results (ft) for Reynolds Creek Study Site "G6" using the STGQ model.

Transcect	Distance from next downstream transect (ft)	14.9 cfs			17.9 cfs			31.4 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
15	0	96.91	96.91	0.00	96.95	96.95	0.00	97.11	97.11	0.00
16	24	97.38	97.38	0.01	97.44	97.43	-0.01	97.57	97.58	0.01
17	18	98.06	98.04	-0.02	98.06	98.08	0.02	98.18	98.18	0.00
18	14	98.29	98.30	0.01	98.33	98.32	-0.01	98.38	98.39	0.01

Table B-9. Water surface elevation calibration results (ft) for Middle Fork John Day River-Camp Creek to Big Boulder Creek Study Site "P1" using the WSP model.

Transect	Distance from next downstream transect (ft)	28.5 cfs			63 cfs			279.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	97.15	97.15	0.00	97.44	97.44	0.00	98.11	98.11	0.00
2	43	97.24	97.21	-0.03	97.58	97.55	-0.03	98.43	98.38	-0.05
3	20	97.26	97.23	-0.03	97.63	97.59	-0.04	98.43	98.48	0.05
4	36	97.25	97.24	-0.01	97.61	97.61	0.00	98.56	98.52	-0.04

Table B-10. Water surface elevation calibration results (ft) for Middle Fork John Day River-Camp Creek to Big Boulder Creek Study Site "P3" using the WSP model.

Transect	Distance from next downstream transect (ft)	28.5 cfs			63 cfs			279.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
5	0	96.68	96.68	0.00	97.10	97.10	0.00	98.44	98.44	0.00
6	24.5	96.80	96.75	-0.05	97.20	97.19	-0.01	98.46	98.49	0.03
7	32	96.82	96.79	-0.03	97.29	97.25	-0.05	98.56	98.58	0.02
8	31	96.82	96.79	-0.03	97.27	97.25	-0.02	98.54	98.59	0.05

Table B-11. Water surface elevation calibration results (ft) for Middle Fork John Day River-Camp Creek to Big Boulder Creek Study Site "R6" using the STGQ model.

Transect	Distance from next downstream transect (ft)	28.5 cfs			63 cfs			279.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
9	0	95.74	95.72	-0.02	96.09	96.12	0.04	97.30	97.28	-0.02
10	12.5	95.98	95.97	-0.01	96.32	96.34	0.02	97.38	97.36	-0.01
11	23.5	96.13	96.11	-0.01	96.47	96.49	0.02	97.46	97.45	-0.01
12	27.5	96.18	96.17	0.00	96.52	96.52	0.00	97.49	97.49	0.00

Table B-12. Water surface elevation calibration results (ft) for Middle Fork John Day River-Camp Creek to Big Boulder Creek Study Site “R35” using the STGQ model.

Transect	Distance from next downstream transect (ft)	28.5 cfs			63 cfs			279.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
13	0	96.97	96.96	-0.01	97.16	97.18	0.02	97.82	97.81	-0.01
14	19	97.14	97.14	0.00	97.38	97.38	0.00	98.02	98.02	0.00
15	18.5	97.27	97.26	-0.01	97.49	97.50	0.01	98.15	98.14	-0.01
16	33	97.36	97.35	-0.01	97.60	97.62	0.02	98.33	98.32	-0.01
17	35	97.40	97.37	-0.03	97.65	97.70	0.05	98.53	98.51	-0.02
18	24	97.42	97.39	-0.03	97.69	97.74	0.05	98.60	98.58	-0.02

Table B-13. Water surface elevation calibration results (ft) for Middle Fork John Day River-Camp Creek to Big Boulder Creek Study Site “R52” using the STGQ model.

Transect	Distance from next downstream transect (ft)	28.5 cfs			63 cfs			279.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
19	0	95.93	95.92	-0.01	96.24	96.26	0.02	97.22	97.21	-0.01
20	53	96.48	96.46	-0.02	96.70	96.74	0.04	97.58	97.56	-0.02
21	35	96.65	96.63	-0.02	96.91	96.95	0.04	97.81	97.79	-0.02
22	19.5	96.68	96.65	-0.03	96.93	96.99	0.06	97.91	97.89	-0.02
23	17	96.67	96.65	-0.02	96.96	97.00	0.04	97.96	97.94	-0.02

Table B-14. Water surface elevation calibration results (ft) for Middle Fork John Day River-Camp Creek to Big Boulder Creek Study Site “G69” using the STGQ model.

Transect	Distance from next downstream transect (ft)	28.5 cfs			63 cfs			279.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
24	0	96.22	96.20	-0.02	96.52	96.56	0.04	97.49	97.47	-0.02
25	42.5	96.35	96.34	-0.01	96.68	96.70	0.02	97.67		

Table B-15. Water surface elevation calibration results (ft) for Middle Fork John Day River-Camp Creek to Big Boulder Creek Study Site “R65” using the WSP model.

Transect	Distance from next downstream transect (ft)	28.5 cfs			63 cfs			279.3 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
26	0	91.81	91.81	0.00	92.09	92.09	0.00	92.79	92.79	0.00
27	5.5	91.82	91.82	0.00	92.15	92.11	-0.04	92.80	92.84	0.04
28	22	91.84	91.84	0.00	92.16	92.14	-0.02	92.99	92.95	-0.04
29	25.5	91.86	91.85	-0.01	92.21	92.17	-0.04	93.10	93.06	-0.04

Table B-16. Water surface elevation calibration results (ft) for Middle Fork John Day River-Caribou Creek to Vincent Creek Study Site "G4-lower" using the STGQ model.

Transcect	Distance from next downstream transect (ft)	14.3 cfs			23.9 cfs			172.7 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	89.10	89.08	-0.02	89.26	89.29	0.03	90.53	90.52	-0.01
2	29	89.11	89.11	0.00	89.31	89.31	0.01	90.60	90.60	0.00
3	29	89.17	89.17	0.00	89.38	89.38	0.00	90.63	90.63	0.00
4	40	89.34	89.31	-0.03	89.47	89.51	0.04	90.78	90.77	-0.01
5	21	89.67	89.63	-0.04	89.76	89.81	0.05	91.05	91.04	-0.01
6	28	90.13	90.09	-0.04	90.16	90.21	0.06	91.23	91.22	-0.01

Table B-17. Water surface elevation calibration results (ft) for Middle Fork John Day River-Caribou Creek to Vincent Creek Study Site "G4-upper" using the WSP model.

Transect	Distance from next downstream transect (ft)	14.3 cfs			23.9 cfs			172.7 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
7	0	92.53	92.53	0.00	92.62	92.62	0.00	93.40	93.40	0.00
8	88	92.59	92.58	-0.01	92.71	92.69	-0.02	93.44	93.47	0.03
9	47	92.61	92.59	-0.02	92.76	92.71	-0.05	93.58	93.56	-0.02
10	45	92.63	92.59	-0.04	92.76	92.72	-0.04	93.63	93.62	-0.01
11	62	92.64	92.60	-0.04	92.79	92.74	-0.05	93.71	93.72	0.01

Table B-18. Water surface elevation calibration results (ft) for Middle Fork John Day River-Caribou Creek to Vincent Creek Study Site "P31" using the WSP model (transects 12-19) and MANSQ (transects 21-22).

Transect	Distance from next downstream transect (ft)	13.2 cfs			30.1 cfs			184.5 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
12	0	97.66	97.66	0.00	97.94	97.94	0.00	98.60	98.60	0.00
13	9	97.65	97.67	0.02	98.00	97.96	-0.05	98.67	98.63	-0.03
14	33	97.66	97.68	0.02	97.99	97.97	-0.01	98.81	98.78	-0.03
15	36.5	97.66	97.68	0.02	98.00	97.98	-0.02	98.80	98.79	-0.01
16	24	97.67	97.69	0.02	98.00	98.00	0.00	98.92	98.87	-0.05
17	10.5	97.67	97.70	0.03	98.01	98.01	0.00	98.96	98.91	-0.05
18	13.5	97.68	97.70	0.02	98.01	98.03	0.02	98.97	99.02	0.05
19	14.5	97.69	97.70	0.01	98.02	98.03	0.01	98.99	99.02	0.03
20	34	98.16	98.16	0.00	98.33	98.36	0.03	99.15	99.15	0.00
21	23	98.44	98.42	-0.02	98.58	98.61	0.03	99.31	99.33	0.02
22	32.5	98.51	98.46	-0.05	98.71	98.72	0.01	99.44	99.39	-0.05

Table B-19 Water surface elevation calibration results (ft) for Middle Fork John Day River-Caribou Creek to Vincent Creek Study Site "R46" using the STGQ model.

Transect	Distance from next downstream transect (ft)	12.9 cfs			30.6 cfs			171.9 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
23	0	96.96	96.98	0.02	97.29	97.24	-0.04	98.18	98.21	0.03
24	43	97.11	97.10	-0.01	97.38	97.40	0.02	98.32	98.31	-0.01
25	42	97.31	97.30	-0.01	97.53	97.56	0.03	98.42	98.41	-0.01
26	78	97.54	97.51	-0.03	97.82	97.87	0.05	98.93	98.91	-0.02
27	14	97.54	97.51	-0.03	97.84	97.89	0.05	99.00	98.98	-0.02

Table B-20 Water surface elevation calibration results (ft) for Granite Boulder Study Site "Low" using the STGQ (transects 1,2,6,7) and WSP (transects 3,4,5) models.

Transect	Distance from next downstream transect (ft)	1.9 cfs			16.0 cfs			38.7 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	96.57	96.57	0.00	96.95	96.94	-0.01	97.16	97.17	0.01
2	9	97.12	97.12	0.00	97.45	97.44	-0.01	97.61	97.62	0.01
3	103	99.54	99.55	0.01	100.00	100.00	0.00	100.32	100.32	0.00
4	6	99.57	99.55	-0.01	100.06	100.05	-0.01	100.38	100.43	0.05
5	5	99.57	99.55	-0.02	100.08	100.06	-0.02	100.45	100.45	0.00
6	23	100.32	100.33	0.01	101.00	100.95	-0.05	101.33	101.37	0.04
7	18	101.49	101.48	0.00	101.83	101.85	0.02	102.09	102.07	-0.02

Table B-21 Water surface elevation calibration results (ft) for Granite Boulder Study Site "Mid" using the STGQ (transects 8, 9 , 13, 14) and WSP (transects 10, 11, 12) models.

Transect	Distance from next downstream transect (ft)	2.6 cfs			15.8 cfs			35.0 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
8	0	97.66	97.66	0.00	97.95	97.97	0.02	98.18	98.17	-0.01
9	7	97.69	97.68	-0.01	98.00	98.03	0.03	98.27	98.25	-0.02
10	47	98.81	98.81	0.00	98.98	98.98	0.00	99.21	99.21	0.00
11	13	98.82	98.81	-0.01	99.03	99.02	-0.01	99.31	99.31	0.00
12	5	98.83	98.81	-0.02	99.06	99.02	-0.04	99.32	99.31	0.00
13	16	99.79	99.79	0.00	100.10	100.10	0.00	100.30	100.30	0.00
14	10	99.90	99.89	-0.01	100.16	100.21	0.05	100.44	100.41	-0.03

Table B-22 Water surface elevation calibration results (ft) for Granite Boulder Study Site "High" using the WSP (transects 15 and 16) and STGQ (transects 17, 18, 19) models.

Transect	Distance from next downstream transect (ft)	4.0 cfs			15.4 cfs			33.8 cfs		
		Water surface elevations (ft)								
		Measured	Simulated	Difference	Measured	Simulated	Difference	Measured	Simulated	Difference
15	0	95.57	95.57	0.00	96.17	96.17	0.00	96.45	96.45	0.00
16	12	95.58	95.60	0.02	96.21	96.21	0.00	96.53	96.54	0.01
17	50	97.78	97.78	0.00	98.05	98.06	0.01	98.32	98.31	-0.01
18	13	98.02	97.99	-0.03	98.22	98.26	0.04	98.50	98.47	-0.03
19	11	98.18	98.20	0.02	98.50	98.51	0.01	98.82	98.81	-0.01

Table B-23 Water surface elevation calibration results (ft) for Dad's Creek Study Site using MANSQ (transects 1 and 2) and WSP (transects 3-6) models.

Transect	Distance from next downstream transect (ft)	0.1 cfs			5.0 cfs		
		Measured	Simulated	Difference	Measured	Simulated	Difference
1	0	95.00	95.02	0.02	95.28	95.28	0.00
2	10	95.28	95.28	0.00	95.61	95.61	0.00
3	15	95.49	95.49	0.00	95.93	95.93	0.00
4	7	95.50	95.49	-0.01	95.96	95.93	-0.03
5	36.5	96.64	96.64	0.00	96.97	96.97	0.00
6	11.5	96.67	96.64	-0.03	97.03	97.02	-0.01

Velocity Adjustment Factors

Table B-24. Middle Fork John Day River Camp Creek to Big Boulder Creek velocity adjustment factors (VAF).

	Discharge (cfs)																			
Transect	10	20	29	30	40	50	60	63	80	100	120	140	160	180	200	220	240	260	279	280
1																				
2	0.80	1.05	1.17	0.89	0.95	0.99	1.03	1.03	0.78	0.82	0.85	0.88	0.91	0.93	0.95	0.97	1.04	1.06	1.15	1.14
3	0.62	0.89	1.05	0.72	0.83	0.92	1.00	1.02	0.57	0.63	0.68	0.73	0.77	0.80	0.83	0.87	0.93	0.96	1.03	1.03
4	0.51	0.80	0.99	0.62	0.72	0.82	0.90	0.93	0.67	0.74	0.80	0.85	0.89	0.93	0.97	1.00	1.09	1.12	1.21	1.21
5	Hydraulic control																			
6	0.93	0.95	0.96	0.82	0.84	0.85	0.87	0.88	0.93	0.94	0.95	0.97	0.97	0.98	0.98	0.99	1.01	1.01	1.02	1.02
7	0.48	0.70	0.84	0.58	0.66	0.73	0.79	0.81	0.60	0.65	0.70	0.75	0.79	0.83	0.86	0.90	0.93	0.96	0.99	0.99
8	0.48	0.73	0.88	0.33	0.40	0.46	0.51	0.53	0.77	0.82	0.86	0.91	0.94	0.97	1.00	1.03	1.06	1.09	1.11	1.11
9	0.93	0.88	0.86	0.87	0.83	0.81	0.80	0.80	0.88	0.88	0.89	0.90	0.91	0.92	0.94	0.95	0.96	0.97	0.98	0.98
10	0.80	0.86	0.90	0.86	0.88	0.88	0.89	0.89	0.85	0.87	0.89	0.91	0.93	0.95	0.97	0.98	1.00	1.01	1.03	1.03
11	0.69	0.88	0.99	0.80	0.88	0.94	1.00	1.02	0.64	0.70	0.75	0.80	0.84	0.88	0.92	0.96	0.99	1.02	1.05	1.06
12	0.72	0.89	0.99	0.78	0.87	0.94	1.00	1.02	0.61	0.67	0.71	0.75	0.79	0.82	0.85	0.88	0.91	0.93	0.95	0.96
13	0.66	0.80	0.88	0.85	0.89	0.92	0.94	0.95	0.64	0.67	0.70	0.72	0.75	0.77	0.79	0.82	0.83	0.85	0.87	0.87
14	0.64	0.74	0.80	0.71	0.76	0.80	0.83	0.84	0.60	0.63	0.67	0.69	0.72	0.75	0.77	0.80	0.82	0.84	0.86	0.86
15	0.76	0.88	0.96	0.84	0.89	0.93	0.96	0.98	0.78	0.82	0.86	0.90	0.93	0.96	0.99	1.02	1.05	1.07	1.10	1.10
16	0.76	0.97	1.10	0.74	0.81	0.87	0.93	0.95	0.67	0.72	0.77	0.82	0.86	0.90	0.94	0.97	1.01	1.04	1.07	1.07
17	0.92	1.01	1.09	0.87	0.94	1.00	1.06	1.08	0.65	0.71	0.76	0.81	0.85	0.90	0.94	0.98	1.01	1.05	1.08	1.08
18	0.68	0.84	0.96	0.64	0.72	0.80	0.87	0.89	0.58	0.64	0.70	0.76	0.81	0.86	0.91	0.95	1.00	1.04	1.08	1.08
19	1.16	1.07	1.07	1.06	1.06	1.06	1.08	1.08	0.82	0.84	0.86	0.88	0.91	0.93	0.95	0.97	0.99	1.00	1.02	1.02
20	1.08	0.94	0.92	0.87	0.85	0.85	0.85	0.85	0.85	0.86	0.87	0.89	0.90	0.91	0.92	0.93	0.94	0.95	0.96	0.96
21	0.99	1.00	1.04	0.82	0.86	0.89	0.92	0.93	0.71	0.75	0.79	0.82	0.86	0.89	0.92	0.94	0.97	0.99	1.02	1.02
22	0.92	1.00	1.07	0.80	0.86	0.91	0.96	0.97	0.72	0.76	0.80	0.83	0.87	0.90	0.93	0.95	0.98	1.00	1.03	1.03
23	0.81	0.93	1.02	0.70	0.76	0.82	0.87	0.89	0.66	0.72	0.77	0.81	0.85	0.89	0.93	0.97	1.00	1.03	1.06	1.06
24	0.93	0.87	0.87	0.93	0.93	0.94	0.96	0.96	0.85	0.87	0.89	0.92	0.94	0.96	0.98	1.00	1.01	1.03	1.05	1.05
25	0.74	0.79	0.84	0.72	0.77	0.81	0.84	0.86	0.68	0.73	0.77	0.80	0.84	0.87	0.90	0.93	0.96	0.98	1.01	1.01
26	Hydraulic control																			
27	0.64	0.81	0.93	0.96	1.01	1.05	1.08	1.09	0.61	0.65	0.69	0.73	0.77	0.80	0.83	0.86	0.88	0.91	0.93	0.93
28	0.60	0.86	1.04	0.86	0.97	1.05	1.11	1.13	0.58	0.64	0.69	0.74	0.78	0.82	0.85	0.89	0.92	0.94	0.97	0.97
29	0.41	0.66	0.83	0.93	1.10	1.24	1.35	1.38	0.70	0.80	0.88	0.96	1.03	1.10	1.16	1.21	1.26	1.30	1.33	1.34

Table B-25. Middle Fork John Day River Caribou Creek to Vincent Creek velocity adjustment factors (VAF).

	Discharge (cfs)																					
Transect	6	10	13	20	30	31	40	50	60	70	80	90	100	110	120	130	140	150	160	170	172	175
1	0.92	1.04	1.10	0.89	1.00	1.00	0.71	0.75	0.79	0.82	0.86	0.89	0.92	0.95	0.97	1.00	1.02	1.05	1.07	1.09	1.10	1.10
2	0.85	0.94	0.99	1.00	1.10	1.10	0.82	0.87	0.90	0.94	0.96	0.99	1.01	1.04	1.06	1.08	1.09	1.11	1.13	1.14	1.14	1.15
3	0.86	0.95	1.01	0.53	0.60	0.60	0.67	0.72	0.76	0.80	0.84	0.87	0.91	0.94	0.97	0.99	1.02	1.05	1.07	1.09	1.10	1.11
4	1.20	1.09	1.05	0.87	0.85	0.85	1.02	1.03	1.05	1.06	1.07	1.08	1.10	1.11	1.12	1.13	1.14	1.15	1.16	1.17	1.17	1.18
5	1.59	1.32	1.20	0.93	0.83	0.82	0.99	0.99	0.99	0.99	0.99	0.99	1.00	1.00	0.99	0.99	0.98	0.98	0.97	0.96	0.96	0.96
6	1.95	1.71	1.61	1.14	1.06	1.06	1.54	1.47	1.42	1.38	1.34	1.30	1.26	1.23	1.19	1.17	1.14	1.12	1.10	1.08	1.07	1.06
7	Hydraulic control																					
8	0.86	1.05	1.15	0.89	1.03	1.03	0.63	0.68	0.72	0.78	0.81	0.84	0.87	0.93	0.95	0.97	1.00	1.02	1.07	1.09	1.09	1.10
9	0.67	1.01	1.22	0.99	1.32	1.33	0.44	0.51	0.58	0.65	0.70	0.75	0.80	0.87	0.92	0.96	1.00	1.05	1.11	1.15	1.16	1.17
10	0.81	1.14	1.33	1.10	1.36	1.37	0.59	0.65	0.71	0.78	0.83	0.87	0.91	0.98	1.01	1.05	1.08	1.11	1.19	1.22	1.22	1.23
11	0.57	0.85	1.03	0.88	1.17	1.18	0.40	0.46	0.52	0.59	0.64	0.68	0.73	0.79	0.84	0.88	0.91	0.95	1.02	1.06	1.06	1.07
12	Hydraulic control																					
13	0.62	0.84	0.97	0.75	0.95	0.96	0.52	0.59	0.64	0.70	0.74	0.78	0.83	0.86	0.90	0.93	0.96	0.99	1.03	1.05	1.06	1.07
14	0.45	0.71	0.89	0.68	0.97	0.99	0.35	0.43	0.50	0.56	0.63	0.69	0.75	0.81	0.87	0.93	0.98	1.04	1.10	1.15	1.16	1.17
15	0.49	0.75	0.92	0.65	0.90	0.92	0.36	0.43	0.49	0.54	0.60	0.65	0.70	0.74	0.79	0.83	0.87	0.91	0.96	0.99	1.00	1.01
16	0.67	0.82	0.92	0.81	0.98	0.99	0.61	0.67	0.73	0.78	0.82	0.87	0.90	0.94	0.97	1.00	1.03	1.05	1.12	1.15	1.15	1.16
17	0.55	0.72	0.82	0.69	0.86	0.87	0.56	0.63	0.69	0.74	0.78	0.82	0.86	0.90	0.93	0.96	0.99	1.01	1.08	1.11	1.12	1.12
18	0.42	0.61	0.74	0.62	0.82	0.83	0.47	0.55	0.61	0.68	0.73	0.79	0.84	0.88	0.93	0.97	1.00	1.04	1.10	1.13	1.14	1.15
19	0.44	0.64	0.77	0.67	0.88	0.89	0.53	0.61	0.68	0.74	0.80	0.85	0.89	0.93	0.97	1.00	1.03	1.06	1.13	1.15	1.16	1.16
20	0.95	0.99	0.99	0.88	0.84	0.84	1.31	1.27	1.26	1.21	1.21	1.20	1.20	1.19	1.19	1.18	1.18	1.17	1.17	1.17	1.17	1.16
21	0.90	0.99	1.04	0.87	0.93	0.94	0.81	0.78	0.82	0.85	0.88	0.91	0.94	0.96	0.98	1.00	1.02	1.03	1.05	1.07	1.07	1.07
22	0.83	1.04	1.10	0.77	0.93	0.94	0.52	0.58	0.64	0.70	0.75	0.80	0.84	0.88	0.92	0.96	1.00	1.04	1.07	1.10	1.11	1.12
23	1.04	0.97	0.96	1.15	1.18	1.19	0.96	0.98	1.00	1.01	1.02	1.04	1.05	1.06	1.07	1.08	1.09	1.10	1.11	1.12	1.12	1.12
24	0.86	0.96	1.02	0.99	1.11	1.12	0.76	0.81	0.85	0.89	0.93	0.96	0.99	1.02	1.05	1.07	1.10	1.12	1.14	1.17	1.17	1.18
25	1.10	0.98	0.96	0.83	0.85	0.85	0.79	0.82	0.84	0.87	0.89	0.91	0.93	0.95	0.97	0.99	1.01	1.02	1.04	1.06	1.06	1.06
26	0.74	0.89	0.98	0.76	0.90	0.91	0.64	0.70	0.75	0.80	0.84	0.88	0.92	0.96	0.99	1.03	1.06	1.09	1.12	1.14	1.15	1.16
27	0.70	0.88	0.99	0.79	0.96	0.97	0.61	0.67	0.73	0.78	0.83	0.88	0.93	0.97	1.01	1.05	1.09	1.12	1.16	1.19	1.20	1.21

Table B-26. John Day River Cottonwood Galley velocity adjustment factors (VAF).

	Discharge (cfs)																		
Transect	20	30	40	44	50	60	70	80	83	90	100	110	120	130	140	150	160	170	175
1	1.38	1.24	1.08	1.04	0.96	0.92	0.89	0.88	0.87	0.91	0.90	0.89	0.89	0.89	0.88	0.88	0.88	0.88	0.88
2	0.51	0.62	0.72	0.74	0.70	0.76	0.82	0.87	0.90	0.69	0.73	0.76	0.80	0.83	0.86	0.89	0.92	0.94	0.95
3	0.82	0.97	1.10	1.12	0.93	1.01	1.08	1.15	1.19	0.89	0.94	0.98	1.02	1.05	1.09	1.12	1.18	1.26	1.27
4	0.62	0.83	1.02	1.08	0.79	0.89	0.98	1.06	1.09	0.77	0.82	0.86	0.90	0.94	0.98	1.01	1.08	1.18	1.19
5	Hydraulic control																		
6	0.63	0.78	0.91	0.93	0.69	0.76	0.82	0.88	0.91	0.77	0.80	0.83	0.86	0.89	0.91	0.93	0.96	1.00	1.00
7	0.70	0.90	1.06	1.11	1.26	1.38	1.50	1.59	1.64	0.96	0.99	1.02	1.05	1.07	1.09	1.11	1.19	1.29	1.30
8	0.51	0.67	0.80	0.84	0.66	0.73	0.79	0.84	0.86	0.96	1.02	1.07	1.12	1.16	1.21	1.25	1.32	1.40	1.42
9	0.98	0.99	1.01	1.02	1.12	1.13	1.14	1.16	1.16	1.05	1.06	1.08	1.09	1.10	1.12	1.13	1.14	1.15	1.16
10	0.88	1.01	1.11	1.14	0.94	1.00	1.06	1.11	1.12	0.95	0.99	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.22
11	0.85	1.01	1.14	1.19	0.96	1.01	1.07	1.13	1.15	0.89	0.93	0.96	1.00	1.04	1.07	1.06	1.09	1.11	1.13
12	0.69	0.77	0.83	0.85	0.94	0.99	1.03	1.07	1.08	1.10	1.13	1.16	1.18	1.21	1.22	1.24	1.25	1.27	1.28
13	0.90	1.03	1.13	1.17	1.06	1.12	1.18	1.24	1.25	1.13	1.17	1.20	1.23	1.26	1.28	1.31	1.33	1.35	1.36
14	1.27	1.20	1.13	1.11	1.13	1.09	1.06	1.03	1.03	1.11	1.10	1.09	1.09	1.08	1.08	1.08	1.08	1.08	1.08
15	0.76	0.86	0.94	0.96	0.83	0.88	0.93	0.97	0.98	0.76	0.79	0.82	0.85	0.87	0.90	0.92	0.95	0.97	0.98
16	1.07	0.93	0.85	0.83	0.86	0.83	0.81	0.80	0.80	1.09	1.07	1.06	1.06	1.05	1.04	1.04	1.04	1.03	1.03
17	0.72	0.77	0.80	0.82	0.86	0.89	0.91	0.94	0.95	0.90	0.92	0.94	0.96	0.97	0.99	1.01	1.02	1.04	1.04
18	Hydraulic control																		
19	1.01	1.09	1.16	1.11	0.77	0.80	0.84	0.87	0.94	0.82	0.84	0.87	0.89	0.91	0.93	0.96	0.98	1.00	0.98
20	0.72	0.90	1.06	1.07	0.78	0.85	0.91	0.97	1.04	0.82	0.87	0.91	0.96	1.00	1.04	1.08	1.11	1.15	1.15
21	0.57	0.76	0.92	0.96	0.85	0.95	1.03	1.09	1.17	0.93	0.98	1.03	1.07	1.10	1.14	1.17	1.20	1.23	1.22

Table B-27. Dad's Creek velocity adjustment factors (VAF).

Transect	Discharge (cfs) 0.1	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7	7.5	8	8.5	9	10	11	12	13	14	14.5
1	0.70	0.30	0.43	0.54	0.62	0.70	0.77	0.83	0.89	0.95	1.00	1.04	1.09	1.13	1.18	1.22	1.25	1.29	1.33	1.40	1.47	1.53	1.56	1.55	1.55
2	0.37	0.31	0.44	0.54	0.63	0.71	0.78	0.84	0.90	0.96	0.98	1.02	1.06	1.10	1.14	1.18	1.22	1.25	1.29	1.36	1.43	1.49	1.55	1.61	1.64
3	0.74	0.32	0.49	0.62	0.74	0.84	0.94	1.03	1.11	1.19	1.24	1.33	1.40	1.46	1.52	1.59	1.65	1.70	1.76	1.87	1.98	2.08	2.18	2.27	2.31
4	0.70	0.19	0.31	0.42	0.51	0.59	0.67	0.74	0.81	0.88	0.93	1.00	1.05	1.11	1.16	1.21	1.27	1.31	1.36	1.46	1.55	1.63	1.72	1.80	1.84
5	0.76	0.94	0.98	1.02	1.05	1.06	1.07	1.08	1.08	1.07	1.05	1.07	0.92	0.93	0.95	0.97	0.98	0.99	1.00	1.02	1.03	1.05	1.06	1.07	1.07
6	0.51	0.27	0.46	0.62	0.76	0.88	0.99	1.09	1.19	1.27	1.35	1.43	1.44	1.52	1.59	1.67	1.73	1.80	1.87	2.00	2.12	2.24	2.35	2.46	2.51

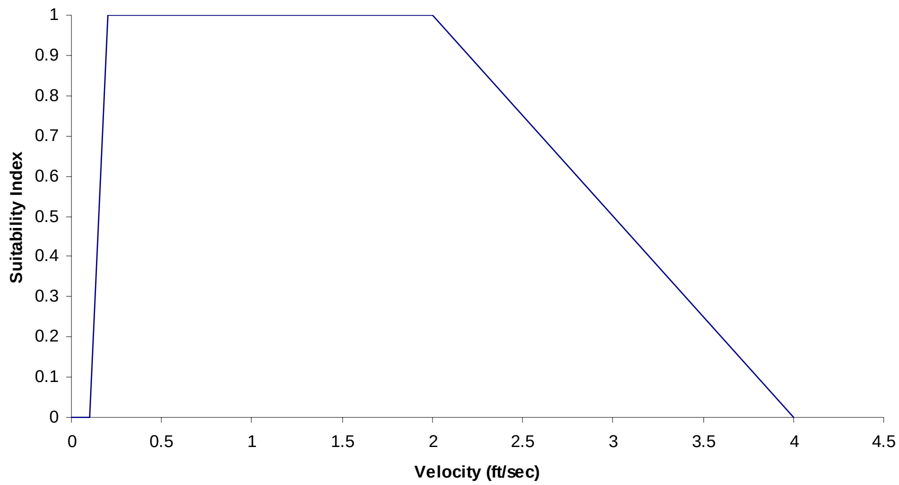
Table B-28. Granite Boulder Creek velocity adjustment factors (VAF).

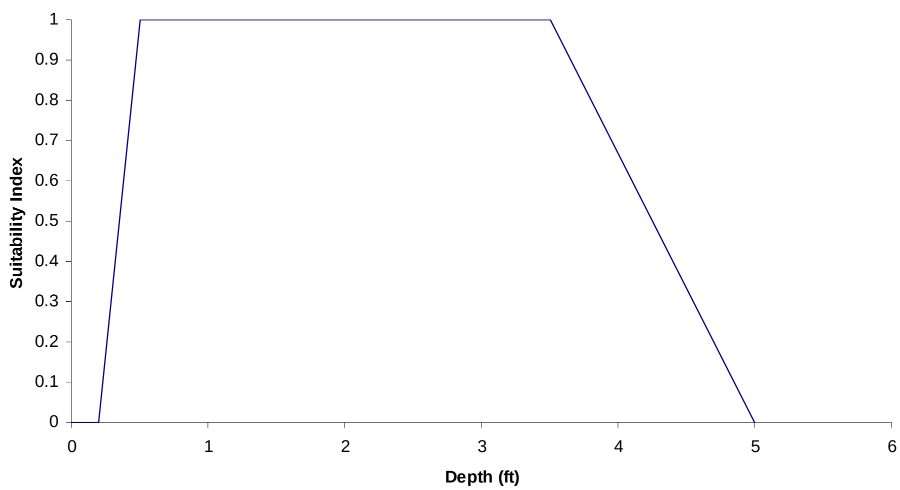
Transect	Discharge (cfs) 2	3	4	6	8	10	12	14	16	18	20	22	24	26	28	30	32	34	35	36	40	44	50	54
1	0.85	0.96	1.04	1.18	0.78	0.85	0.91	0.97	1.02	0.87	0.90	0.92	0.95	0.97	0.99	1.01	1.03	1.05	1.06	1.07	1.11	1.14	1.19	1.22
2	0.77	0.92	1.06	1.28	0.69	0.76	0.82	0.88	0.94	0.67	0.71	0.74	0.78	0.81	0.84	0.87	0.90	0.92	0.94	0.95	1.01	1.06	1.13	1.18
3	Hydraulic control																							
4	0.87	1.15	1.40	1.83	0.63	0.74	0.83	0.92	1.03	0.72	0.77	0.82	0.86	0.90	0.94	0.98	1.02	1.06	1.07	1.09	1.16	1.22	1.31	1.36
5	0.82	1.12	1.40	1.90	0.77	0.87	0.97	1.06	1.18	0.75	0.80	0.85	0.89	0.94	0.98	1.02	1.06	1.10	1.12	1.13	1.20	1.27	1.35	1.41
6	1.10	1.13	1.18	1.25	0.83	0.85	0.88	0.90	0.92	0.76	0.77	0.79	0.81	0.82	0.84	0.85	0.87	0.88	0.89	0.90	0.92	0.95	0.98	1.00
7	0.62	0.75	0.85	1.03	0.57	0.63	0.69	0.75	0.80	0.81	0.85	0.89	0.93	0.96	1.00	1.04	1.07	1.10	1.12	1.13	1.20	1.26	1.34	1.39
8	1.01	1.13	1.23	1.38	0.73	0.78	0.82	0.86	0.90	0.96	0.99	1.02	1.05	1.07	1.10	1.12	1.14	1.16	1.17	1.18	1.22	1.25	1.30	1.33
9	0.97	1.13	1.26	1.48	0.80	0.88	0.94	1.01	1.06	0.87	0.91	0.94	0.98	1.01	1.04	1.07	1.10	1.13	1.14	1.16	1.21	1.26	1.33	1.37
10	Hydraulic control																							
11	0.86	1.22	1.55	2.18	0.91	1.10	1.28	1.45	1.61	0.54	0.58	0.63	0.67	0.72	0.76	0.80	0.84	0.87	0.87	0.91	0.98	1.05	1.14	1.19
12	0.81	1.16	1.50	2.14	0.35	0.43	0.50	0.57	0.63	0.61	0.67	0.72	0.77	0.82	0.87	0.92	0.96	1.01	1.01	1.05	1.14	1.22	1.33	1.40
13	1.57	1.54	1.51	1.53	0.85	0.88	0.91	0.94	0.96	1.01	1.04	1.06	1.08	1.10	1.12	1.14	1.15	1.17	1.18	1.19	1.22	1.26	1.30	1.33
14	1.70	1.58	1.55	1.56	1.01	1.04	1.07	1.10	1.13	1.25	1.28	1.31	1.34	1.37	1.40	1.43	1.46	1.48	1.50	1.51	1.56	1.61	1.68	1.72
15	1.72	1.82	1.97	1.97	1.29	1.32	1.35	1.37	1.39	0.88	0.89	0.90	0.92	0.93	0.94	0.95	0.96	0.97	0.98	0.99	1.00	1.02	1.05	1.07
16	1.30	1.46	1.63	1.80	1.23	1.24	1.25	1.26	1.27	0.86	0.88	0.89	0.90	0.92	0.93	0.94	0.96	0.97	0.97	0.98	1.00	1.02	1.06	1.08
17	1.89	1.88	1.89	1.90	1.22	1.17	1.13	1.12	1.10	1.09	1.08	1.07	1.07	1.07	1.06	1.07	1.07	1.07	1.07	1.07	1.08	1.09	1.10	1.11
18	2.19	2.09	2.12	2.17	0.82	0.87	0.92	0.97	1.01	0.94	0.96	0.99	1.01	1.04	1.06	1.08	1.10	1.13	1.14	1.15	1.18	1.22	1.27	1.30
19	1.40	1.17	1.14	1.22	1.04	1.02	1.02	1.02	1.02	1.12	1.12	1.13	1.14	1.15	1.16	1.17	1.18	1.18	1.19	1.19	1.21	1.23	1.25	1.27

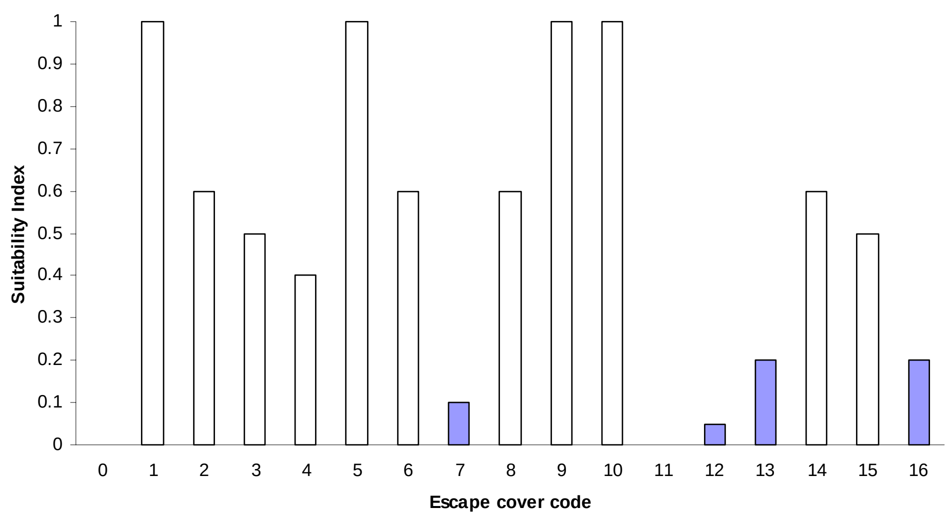
Table B-29. Reynolds Creek velocity adjustment factors (VAF).

	Discharge (cfs)																			
Transect	8	10	12	14	16	18	20	22	24	26	28	30	32	34	36	38	40	42	44	46
1	Hydraulic control																			
2	0.69	0.82	0.93	1.04	0.85	0.92	0.79	0.84	0.89	0.94	0.99	1.04	1.08	1.12	1.17	1.21	1.25	1.29	1.32	1.36
3	0.65	0.77	0.87	0.97	1.14	1.24	0.78	0.82	0.87	0.92	0.96	1.00	1.04	1.08	1.12	1.16	1.19	1.23	1.26	1.30
4	0.96	1.01	1.05	1.07	1.07	1.11	0.88	0.90	0.92	0.94	0.96	0.98	0.99	1.01	1.02	1.04	1.05	1.06	1.08	1.09
5	0.99	1.01	1.04	1.07	1.28	1.26	1.18	1.19	1.20	1.21	1.22	1.23	1.24	1.25	1.26	1.27	1.27	1.28	1.29	1.30
6	0.86	0.87	0.88	0.89	1.15	1.17	0.95	0.97	0.98	1.00	1.01	1.03	1.04	1.05	1.06	1.08	1.09	1.10	1.11	1.12
7	0.98	1.00	1.01	1.03	1.26	1.28	1.22	1.24	1.26	1.28	1.29	1.31	1.32	1.34	1.35	1.36	1.38	1.39	1.40	1.41
8	0.79	0.84	0.89	0.93	0.85	0.88	0.96	0.99	1.02	1.04	1.07	1.09	1.11	1.14	1.16	1.18	1.20	1.22	1.24	1.26
9	1.37	1.24	1.15	1.07	1.23	1.17	1.20	1.16	1.12	1.09	1.06	1.04	1.02	1.00	0.98	0.97	0.96	0.94	0.93	0.92
10	1.01	1.02	1.03	1.03	0.95	0.95	1.11	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.10	1.11	1.11	1.11	1.11
11	0.77	0.77	0.77	0.77	0.92	0.93	1.04	1.05	1.05	1.06	1.07	1.08	1.09	1.09	1.10	1.11	1.12	1.12	1.13	1.13
12	Hydraulic control																			
13	0.93	1.03	1.11	1.18	1.08	1.12	0.95	0.99	1.03	1.06	1.09	1.12	1.15	1.18	1.21	1.23	1.26	1.28	1.31	1.33
14	1.02	1.18	1.33	1.47	0.92	0.99	0.60	0.63	0.67	0.71	0.74	0.77	0.81	0.84	0.87	0.90	0.92	0.95	0.98	1.01
15	0.79	0.85	0.91	0.96	1.00	1.04	0.93	0.96	1.00	1.03	1.06	1.08	1.11	1.14	1.16	1.19	1.21	1.24	1.26	1.28
16	0.65	0.70	0.73	0.76	0.93	0.95	0.83	0.85	0.87	0.88	0.90	0.91	0.93	0.94	0.96	0.97	0.99	1.00	1.01	1.02
17	0.67	0.77	0.85	0.94	1.05	1.12	0.65	0.69	0.73	0.76	0.80	0.83	0.87	0.90	0.93	0.96	0.99	1.02	1.05	1.08
18	0.47	0.54	0.61	0.68	0.82	0.88	0.65	0.69	0.73	0.77	0.81	0.85	0.89	0.92	0.96	0.99	1.03	1.06	1.10	1.13

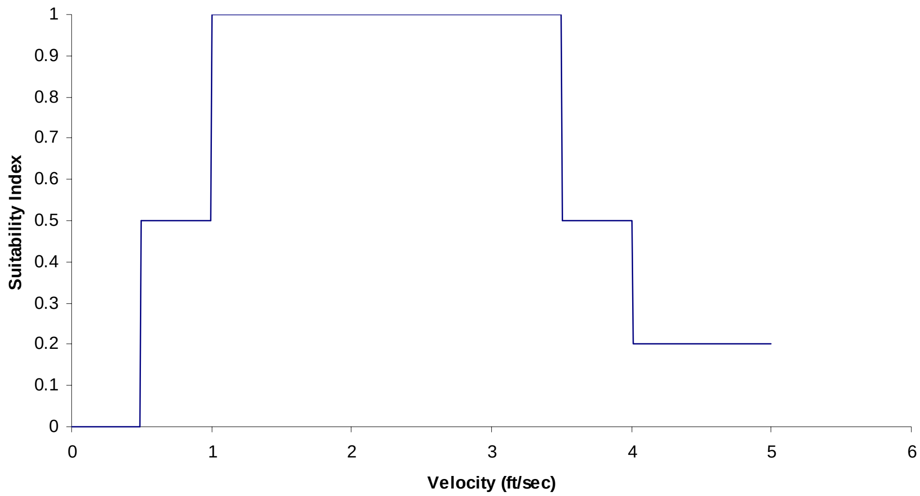
Appendix C - Habitat Suitability Criteria
Note: See HSC workshop notes for coding details
Steelhead - juvenile

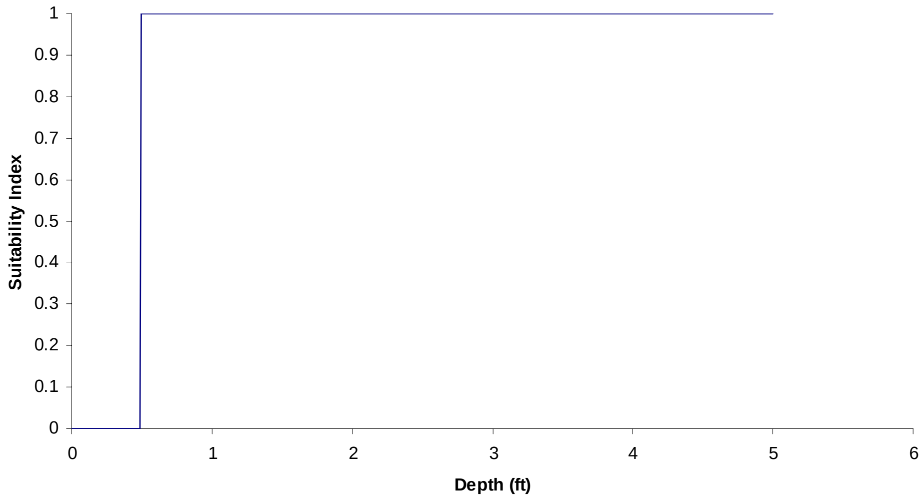


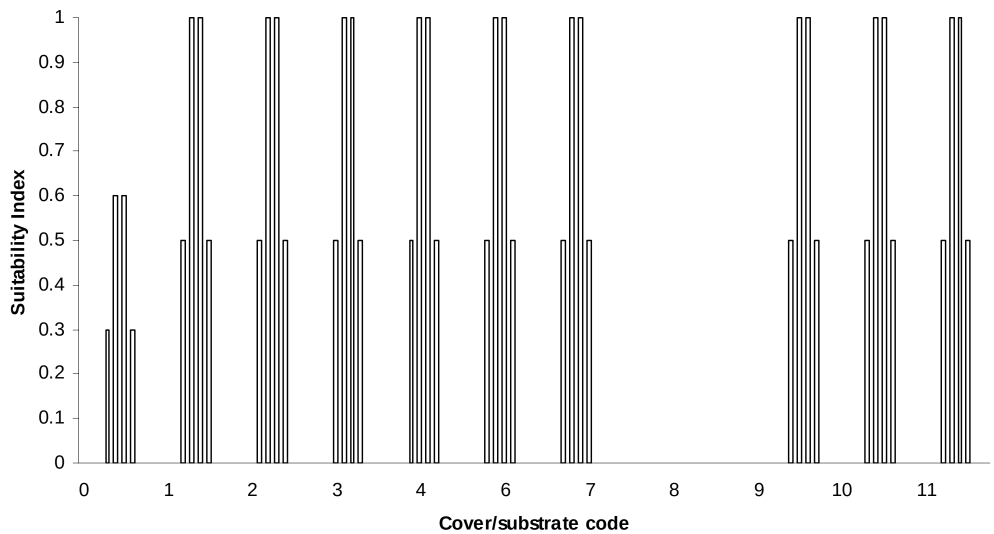




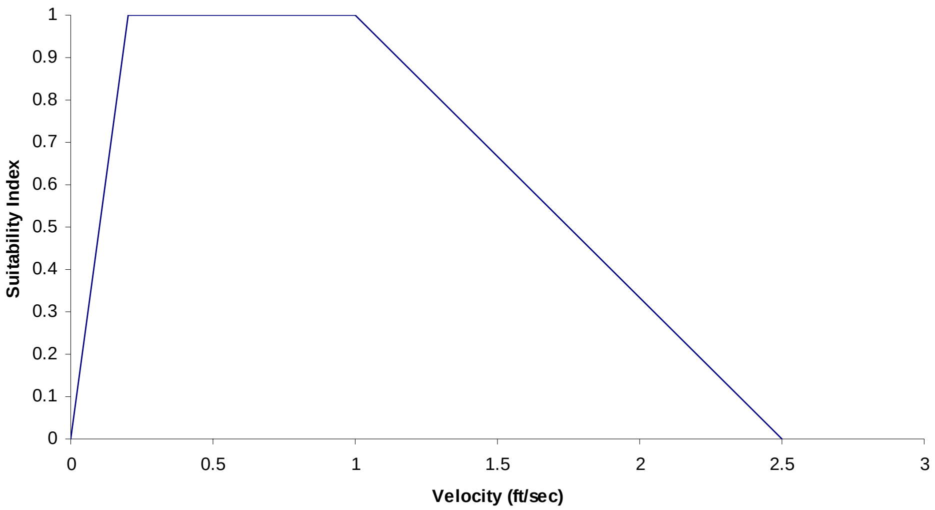
Steelhead-spawning

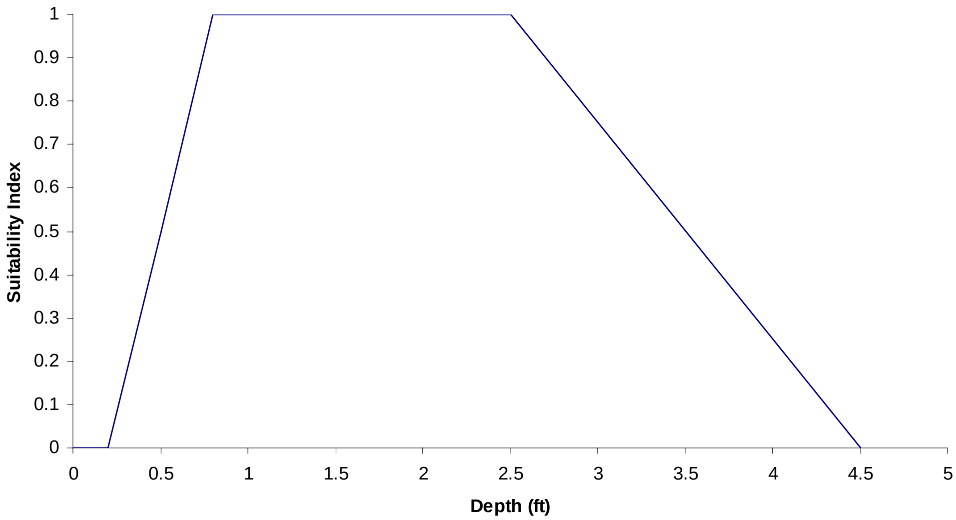


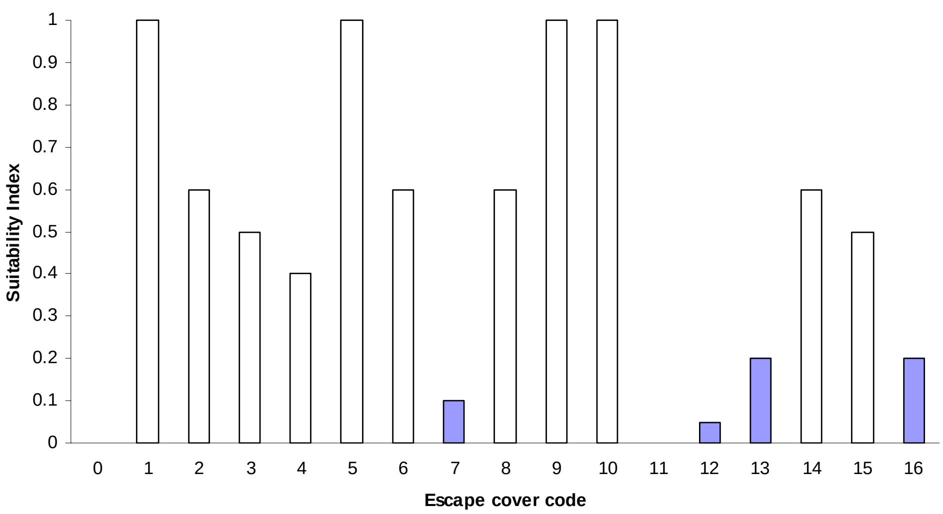




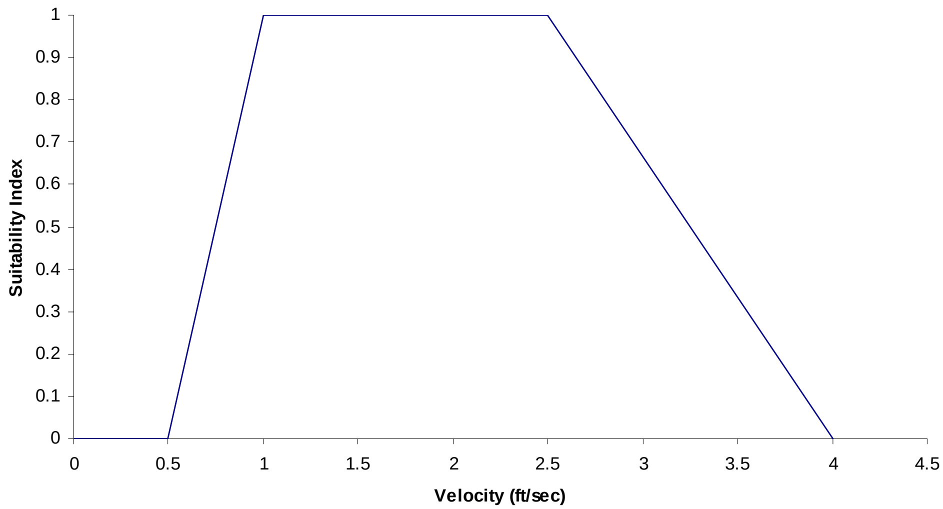
Chinook salmon-juvenile

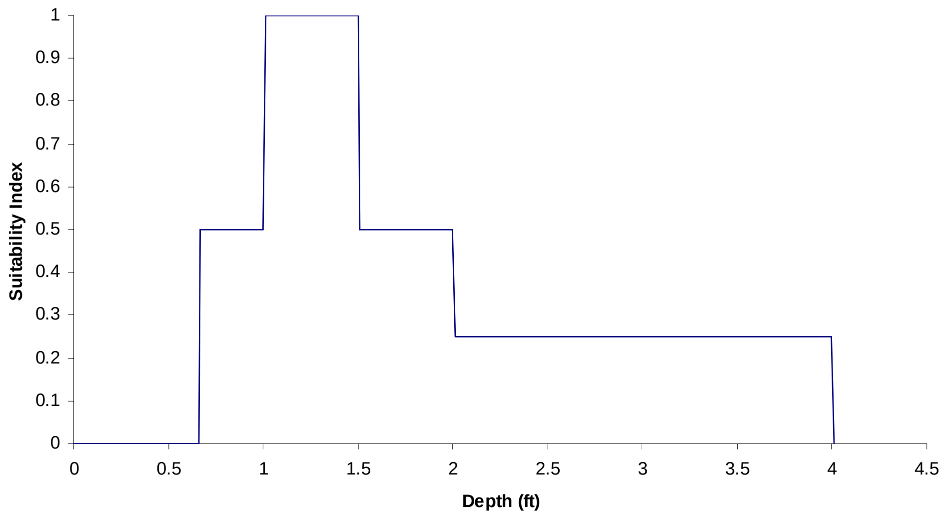


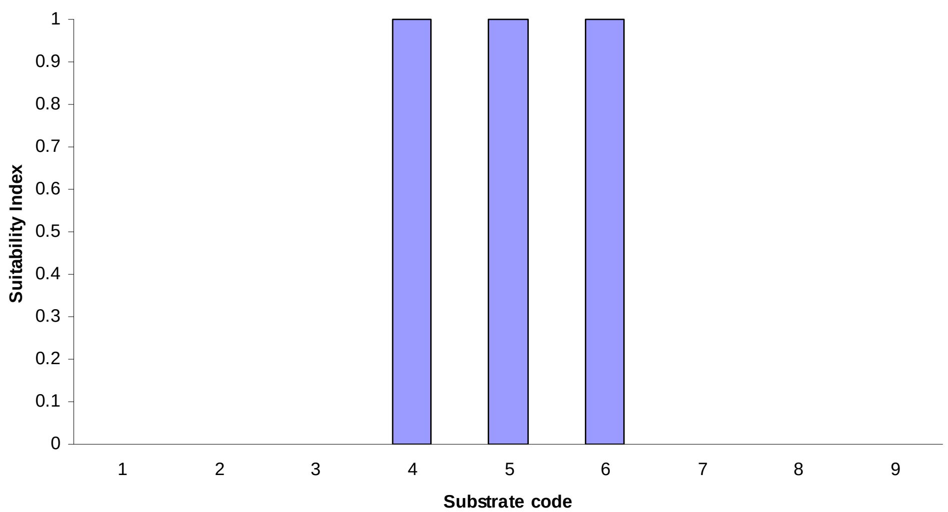




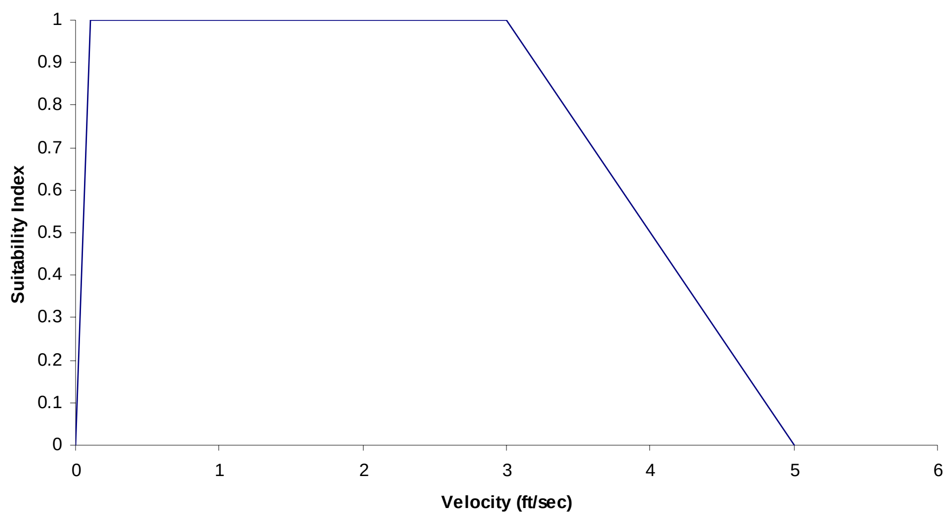
Chinook salmon-spawning

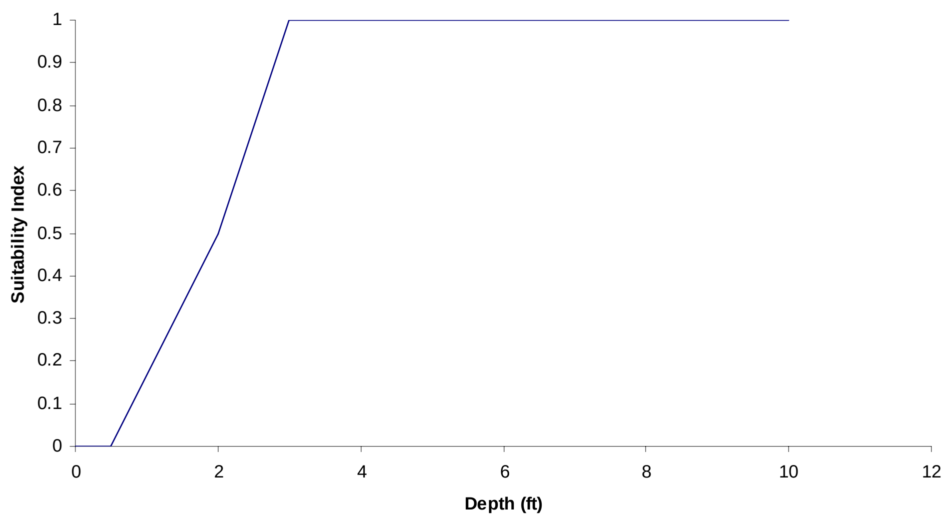


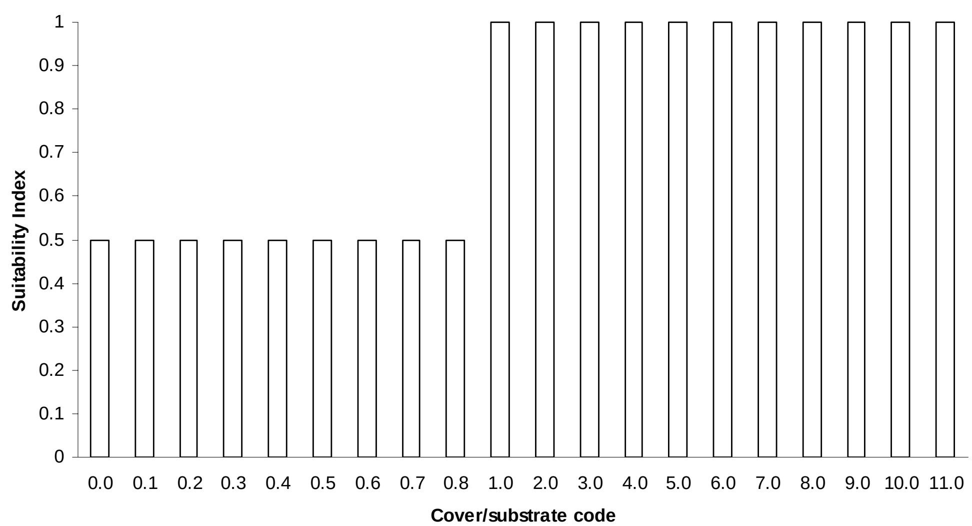




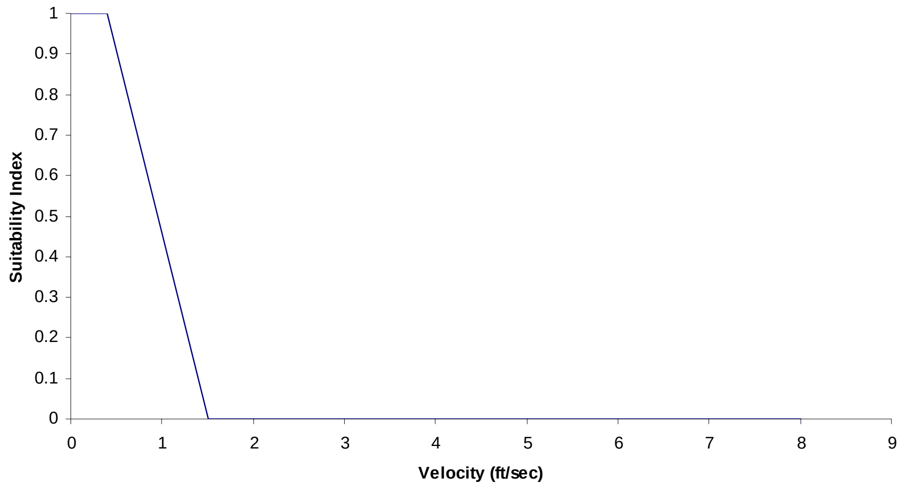
Chinook salmon-holding

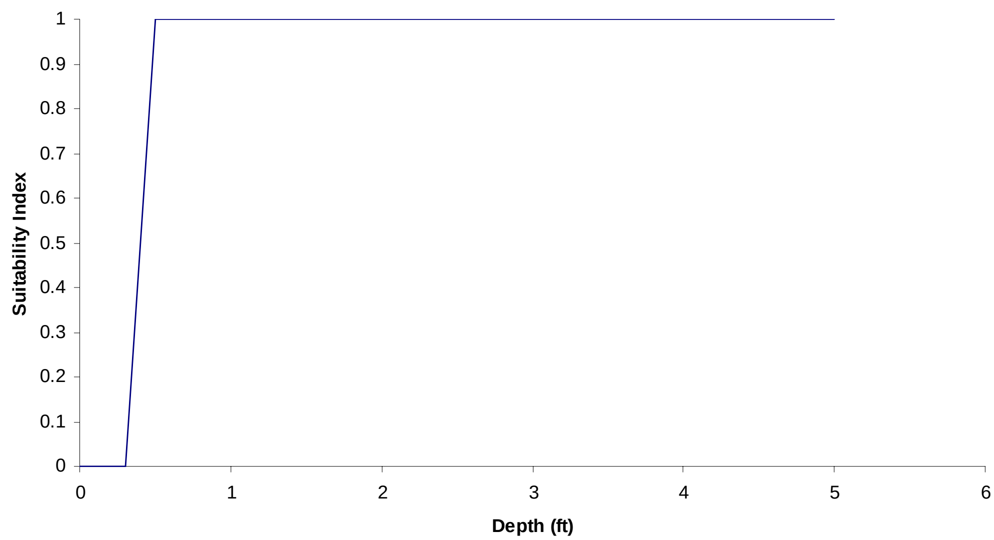


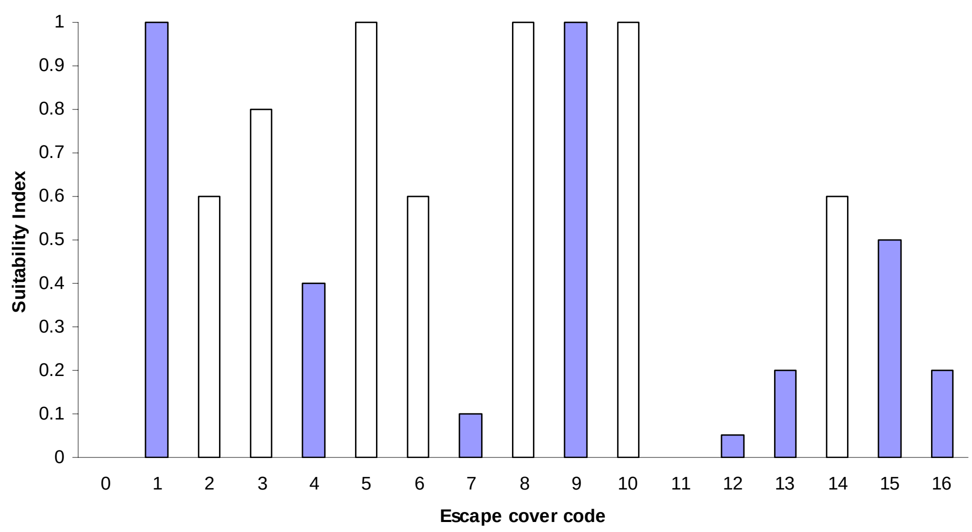




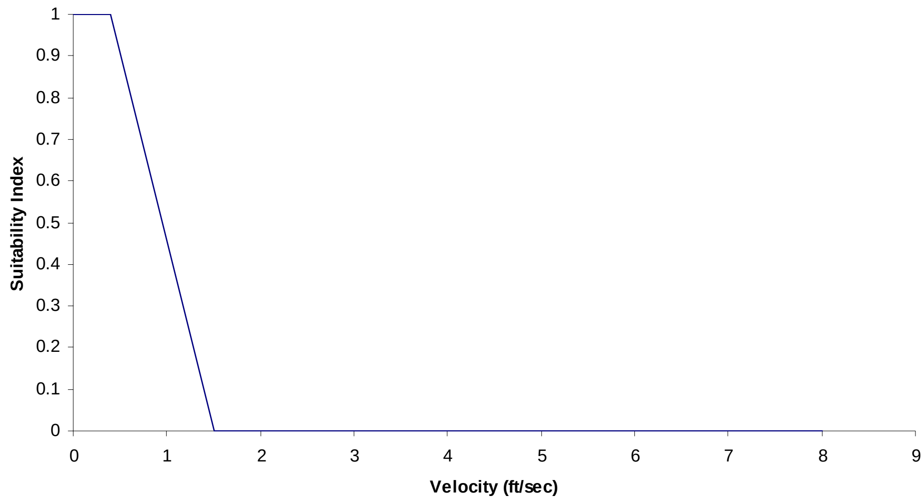
Bull trout – resident juvenile and adult

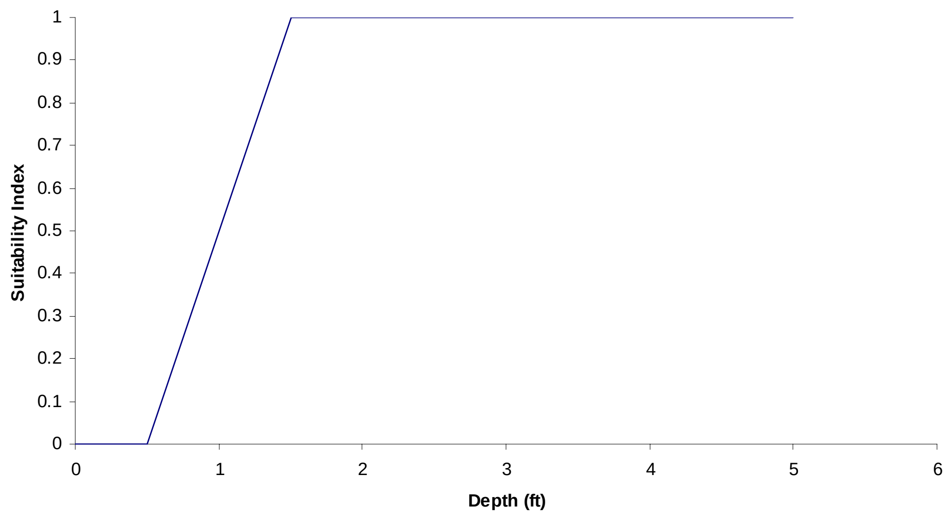


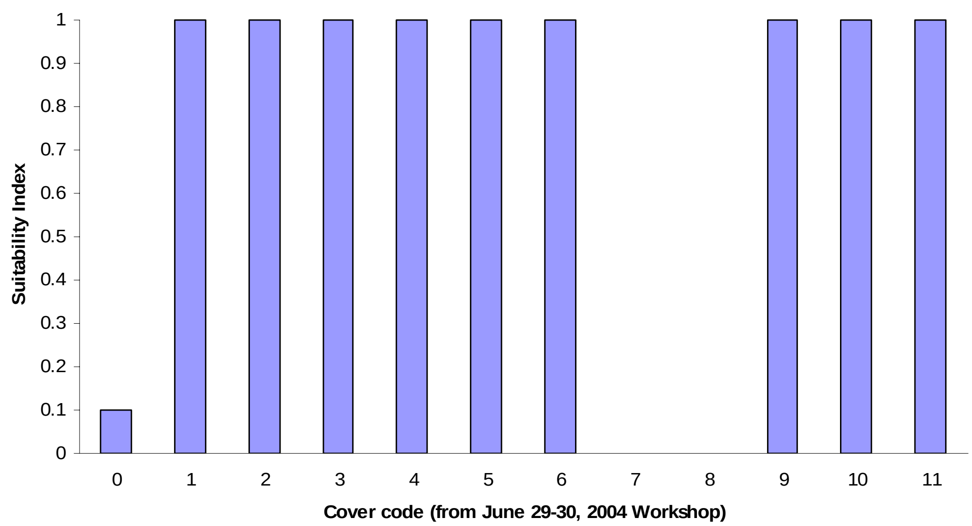




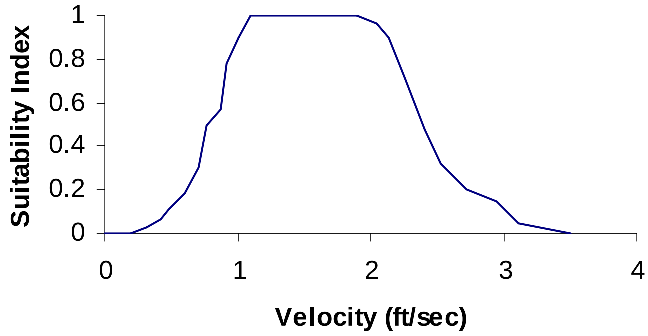
Bull trout-fluvial adult

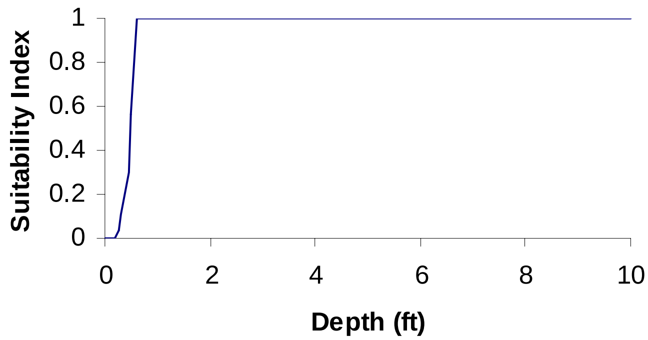


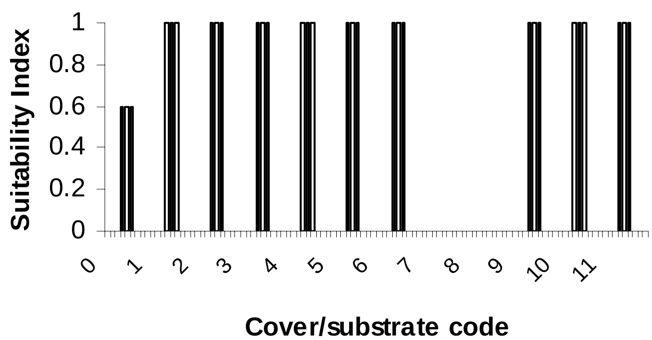




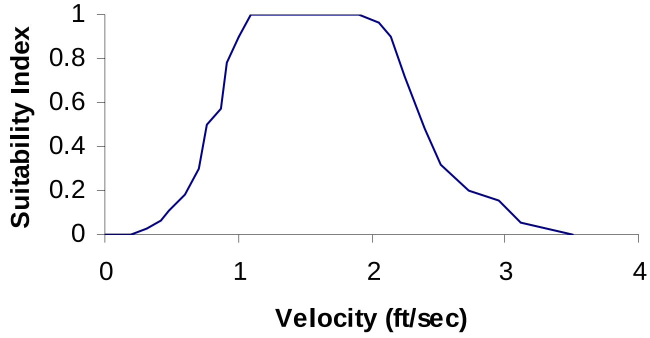
Bull trout-fluvial spawning

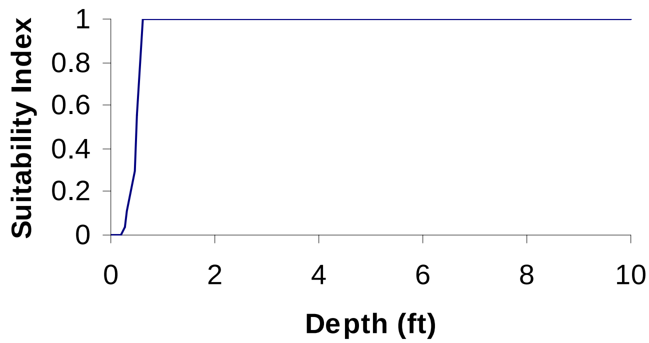


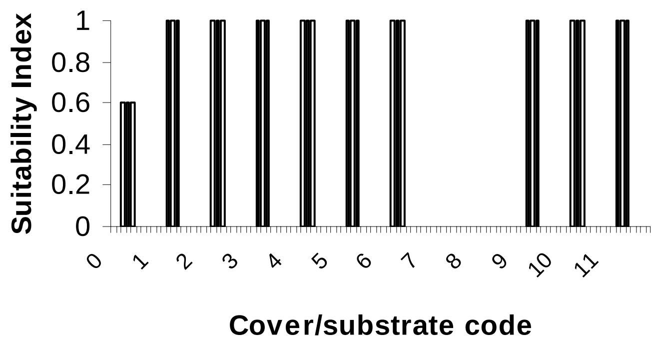




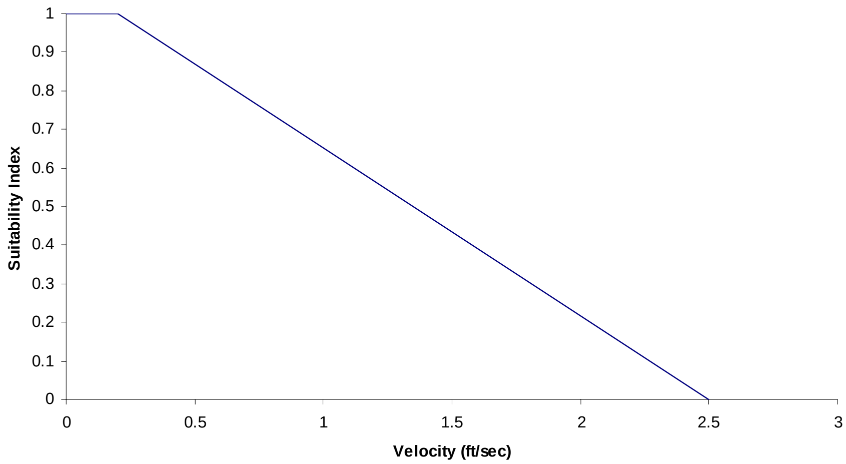
Bull trout-resident spawning

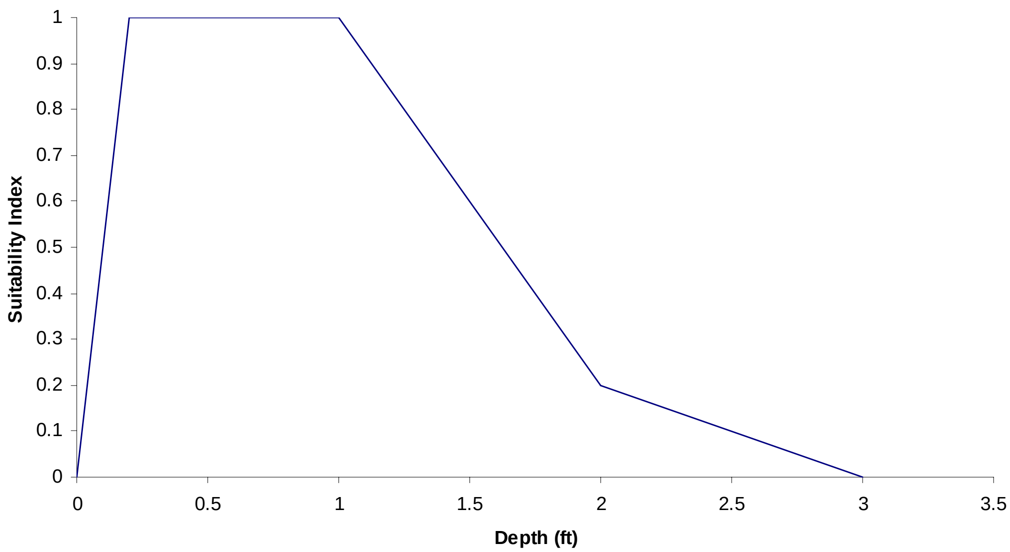


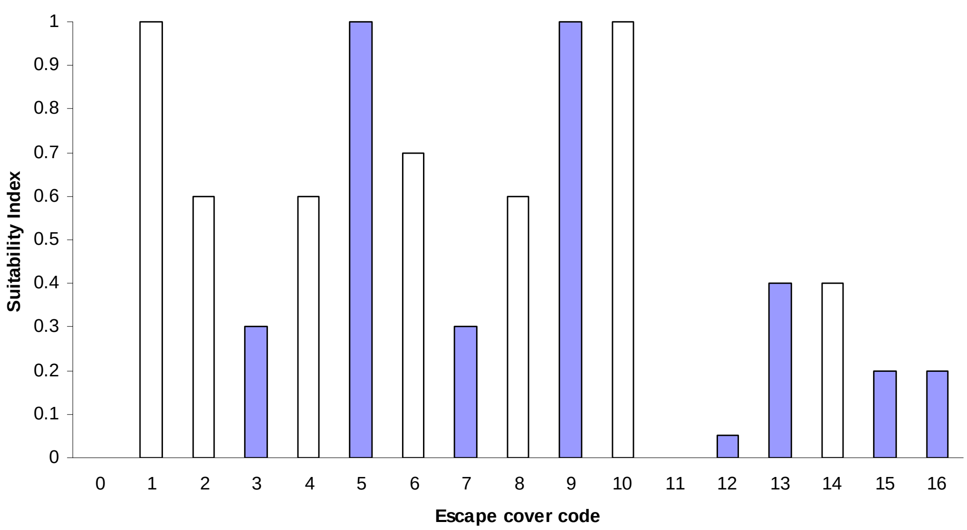




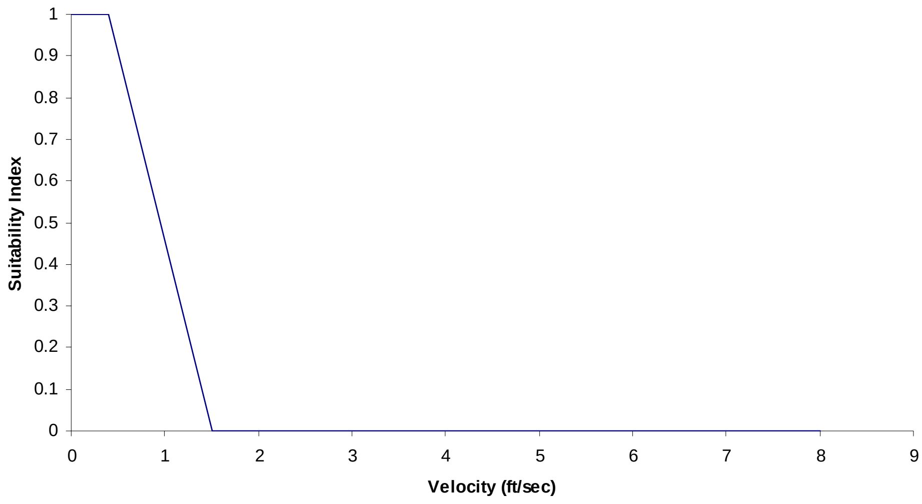
Steelhead fry

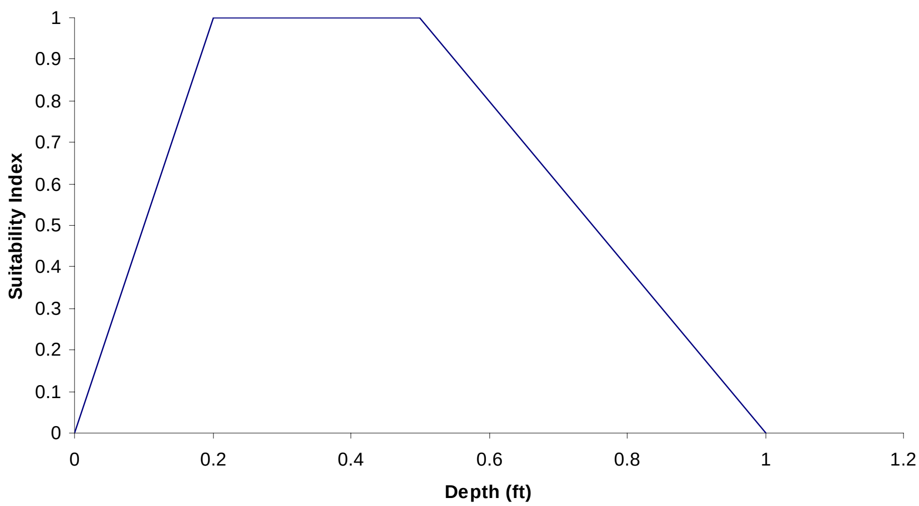


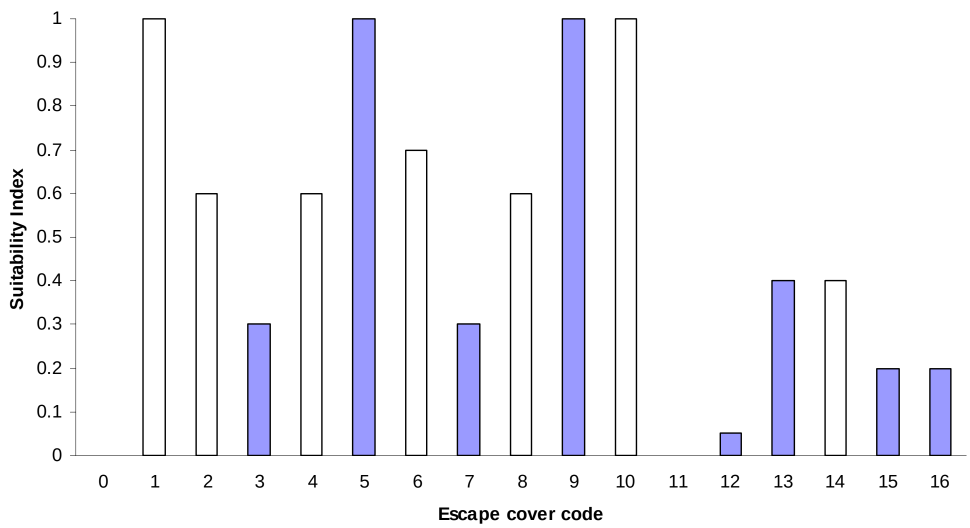




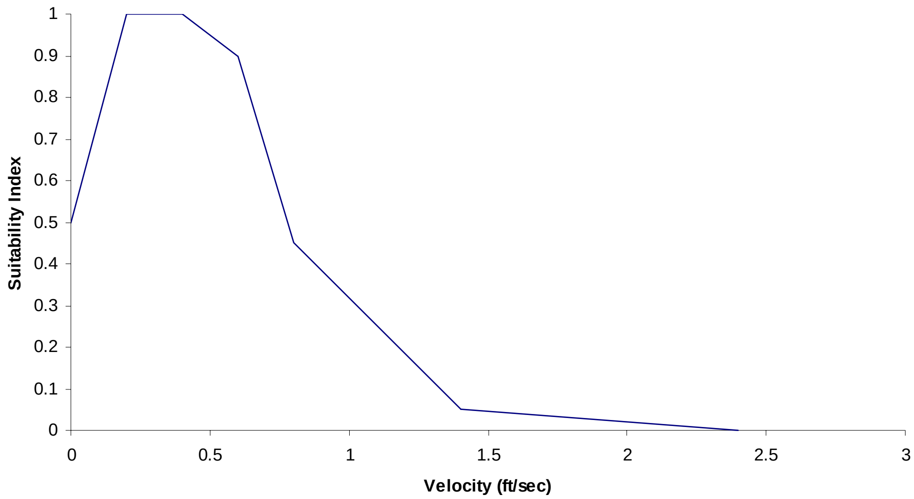
Bull trout fry

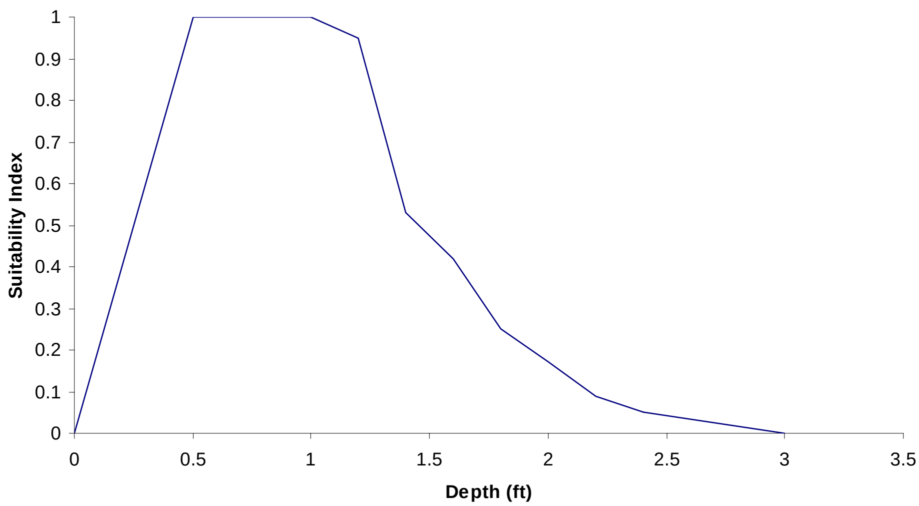


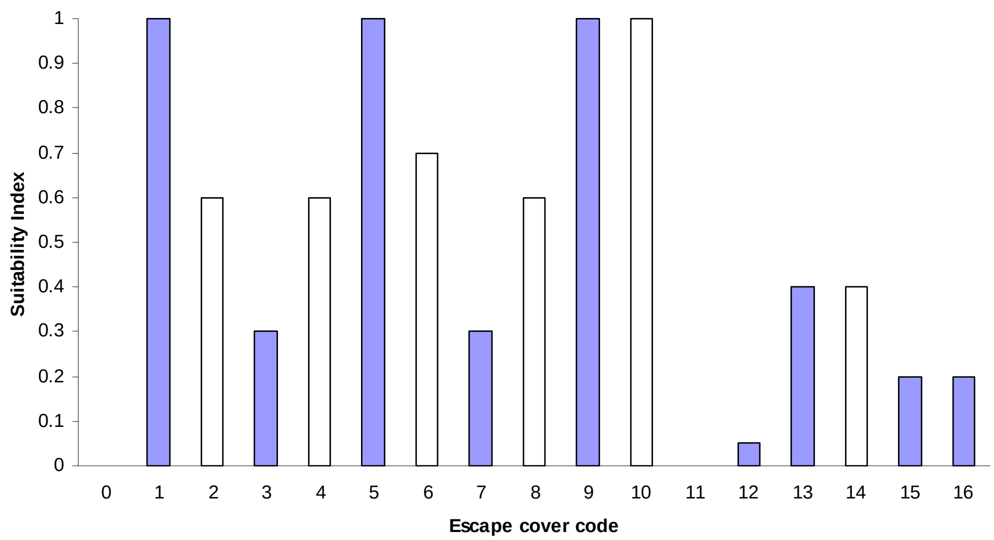




Chinook salmon fry







John Day Habitat Suitability Criteria (HSC) Workshop Notes
(June 29-30, 2004)
Ron Sutton, Bureau of Reclamation

June 29, 2004
Attendees:
Mark Croghan, Bureau of Reclamation
Ron Sutton, Bureau of Reclamation
Steve Ryan, Bureau of Reclamation
Rinda Tisdale-Hein, Bureau of Reclamation
Jim Henriksen, USGS
Terry Maret, USGS
Randy Tweten, NOAA Fisheries
John Kinney, Fish and Wildlife Service
Rick Kruger, Oregon Department of Fish and Wildlife
Tim Unterwegner, Oregon Department of Fish and Wildlife
Rich Gritz, Forest Service
Kathy Ramsey, Forest Service
John Morris, BLM
Larry Bright, Forest Service

June 29, 2004 - Jim Henriksen of the USGS gave an overview of PHABSIM

- assume most suitable index (SI) = 1.0, where you may always find fish
- velocity starts with mean column; can adjust to nose velocity
- assume channel is in equilibrium within the scale of time we are working
- types of HSCs
    - binary
    - normal distribution (rare)
    - variable distribution
    - conditional (e.g., cover, shallow water SI=1.0 or cover, deep water SI=1.0)
- Categories
    - Category I – profession opinion and literature
    - Category II – frequency distribution – can be biased by % of suitable habitat – need to sample full range of flows
    - Category III – preference – adjust for what's available – assume equal sampling effort
- verification studies – sample suitable cells so see if fish are present (assumes fully seeded streams) see Bovee and Thomas paper
    - determines accuracy of HSCs

John K. – is deep water cover? Treat depth as a conditional cover criteria – depth important for bull trout

Tim U. – temperature might not be suitable (e.g., EDT- 16˚C criteria showed no fish)
Rick K. – if water quality is not suitable, do not use PHABSIM; can incorporate temperature in the model; flow can affect temperature
Mark C. – after getting flow recommendations, then look at temperatures, then determine if it's worth acquiring more water. If you add hot water, what is the benefit? Work with local biologist on a case by case basis – also, look at riparian projects.

Jim H. discussed habitat options in PHABSIM:

- Minimum contiguous width – minimum width that a fish can occupy – may be too narrow for adult fish or a redd may need to be 4' wide
- Delete zero channel index – always "on"
- Near shore habitat factor – e.g., influenced by cover nearshore – large streams
- Habitat calculations:
    - Standard multiplicative (D*V*CI) – one low SI can draw down entire WUA
    - Geometric mean $(D*V*CI)^{1/3}$ - increases habitat - used most frequently

- Lowest limiting factor – use only lowest SI value
- Minimum effective composite SI – set minimum limit – only look at best SI – gives higher probability of suitable habitat
- Velocity
    - Mean column velocity (measured); nose velocity (computed) is slower
    - velocity shelters – cells always protected - need to manipulate transect data
- Adjacent velocity – for each cell location
- Variables – always use depths and velocities; substrate and cover optional

Mesohabitat units represent reach in proportion – vary cell lengths based on proportions – decide if you want to model entire reach or just where fish occur (e.g., pools for juveniles).

Species HSCs
Spring Chinook Spawning:
- most spawn in the mainstem John Day and Middle Fork John Day Rivers

Depth:
- they don't spawn in 10' feet deep water

Concensus – probably spawn in water deeper than 2'; flow dependent
- hard to compare the John Day to other systems
- John K. – complex – many variables to pin down
- Rick K. – use shallower depths because that is available

Concensus – see attached table
Velocity:
- tailout of pools
- can accept 0.8-1.5 ft/sec, but want to know nose velocity
- after reviewing literature curves, group decided to move maximum velocity to 2.5 ft/sec
- potential need to revisit velocity curve above 2.0 ft/sec- important to capture the tails – run habitat with and without tails

Concensus – see attached table
Substrate:
Concensus - use medium gravel to small cobble (SI=1.0) – see attached table

Randy T. - observed spawning constrained by current disturbed conditions- concerned about John Day HSCs not representing natural situation.
Jim H. asked what is baseline?
Tim U. – lost beavers, channelized the stream
John M. – has observed flows coming in subsurface in pastures – not seeing in wilderness settings that fish have changed spawning sites.
Randy T. – if we use these HSCs in this project, we need qualifiers of limitations of data sets – problem of describing current conditions in altered systems.
John K. – can always change HSCs – use these as a starting point
Jim H. – if biologists know another approach, use it, regardless of PHABSIM
Rick K. – HSCs should be on what fish prefer, not what we are doing- need observations under full range of conditions

The group decided to focus on steelhead since it is federally listed as threatened.
Steelhead Spawning:
Depth:
Tim U. – use pocketwater, wider variation; spawners observed at low water, but can only see at low water-limitation; some mainstem spawning in stream margins-mostly in drier years
Kathy – use smaller water, shallower depths than Chinook
John K. – suggested that lumping tributary and mainstem spawners could bias the results due to different adaptations
Rick K. – suggested running two options – see attached table

Velocities:
Tim U. – spawning occurs over wide range of velocities; steelhead spawners use cover to escape – redd can be located in "no cover"; with cover, habitat is better

Jim H. – suggested using minimum composite SI. Wanted group to think about habitat options.

The discussion shifted to “cover”.
Rick K. – recommended deleting fine organics, splitting grasses/bushes, and adding boulders, velocity shelters, and turbulence
John K. – has observed small fish in dark organics
Tim U. – agreed to add boulders
John M. – suggested adding cobbles for small fish
John K. and Randy T. – needed to know the number of cells with no cover – misleading to say 36 cells have a single log across a transect
Rick K. – in lower Klamath River, escape cover is 2’ distance and 0.4’ deep criteria
Jim H. – 1) distance to cover – same SI’s in adjacent cells
2) life stage specific cover – presence/absence by life stage
3) velocity shelter – could occur anywhere – nose velocity
Tim U. – irrigators start irrigation in early June; allowed to withdraw in April

Jim H. and Rick K. – cautioned the group to be careful assigning SI’s to individual cover types
Randy T. – three functions of cover – escape, velocity, and overhead (hiding) – assign a value of 1 to each function

Options:
-Run a sensitivity analysis – with and without cover
-Randy T. – increase “n” value to keep velocity low
-Terry M. – modeled only juvenile preferred habitats, such as pools
- minimum composite suitability – assign to keep velocities low

Tim U. – cover code SIs not the same
- need to rate codes from high to low
cover codes for fry and juvenile steelhead were rated based on the three functions above – see attached tables

Randy T. – is model sensitive enough to describe fry life stage? Suggest running model with and without fry cover
John K.-fry use margins and camouflage habitat

Jim H. – suggested only modeling the margin in riffles, using the inflection point in the wetted perimeter vs flow graph to pick higher flows to model. Only model distance to edge.
Rick K. – another option is to use the minimum effective composite SI – turn on at 0.8 – see Bovee and Thomas (25-75% range)

June 30, 2004
Attendees:
Mark Croghan, Bureau of Reclamation
Ron Sutton, Bureau of Reclamation
Steve Ryan, Bureau of Reclamation
Chelsie Morris, Bureau of Reclamation
Rinda Tisdale-Hein, Bureau of Reclamation
Randy Tweten, NOAA Fisheries
John Kinney, Fish and Wildlife Service
Rick Kruger, Oregon Department of Fish and Wildlife
Tim Unterwegner, Oregon Department of Fish and Wildlife
Rich Gritz, Forest Service
Kathy Ramsey, Forest Service
John Morris, BLM

Continued cover and velocity shelter discussion.
Velocity Shelters – record “VS” in field notes – doesn’t have to be on the transect – cover items are only on transect

If wood influences hydraulics, call it "large wood"-20" diameter and 20' long (less than this, called "bush") – judgment as functioning as large wood
Refer to ODFW protocol with questions about cover

Depth as cover? Distance to cover

- for spawning, if transect is on spawning gravels, look at nearest deep area; steelhead spawning cover attribute – looking for hiding cover in all cover types except fine organics and grass

Concensus that spawning needed a separate cover code

- juvenile cover is within a cell, spawning cover includes larger distances
- steelhead spawning cover code system examples:
    - substrate.cover SI
      3.0 – without cover 0.5 x 0.6 = 0.3
      3.1 – with cover 0.5 x 1.0 = 0.5
      4.0 – without cover 1.0 x 0.6 = 0.6
      4.1 – with cover 1.0 x 1.0 = 1.0
      5.0 – without cover 1.0 x 0.6 = 0.6
      5.1 – with cover 1.0 x 1.0 = 1.0
      6.0 – without cover 0.5 x 0.6 = 0.3, etc. – see attached table

Steelhead Fry:

- 90-99% of fry habitat covered by juvenile model

Concensus - do not model because PHABSIM model is not sensitive enough

Steelhead Juvenile:
Depth and velocity
Concensus – see attached table

Substrate and cover:

- Codes entered for each cell and apply Lostine SIs
- Coding system – Substrate.Cover (e.g., 1.2) – enter largest of substrate or cover (e.g. 6.1 SI = 1.0) – Ron S. will work out details with Rick K.

Steelhead Adult Holding:
Tim U. – steelhead do not hold in the John Day River system
Concensus - do not model.

Bull Trout Fry:
John M. – fry stay in margins in slow velocity in substrate
Tim U. – fry prefer slow moving water
John K. – fry found everywhere
Rick K – suggested not to model fry
Concensus – do not model fry

Bull Trout Juvenile and adult resident:

- Juvenile size - < 6" long; subadult – 250 mm; > 250 mm – fluvial – John M. has seen resident bull trout about 10" long and doesn't see fluvial behavior in fish <250 mm

Tim U. juveniles and adults have same habitat requirements

Depth:
John K. – disregard Lewis River HSCs – many large boulders in Lewis River
Concensus - see attached table

Velocity:

- Nose velocity only uses constant "n" value for entire reach (overall channel characteristic)

Concensus - run both mean column and nose velocity and check for differences in output using upper Salmon River HSCs

Substrate:
Concensus – do not model substrate for juveniles

Cover:
Concensus – see attached table

Bull Trout Adult Rearing >250 mm (?) - fluvial:
John K. – fluvial adults limited by depth and temperature
Concensus – see attached table

Bull Trout Adult Spawning:
- resident use smaller substrates than fluvial

Concensus – model resident and fluvial spawning separately – see attached table

Adult Passage:
Tim U. – could be an issue on the Middle Fork John Day River
- look for shallowest riffle in stream segment

Randy T. – questioned whether the right transects were selected
Tim U. – mentioned another shallow area below Camp Creek – Mark C. and Tim U. will look at it to determine if it is a bottleneck – if so, then this would be a new site to address just "passage"
Rick K. – discussed methodology – measure depths across shallowest transect at several flows until you meet Oregon depth criteria – get % of channel width that meets criteria; velocities don't apply to shallow riffles.
John M. – Oregon's passage criteria seems too deep – suggested modifying Oregon's criteria for just trout
John Day fish are smaller and use shallower depths
Concensus – adopt following criteria:
0.6' – adult steelhead, Chinook salmon, and fluvial bull trout
0.4' – juvenile steelhead, resident bull trout – see attached graphs

Chinook Salmon Juvenile:
Depths, velocities, substrate:
John M. – juveniles associated with cover and shallow water
Tim U. – juveniles not found in middle of deep pools based on electrofishing surveys
John K. – delete Swift bypass HSCs
Concensus – see attached table

Cover:
Concensus – use large of substrate or cover codes – see attached table
Example:
3.0 (substrate.cover) – use substrate SI
3.1 – use cover SI
– Ron S. will work out details with Rick K.

Chinook Adult Holding:
-related to cover and velocity shelters
Concensus – see attached table

Worksheets for fish use of microhabitat variables in the John Day River subbasin.

Species:_Steelhead – tributaries and mainstem

Life Stage:	Depth (ft)	Velocity (ft/sec)	Substrate	Cover
Fry -don't model-model not sensitive enough				Code-SI 0-0.0 1-0.3 2-0.3 3-1.0 4-1.0 5-0.6 6-NA 7-0.6 8-0.3 9-0.3 10-0.6 11-0.3 12-NA
Juvenile	Yes Depth (ft) SI 0.0 0 0.2 0 0.5 1.0 3.5 1.0 5.0 0	Yes Vel (ft/sec) SI 0 0 0.1 0 0.2 1.0 2.0 1.0 4.0 0	Yes Follow Lostine curve (R2 Resource 1998) except woody debris not applicable for substrate; Use raw data set-enter larger of substrate or cover-work out details with Rick Kruger	Code-SI 0-0.0 1-1.0 2-0.3 3-1.0 4-1.0 5-0.6 6-NA 7-0.0 8-0.3 9-0.6 10-0.6 11-0.3 12-NA
Adult holding Don't hold-Tim-don't model				
Adult Spawning	Yes Option 1- Depth (ft) SI 0.0 0 0.49 0 0.5 1.0 1.0 1.0 2.0 0.5 3.0 0.0 Option 2- Depth (ft) SI <0.5 0 ≥0.5 1.0	Yes Velocity (ft/sec) SI 0 0 0.49 0 0.5 0.5 0.99 0.5 1.0 1.0 3.5 1.0 3.51 0.5 4 0.5 4.01 0.2	Yes Range- Code 3– SI=0.5 Code 4,5-SI=1.0 Code 6-SI=0.5 Other codes-SI=0.0	Yes No cover-SI=0.6 With cover –SI=1.0-(conditional) Any codes except 7 or 8 within 30' upstream or downstream

Substrate codes:
0 – organic detritus
1 – silt, clay
2 – sand
3 – small gravel 0.1-0.5"
4 – med gravel 0.5-1.5"
5 – large gravel 1.5-3"
6 – small cobble 3-6"
7 – large cobble 6-12"
8 – boulder >12"
9 – bedrock

Cover codes:
0 – no cover
1 – undercut bank
2 – overhanging vegetation
3 - rootwad
4 - logjam
5 – large wood
6- spawning cover(dominant= codes3,4,5,11,12)
7 – fine organic substrate
8 – grass
9 – bushes
10 – boulders
11 – turbulence
12 – pool/run (use with code 6 spawning cover)

Species:_Bull Trout

Life Stage:	Depth (ft)	Velocity (ft/sec)	Substrate	Cover
Fry Don't model				
Juvenile and adult resident- 60-250 mm length	Depth SI 0 0 0.3 0 0.5 1.0 10 1.0	Velocity SI Mean column: 0 0 0.1 1.0 1.5 1.0 3.0 0.2 4.5 0 Nose velocity: Use upper Salmon criteria (EA Engineering 1991) Run both	Don't model-	All codes = 1.0, one cell adjacent = 1.0, except 7 and 8; 7 and 8, SI=0.0 no cover=0.1 check later
Adult rearing >250 mm (?)-fluvial	Depth SI 0 0 0.5 0 1.5 1.0 10 1.0	Velocity SI Mean column: 0 0 0.2 0 0.4 1.0 2.5 1.0 3.0 0.2 5 0.1 6 0 Nose velocity: Use upper Salmon criteria (EA Engineering 1991) Run both	Don't model-	All codes = 1.0, one cell adjacent = 1.0, except 7 and 8; 7 and 8, SI=0.0 no cover=0.1 check later
Adult Spawning-fluvial	Depth SI Use upper Salmon (EA Engineering 1991)	Use Pruitt and Nadeau (1978)	Codes 3,4,5- SI=1.0; other codes-SI=0	Yes-in tribs No cover-SI=0.6 With cover –SI=1.0-(conditional) Any codes except 7 or 8 within 10' radius
Adult Spawning-resident	Depth SI Use upper Salmon (EA Engineering 1991)	Use Pruitt and Nadeau (1978)	Codes 2,3,4-SI=1.0;other codes-SI=0	Yes-in tribs No cover-SI=0.6 With cover –SI=1.0-(conditional) Any codes except 7 or 8 within 5' radius

0 – organic detritus
1 – silt, clay
2 – sand
3 – small gravel 0.1-0.5"
4 – med gravel 0.5-1.5"
5 – large gravel 1.5-3"
6 – small cobble 3-6"
7 – large cobble 6-12"
8 – boulder >12"
9 – bedrock

0 – no cover
1 – undercut bank
2 – overhanging vegetation
3 - rootwad
4 - logjam
5 – large wood
6- spawning cover(dominant= codes3,4,5,11,12)
7 – fine organic substrate
8 – grass
9 – bushes
10 – boulders
11 – turbulence
12 – pool/run (use with code 6 spawning cover)

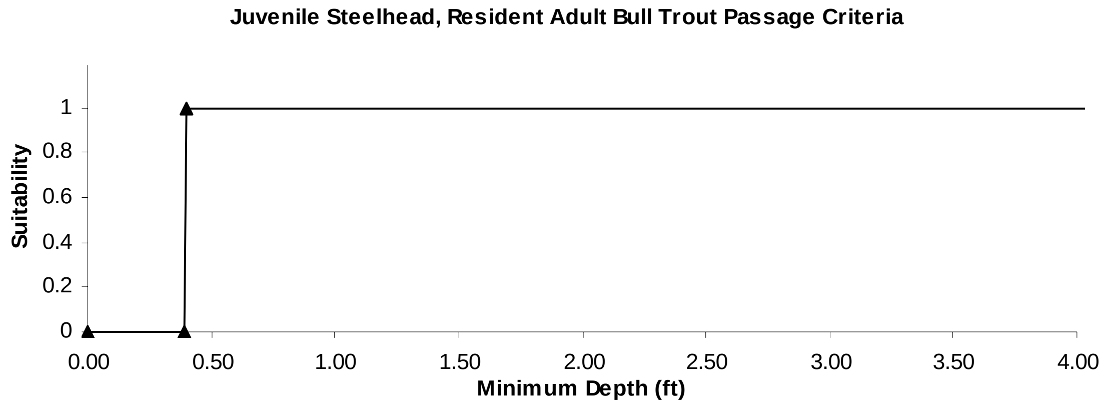
Species:_Spring Chinook Salmon

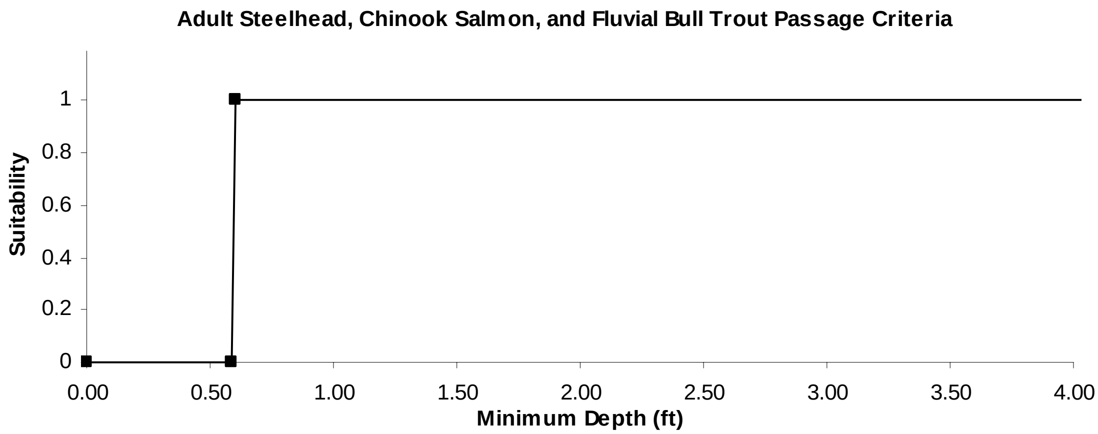
Life Stage:	Depth (ft)	Velocity (ft/sec)	Substrate	Cover
Fry Don't model				
Juvenile	Depth SI 0 0 0.2 0 0.5 0.5 0.8 1.0 2.5 1.0 4.5 0	Velocity SI 0 0 0.2 1.0 1.0 1.0 2.5 0	Codes SI 0 0 1 0 2 0.3 3 0.3 4 0.8 5 1.0 6 1.0 7 0.8 8 0.5 9 0	Enter larger of substrate or cover-work out details with Rick Kruger- Code-SI 0-0.0 1-1.0 2-0.3 3-1.0 4-1.0 5-0.6 6-NA 7-0.0 8-0.3 9-0.6 10-0.6 11-0.3 12-NA
Adult holding	Depth SI 0 0 1.0 0.25 2.0 0.5 3.0 1.0 10 1.0	Velocity SI 0 0 0.1 1.0 3.0 1.0 5.0 0	Don't model	Code-SI 0-0.0 1-1.0 2-1.0 3-1.0 4-1.0 5-1.0 6-NA 7-0 8-0 9-0 10-1.0 11-1.0 12-1.0
Adult Spawning	yes range- Depth (ft) SI 0.67 0.5 1 0.5 1.01 1.0 1.5 1.0 1.51 0.5 2 0.5 2.01 0.25 4 0.25	Yes Range- 0.8-2.5 -ft/sec mean column-1.0 SI need to revisit-run sensitivity on with and w/o tails-generate nose velocities	Yes Codes 4,5,6-1.0 SI-concensus	no

Substrate codes:
0 – organic detritus
1 – silt, clay
2 – sand
3 – small gravel 0.1-0.5"
4 – med gravel 0.5-1.5"
5 – large gravel 1.5-3"
6 – small cobble 3-6"
7 – large cobble 6-12"
8 – boulder >12"
9 – bedrock

Cover codes:
0 – no cover
1 – undercut bank
2 – overhanging vegetation
3 - rootwad
4 - logjam
5 – large wood
6- spawning cover(dominant= codes3,4,5,11,12)
7 – fine organic substrate
8 – grass
9 – bushes
10 – boulders
11 – turbulence
12 – pool/run (use with code 6 spawning cover)

Adult Passage Criteria:





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R2 Resource Consultants, Inc. 1998. Lostine River instream flow study. Final Report. Prepared for Nez Perce Tribe and Oregon Dept. of Fish and Wildlife.

John Day River Instream Flow Workshop Notes
July 25-26, 2005
Ron Sutton, Bureau of Reclamation

July 25, 2005
Attendees:
Ron Sutton, Reclamation
Chelsie Morris, Reclamation
Jim Morrow, NMFS
Terry Maret, USGS
Eric Rothwell, NMFS
Randy Tweeten, NMFS
Mark Croghan, Reclamation
Tim Unterwegner, Oregon Department Fish and Wildlife
Rick Kruger, Oregon Department Fish and Wildlife
Thom Hardy, Utah State University

Dr. Thom Hardy gave a presentation on escape cover for fry and juvenile salmonids.

1) 1-d modeling on transects – note what features are escape cover and how far away; cover does not have to be on the transect – judgement – distance and cover definition are key information

Distance to cover suitability criteria can be either binary or continuous – 0.4 depth threshold for Chinook fry used in Klamath River

Missing data in John Day –

a) within threshold distance in a radius around each transect vertical, distance and identity to juvenile and fry escape cover – problem if velocity at escape cover location is not suitable and not on transect – judgement
b) HSC fish observations in John Day
c) Escape cover (EC) modifier is not in current USGS version of PHABSIM $(D * V * CI)^{1/3} * EC$ – the EC variable has more effect on result – USGS is currently revising the model to incorporate EC – should be done by end of September.

Comment from Terry Maret – in small streams, entire channel can be 1.0 EC suitability because distance to EC covers the width of the stream – driven by depth and velocity in that case.

2) 2-d modeling – Thom's model searches distances around nodes – looks 360º - area-weighted average preferred for assigning final suitability index at node
3) Thom showed Klamath example with and without EC; less flow, more habitat without EC compared to with EC. EC was only on river's edge – quantity and quality of habitat differed (being published). Vegetative EC given SI = 1.0; hard substrate SI = 0.17.

Ron Sutton showed current PHABSIM WUA vs Q results for juvenile Chinook and steelhead compared to available hydrology in John Day – less flow did not always result less habitat, particularly for steelhead, depending on stream reach, and no major problems were consistently apparent when compared to available natural hydrology estimates.

Most of the group wanted a re-run of John Day PHABSIM using EC because of importance of EC to juvenile and fry salmonids. Tim Unterwegner noted that fry bull trout use sedges in shallow water; bull trout juvenile behavior not much different than steelhead and Chinook.

Escape cover-

a) fry – similar among species – 0-55 mm length
b) steelhead and Chinook juveniles – 55-150 mm

Cover codes for use in 1-d modeling – Thom Hardy will send EC categories and SI coding from Klamath River (recently revised by Gary Smith) – 22 codes – use to re-code EC in the field – use for steelhead, Chinook, and bull trout. In the field, record distance to cover code (threshold distances from Klamath River - 2 ft for fry; 6 ft for juveniles). Also record what cover is present (all cover types). In the model, use binary coding -

Threshold depths – assume minimum depth is average body depth of fish – get information from Tim Unterwegner.

Velocity in EC – if > maximum velocity of HSC @ 0.0 (SI) – binary:
1 if < threshold maximum velocity
0 if > threshold maximum velocity

On transect- for pools, make a note if there is a significant depth within depth threshold when scanning

Snorkeling for fish – if not on transect, look at morphology and record similarity compared to transect – note locations of fish on a map – do fish observations in fall after temperature influences fish locations – Tim Unterwegner said there are good numbers of juveniles in Middle Fork John Day – try to get 50-100 observations with 1-50 fish per observation – labor about 2 days/site – ask Jim Henriksen how to do the snorkeling to match attributes of where you find fish with same attributes along transects.

Group developed concensus for using depth and velocity HSCs for steelhead and Chinook fry. Rick Kruger will check with McKenzie River HSCs before agreeing to bull trout fry HSCs. See attached table.

Group discussed various optional HSCs from first workshop in June, 2004.
Steelhead Spawning Depth:
Concensus – see attached table
Chinook Spawning Velocity:
Ron Sutton ran another optional HSC – spawning velocity of 0.0 should not have an SI = 0.0
Concensus – see attached table

July 26, 2005
Attendees:
Ron Sutton – Reclamation
Chelsie Morris – Reclamation
Mark Croghan – Reclamation
Terry Maret, USGS
Randy Tweeten, NMFS
Tim Unterwegner, Oregon Department Fish and Wildlife
Rick Kruger, Oregon Department Fish and Wildlife

Bull trout juvenile and adults
Bull trout nose vs mean column velocity HSCs. Compared WUA results – discussed pluses and minuses of using mean column and nose velocities with different WUA results.
Concensus – see attached table – use only nose velocity

Chinook Salmon Adult Holding
Reclamation will record velocity shelters (VS) in field along each transect as they measure escape cover for juveniles. Also, identify distance and cover type at each cell and take photos of each transect.

Group discussed value of cover and substrate.
Concensus-
Holding cover SI = 1.0
Substrate SI = 0.5
Enter larger of substrate or cover-see attached table

Depth HSC adjusted to give some depth (0.5 ft) before SI > 0.0
Concensus – see attached table

HSC decisions at workshop:

Species: Chinook Salmon____________________

Life Stage:	Depth (ft)	Velocity (ft/sec)	Substrate	Cover
Fry	Taken primarily from Klamath site-specific Depth SI 0 0 0.5 1.0 1.0 1.0 1.2 0.95 1.4 0.53 1.6 0.42 1.8 0.25 2.0 0.17 2.2 0.09 2.4 0.05 3.0 0	Taken primarily from Klamath envelope and site-specific Velocity SI 0 0.5 0.2 1.0 0.4 1.0 0.6 0.9 0.8 0.45 1.4 0.05 2.4 0		
Adult holding	Depth SI 0 0.0 0.5 0.0 2.0 0.5 3.0 1.0 100 1.0		All substrate codes, SI = 0.5 Enter larger of substrate or cover	No cover, SI = 0.5; All cover codes, SI = 1.0
Spawning		Velocity SI 0.5 0 1.0 1.0 2.5 1.0 4.0 0		

Species:__Steelhead___________________

Life Stage:	Depth (ft)	Velocity (ft/sec)
Fry	Depth SI 0 0 0.2 1.0 1.0 1.0 2.0 0.2 3.0 0	Velocity SI 0 1.0 0.2 1.0 2.5 0
Adult Spawning	Depth SI < 0.5 0 ≥ 0.5 1.0	

Species:__Bull trout___________________

Life Stage:	Depth (ft)	Velocity (ft/sec)
Fry	Depth SI 0 0 0.2 1.0 0.5 1.0 1.0 0	Velocity SI 0 1.0 0.4 1.0 1.5 0 same as upper Salmon
Juvenile and adult resident- 60-250 mm length		Use nose velocity: Velocity SI 0 1.0 0.4 1.0 1.5 0 same as upper Salmon
Adult rearing- >250 mm - fluvial		Use nose velocity: Velocity SI 0 1.0 0.4 1.0 1.5 0 same as upper Salmon

Appendix D – Weighted Usable Area (WUA) Versus Discharge Relationships

Table D-1. Weighted usable area (WUA) versus discharge relationships for fluvial spawning and resident spawning bull trout at John Day River – Cottonwood Galley.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft		Percent of maximum habitat	
		Fluvial spawning	Resident spawning	Fluvial spawning	Resident spawning
20	29895	3916	1009	62.3	42.7
30	32911	4855	1375	77.2	58.2
40	34563	5414	1616	86.1	68.4
44	35026	5629	1687	89.5	71.4
50	35553	5904	1808	93.9	76.5
60	36313	6244	2069	99.3	87.6
70	37071	6287	2259	100.0	95.6
80	37802	6177	2363	98.2	100.0
83	37874	6061	2333	96.4	98.7
90	38829	6023	2334	95.8	98.8
100	40491	5872	2313	93.4	97.9
110	41193	5657	2328	90.0	98.5
120	41599	5408	2309	86.0	97.7
130	42197	5116	2266	81.4	95.9
140	42662	4768	2207	75.8	93.4
150	43487	4450	2127	70.8	90.0
160	43960	4156	2052	66.1	86.9
170	44302	3814	1981	60.7	83.8
175	44600	3672	1946	58.4	82.3

Table D-2. Weighted usable area (WUA) versus discharge relationships for bull trout fry, juveniles, and adults at John Day River – Cottonwood Galley.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft			Percent of maximum habitat		
		Fry	Juvenile and adult resident	Adult fluvial	Fry	Juvenile and adult resident	Adult fluvial
20	29895	4828	3710	4293	98.8	83.4	82.3
30	32911	4889	4039	4800	100.0	90.8	92.1
40	34563	4777	4245	5103	97.7	95.5	97.9
44	35026	4578	4314	5213	93.6	97.0	100.0
50	35553	4615	4397	5207	94.4	98.9	99.9
60	36313	4519	4425	5079	92.4	99.5	97.4
70	37071	4317	4447	4750	88.3	100.0	91.1
80	37802	3854	4248	4380	78.8	95.5	84.0
90	38829	3900	4213	4048	79.8	94.7	77.6
100	40491	4237	4215	3854	86.7	94.8	73.9
110	41193	4342	4171	3689	88.8	93.8	70.8
120	41599	4247	4171	3676	86.9	93.8	70.5
130	42197	4224	4157	3591	86.4	93.5	68.9
140	42662	4183	4186	3514	85.6	94.1	67.4
150	43487	4180	4295	3464	85.5	96.6	66.5
160	43960	4171	4273	3401	85.3	96.1	65.2
170	44302	4150	4230	3291	84.9	95.1	63.1
175	44600	4252	4352	3278	87.0	97.9	62.9

Table D-3. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at John Day River – Cottonwood Galley.

Discharge	Total	WUA (ft^2)/1000 ft				Percent of maximum habitat			
(cfs)	(ft^2)/1000 ft	Spawning	Holding	Fry	Juvenile	Spawning	Holding	Fry	Juvenile
20	29895	4060	6279	5421	4047	30.0	40.7	100.0	80.4
30	32911	6688	7901	5325	4482	49.4	51.2	98.2	89.1
40	34563	8671	9394	5201	4702	64.0	60.9	95.9	93.4
44	35026	9344	9986	5179	4740	69.0	64.7	95.5	94.2
50	35553	9853	10571	5154	4943	72.7	68.5	95.1	98.2
60	36313	11556	11512	4981	5032	85.3	74.6	91.9	100.0
70	37071	12097	12350	4702	4736	89.3	80.0	86.7	94.1
80	37802	12382	13086	4359	4345	91.4	84.8	80.4	86.4
83	37874	12434	13180	4205	4140	91.8	85.4	77.6	82.3
90	38829	13074	13676	4296	4120	96.5	88.6	79.3	81.9
100	40491	13391	14238	4530	4039	98.8	92.3	83.6	80.3
110	41193	13549	14775	4645	3956	100.0	95.8	85.7	78.6
120	41599	13164	15165	4661	3971	97.2	98.3	86.0	78.9
130	42197	12738	15358	4723	4003	94.0	99.5	87.1	79.6
140	42662	11925	15428	4745	4090	88.0	100.0	87.5	81.3
150	43487	11435	15416	4830	4146	84.4	99.9	89.1	82.4
160	43960	10759	15289	4817	4103	79.4	99.1	88.9	81.5
170	44302	9818	14942	4736	3932	72.5	96.8	87.4	78.1
175	44600	9336	14940	4797	3925	68.9	96.8	88.5	78.0

Table D-4. Weighted usable area (WUA) versus discharge relationships for steelhead at John Day River – Cottonwood Galley.

Discharge	Total	WUA (ft^2)/1000 ft			Percent of maximum habitat		
(cfs)	(ft^2)/1000 ft	Spawning	Fry	Juvenile	Spawning	Fry	Juvenile
20	29895	7479	7601	4724	42.7	95.2	62.7
30	32911	10602	7918	5671	60.6	99.2	75.3
40	34563	12236	7981	6360	69.9	100.0	84.4
44	35026	12777	7933	6584	73.0	99.4	87.4
50	35553	13335	7971	6940	76.2	99.9	92.1
60	36313	14666	7760	7323	83.8	97.2	97.2
70	37071	14997	7190	7530	85.7	90.1	100.0
80	37802	15905	6692	7496	90.9	83.8	99.5
83	37874	16006	6459	7403	91.5	80.9	98.3
90	38829	16535	6517	7501	94.5	81.7	99.6
100	40491	16861	6699	7534	96.3	83.9	100.0
110	41193	17404	6730	7516	99.4	84.3	99.8
120	41599	17502	6706	7485	100.0	84.0	99.4
130	42197	17256	6653	7380	98.6	83.4	98.0
140	42662	16933	6652	7153	96.8	83.3	95.0
150	43487	16778	6700	7025	95.9	83.9	93.2
160	43960	16391	6694	6850	93.7	83.9	90.9
170	44302	16046	6550	6619	91.7	82.1	87.9
175	44600	15816	6618	6501	90.4	82.9	86.3

Table D-5. Weighted usable area (WUA) versus discharge relationships for fluvial spawning and resident spawning bull trout at Reynolds Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft		Percent of maximum habitat	
		Fluvial spawning	Resident spawning	Fluvial spawning	Resident spawning
8	18293	1663	795	65.1	36.8
10	19170	1751	899	68.5	41.6
12	20211	1889	1015	73.9	47.0
14	20727	1978	1093	77.4	50.6
16	21099	2112	1168	82.7	54.1
18	21381	2406	1402	94.1	64.9
20	21681	2493	1502	97.6	69.5
22	21897	2540	1583	99.4	73.2
24	22290	2550	1672	99.8	77.4
26	22600	2554	1759	100.0	81.4
28	22837	2555	1825	100.0	84.4
30	23102	2514	1874	98.4	86.7
32	23369	2467	1919	96.5	88.8
34	23600	2467	1959	96.6	90.6
36	23761	2455	2001	96.1	92.6
38	24407	2469	2039	96.6	94.4
40	24559	2477	2075	97.0	96.0
42	24709	2479	2107	97.0	97.5
44	24857	2478	2134	97.0	98.7
46	24999	2470	2161	96.7	100.0

Table D-6. Weighted usable area (WUA) versus discharge relationships for bull trout fry, juveniles, and adults at Reynolds Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft			Percent of maximum habitat		
		Fry	Juvenile and adult resident	Adult fluvial	Fry	Juvenile and adult resident	Adult fluvial
8	18293	4522	4100	1878	95.3	81.0	58.2
10	19170	4613	4230	2077	97.3	83.6	64.4
12	20211	4727	4274	2206	99.7	84.5	68.4
14	20727	4743	4309	2306	100.0	85.2	71.5
16	21099	4730	4571	2475	99.7	90.4	76.7
18	21381	4388	4625	2576	92.5	91.4	79.9
20	21681	4390	4752	2615	92.6	93.9	81.1
22	21897	4256	4789	2636	89.7	94.7	81.7
24	22290	4213	4889	2665	88.8	96.6	82.6
26	22600	4164	4910	2712	87.8	97.1	84.1
28	22837	4176	4989	2745	88.1	98.6	85.1
30	23102	4171	5059	2737	87.9	100.0	84.9
32	23369	4090	4993	2627	86.2	98.7	81.4
34	23600	3994	4947	2726	84.2	97.8	84.5
36	23761	3886	4897	2817	81.9	96.8	87.3
38	24407	3761	4773	2920	79.3	94.4	90.5
40	24559	3746	4724	2995	79.0	93.4	92.9
42	24709	3746	4722	3047	79.0	93.4	94.5
44	24857	3734	4742	3104	78.7	93.7	96.2
46	24999	3692	4738	3225	77.8	93.7	100.0

Table D-7. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Reynolds Creek.

Discharge	Total	WUA (ft^2)/1000 ft				Percent of maximum habitat			
(cfs)	(ft^2)/1000 ft	Spawning	Holding	Fry	Juvenile	Spawning	Holding	Fry	Juvenile
8	18293	1049	2476	4923	4469	35.0	34.6	99.7	85.3
10	19170	1236	2882	4922	4660	41.3	40.3	99.7	88.9
12	20211	1389	3190	4938	4833	46.4	44.6	100.0	92.2
14	20727	1516	3517	4906	4894	50.6	49.2	99.4	93.4
16	21099	1743	3961	4912	5003	58.2	55.4	99.5	95.4
18	21381	1989	4287	4602	5018	66.4	60.0	93.2	95.7
20	21681	2096	4531	4674	5108	70.0	63.4	94.7	97.4
22	21897	2274	4744	4658	5179	75.9	66.3	94.3	98.8
24	22290	2614	4961	4609	5202	87.3	69.4	93.3	99.2
26	22600	2674	5171	4588	5242	89.3	72.3	92.9	100.0
28	22837	2649	5411	4508	5193	88.5	75.7	91.3	99.1
30	23102	2666	5678	4393	5114	89.0	79.4	89.0	97.6
32	23369	2658	5864	4263	4953	88.8	82.0	86.3	94.5
34	23600	2658	6070	4265	4901	88.8	84.9	86.4	93.5
36	23761	2605	6306	4249	4877	87.0	88.2	86.0	93.0
38	24407	2732	6528	4245	4856	91.2	91.3	86.0	92.6
40	24559	2892	6687	4275	4780	96.6	93.5	86.6	91.2
42	24709	2889	6818	4286	4742	96.5	95.3	86.8	90.5
44	24857	2908	6955	4291	4737	97.1	97.3	86.9	90.4
46	24999	2994	7151	4296	4703	100.0	100.0	87.0	89.7

Table D-8. Weighted usable area (WUA) versus discharge relationships for steelhead at Reynolds Creek.

Discharge	Total	WUA (ft^2)/1000 ft			Percent of maximum habitat		
(cfs)	(ft^2)/1000 ft	Spawning	Fry	Juvenile	Spawning	Fry	Juvenile
8	18293	1720	6494	5346	41.8	94.7	69.1
10	19170	2159	6592	5862	52.4	96.1	75.8
12	20211	2394	6747	6303	58.1	98.4	81.5
14	20727	2721	6775	6575	66.1	98.8	85.0
16	21099	2919	6859	6651	70.9	100.0	86.0
18	21381	3149	6680	6910	76.4	97.4	89.4
20	21681	3247	6686	7102	78.8	97.5	91.8
22	21897	3383	6656	7288	82.1	97.0	94.2
24	22290	3456	6585	7451	83.9	96.0	96.4
26	22600	3457	6567	7625	83.9	95.7	98.6
28	22837	3606	6478	7689	87.5	94.4	99.4
30	23102	3635	6377	7733	88.3	93.0	100.0
32	23369	3692	6222	7688	89.6	90.7	99.4
34	23600	3942	6173	7652	95.7	90.0	99.0
36	23761	3924	6146	7627	95.3	89.6	98.6
38	24407	4068	6151	7626	98.7	89.7	98.6
40	24559	4086	6125	7584	99.2	89.3	98.1
42	24709	4074	6105	7534	98.9	89.0	97.4
44	24857	4119	6066	7482	100.0	88.4	96.8
46	24999	4098	6031	7409	99.5	87.9	95.8

Table D-9. Weighted usable area (WUA) versus discharge relationships for fluvial spawning and resident spawning bull trout at Middle Fork John Day River-Camp Creek to Big Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Fluvial spawning	WUA (ft^2)/1000 ft Resident spawning	Percent of maximum habitat Fluvial spawning	Percent of maximum habitat Resident spawning
10	33530	1422	191	28.8	18.5
20	38774	2691	397	54.5	38.5
29	42974	3289	531	66.6	51.4
30	43300	3386	540	68.6	52.3
40	45510	3906	631	79.1	61.1
50	46874	4350	726	88.1	70.3
60	48151	4692	819	95.0	79.3
63	48549	4743	849	96.1	82.2
80	50344	4918	924	99.6	89.4
100	51487	4938	981	100.0	94.9
120	52488	4818	1005	97.6	97.3
140	53462	4637	1021	93.9	98.8
160	54662	4404	1015	89.2	98.3
180	55868	4081	1024	82.6	99.1
200	56748	3763	1031	76.2	99.8
220	57677	3436	1027	69.6	99.4
240	58476	3029	1033	61.3	100.0
260	59214	2693	995	54.5	96.3
279	59984	2374	948	48.1	91.7
280	60007	2363	946	47.9	91.6

Table D-10. Weighted usable area (WUA) versus discharge relationships for bull trout fry, juveniles, and adults at Middle Fork John Day River-Camp Creek to Big Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Fry	WUA (ft^2)/1000 ft Juvenile and adult resident	WUA (ft^2)/1000 ft Adult fluvial	Percent of maximum habitat Fry	Percent of maximum habitat Juvenile and adult resident	Percent of maximum habitat Adult fluvial
10	33530	7798	6661	5968	95.3	64.5	40.5
20	38774	8058	8666	9314	98.4	83.9	63.3
29	42974	8186	9150	11192	100.0	88.6	76.0
30	43300	8179	9290	11518	99.9	90.0	78.2
40	45510	7973	9895	13005	97.4	95.8	88.3
50	46874	7186	10328	13880	87.8	100.0	94.3
60	48151	5925	10067	14322	72.4	97.5	97.3
63	48549	5641	9922	14367	68.9	96.1	97.6
80	50344	5623	10042	14726	68.7	97.2	100.0
100	51487	5402	9988	14460	66.0	96.7	98.2
120	52488	5250	9939	14093	64.1	96.2	95.7
140	53462	5020	9610	13392	61.3	93.0	90.9
160	54662	4832	9200	12533	59.0	89.1	85.1
180	55868	4642	8659	11659	56.7	83.8	79.2
200	56748	4460	8101	10755	54.5	78.4	73.0
220	57677	4355	7594	9829	53.2	73.5	66.7
240	58476	4332	7152	9008	52.9	69.3	61.2
260	59214	4321	6808	8360	52.8	65.9	56.8
280	60007	4336	6396	7550	53.0	61.9	51.3

Table D-11. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Middle Fork John Day River-Camp Creek to Big Boulder Creek.

Discharge	Total	WUA (ft^2)/1000 ft				Percent of maximum habitat			
(cfs)	(ft^2)/1000 ft	Spawning	Holding	Fry	Juvenile	Spawning	Holding	Fry	Juvenile
10	33530	591	4872	7908	7024	3.8	17.5	88.9	62.5
20	38774	3192	8587	8514	9050	20.6	30.9	95.8	80.5
29	42974	5027	11151	8770	9834	32.5	40.1	98.6	87.4
30	43300	5639	11540	8796	9988	36.4	41.5	98.9	88.8
40	45510	7347	13552	8891	10819	47.5	48.7	100.0	96.2
50	46874	8999	15189	8734	11247	58.1	54.6	98.2	100.0
60	48151	10511	16685	8130	11222	67.9	60.0	91.5	99.8
63	48549	10688	17064	7895	11052	69.0	61.3	88.8	98.3
80	50344	12062	19218	7665	10669	77.9	69.1	86.2	94.9
100	51487	13148	21164	7252	10070	84.9	76.1	81.6	89.5
120	52488	14133	22897	6778	9421	91.3	82.3	76.2	83.8
140	53462	14863	24334	6345	8680	96.0	87.5	71.4	77.2
160	54662	14895	25422	6052	8163	96.2	91.4	68.1	72.6
180	55868	15378	26432	5873	7661	99.3	95.0	66.1	68.1
200	56748	15480	27134	5598	7298	100.0	97.5	63.0	64.9
220	57677	14750	27575	5389	6828	95.3	99.1	60.6	60.7
240	58476	13860	27764	5182	6287	89.5	99.8	58.3	55.9
260	59214	13068	27820	4989	5697	84.4	100.0	56.1	50.7
279	59984	12359	27631	4884	5323	79.8	99.3	54.9	47.3
280	60007	12313	27623	4884	5323	79.5	99.3	54.9	47.3

Table D-12. Weighted usable area (WUA) versus discharge relationships for steelhead at Middle Fork John Day River-Camp Creek to Big Boulder Creek.

Discharge	Total	WUA (ft^2)/1000 ft			Percent of maximum habitat		
(cfs)	(ft^2)/1000 ft	Spawning	Fry	Juvenile	Spawning	Fry	Juvenile
10	33530	1798	9584	7665	11.6	77.1	49.5
20	38774	5575	10879	9959	35.9	87.5	64.3
29	42974	7185	11792	10916	46.2	94.9	70.4
30	43300	8023	11908	11087	51.6	95.8	71.5
40	45510	8887	12428	12106	57.2	100.0	78.1
50	46874	10464	12407	13166	67.3	99.8	84.9
60	48151	11055	12092	13838	71.1	97.3	89.3
63	48549	11171	11869	13978	71.9	95.5	90.2
80	50344	12489	11471	14662	80.3	92.3	94.6
100	51487	13607	10813	15118	87.5	87.0	97.5
120	52488	14855	10016	15431	95.6	80.6	99.6
140	53462	15365	9234	15499	98.8	74.3	100.0
160	54662	15365	8924	15304	98.8	71.8	98.7
180	55868	15545	8706	15089	100.0	70.1	97.4
200	56748	15438	8460	14746	99.3	68.1	95.1
220	57677	15399	8106	14250	99.1	65.2	91.9
240	58476	15068	7737	13643	96.9	62.3	88.0
260	59214	14733	7297	12929	94.8	58.7	83.4
279	59984	14487	7052	12335	93.2	56.7	79.6
280	60007	14476	7051	12318	93.1	56.7	79.5

Table D-13. Weighted usable area (WUA) versus discharge relationships for fluvial spawning and resident spawning bull trout at Middle Fork John Day River-Caribou Creek to Vincent Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft		Percent of maximum habitat	
		Fluvial spawning	Resident spawning	Fluvial spawning	Resident spawning
6	23124	954	94	34.5	21.5
10	24086	1569	136	56.7	31.1
20	26006	2324	275	84.0	62.9
30	27641	2671	406	96.5	93.0
40	29236	2766	437	99.9	100.0
50	30860	2768	436	100.0	100.0
60	31670	2668	425	96.4	97.2
70	32440	2512	389	90.7	89.1
80	33467	2364	363	85.4	83.0
90	34387	2220	343	80.2	78.5
100	35264	2045	324	73.9	74.3
110	36100	1876	297	67.8	68.1
120	37104	1681	265	60.7	60.6
130	38053	1481	236	53.5	54.1
140	38889	1307	204	47.2	46.7
150	39686	1144	170	41.3	39.0
160	40080	1017	151	36.7	34.5
170	40772	823	127	29.7	29.2
175	41110	761	119	27.5	27.3

Table D-14. Weighted usable area (WUA) versus discharge relationships for bull trout fry, juvenile, and adults at Middle Fork John Day River- Caribou Creek to Vincent Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft			Percent of maximum habitat		
		Fry	Juvenile and adult resident	Adult fluvial	Fry	Juvenile and adult resident	Adult fluvial
6	23124	4860	6517	9030	100.0	84.0	67.4
10	24086	4277	7028	10507	88.0	90.6	78.4
20	26006	3427	7510	12340	70.5	96.8	92.1
30	27641	3234	7569	13138	66.5	97.5	98.1
40	29236	3344	7598	13397	68.8	97.9	100.0
50	30860	3501	7750	13340	72.0	99.8	99.6
60	31670	3508	7757	13179	72.2	99.9	98.4
70	32440	3352	7761	12929	69.0	100.0	96.5
80	33467	3492	7686	12567	71.9	99.0	93.8
90	34387	3513	7643	12189	72.3	98.5	91.0
100	35264	3639	7552	11864	74.9	97.3	88.6
110	36100	3780	7384	11420	77.8	95.1	85.2
120	37104	3953	7184	10983	81.4	92.6	82.0
130	38053	4117	7036	10497	84.7	90.7	78.4
140	38889	4350	6900	9936	89.5	88.9	74.2
150	39686	4546	6743	9372	93.5	86.9	70.0
160	40080	4583	6478	8723	94.3	83.5	65.1
170	40772	4749	6338	8247	97.7	81.7	61.6
175	41110	4781	6230	8054	98.4	80.3	60.1

Table D-15. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Middle Fork John Day River- Caribou Creek to Vincent Creek.

Discharge	Total	WUA (ft^2)/1000 ft				Percent of maximum habitat			
(cfs)	(ft^2)/1000 ft	Spawning	Holding	Fry	Juvenile	Spawning	Holding	Fry	Juvenile
6	23124	847	6002	6772	5701	8.2	33.3	100.0	78.8
10	24086	2813	7424	6685	6456	27.3	41.1	98.7	89.2
20	26006	6810	9559	6149	7129	66.0	53.0	90.8	98.5
30	27641	8927	11053	5570	7213	86.5	61.2	82.3	99.7
40	29236	9922	12195	5466	7236	96.1	67.6	80.7	100.0
50	30860	10266	13182	5522	7146	99.5	73.0	81.5	98.8
60	31670	10322	14008	5492	6942	100.0	77.6	81.1	95.9
70	32440	10168	14736	5368	6641	98.5	81.7	79.3	91.8
80	33467	10135	15358	5336	6381	98.2	85.1	78.8	88.2
90	34387	10038	15904	5265	6144	97.3	88.1	77.8	84.9
100	35264	9699	16392	5217	5932	94.0	90.8	77.0	82.0
110	36100	9472	16821	5137	5670	91.8	93.2	75.9	78.4
120	37104	9027	17234	5083	5479	87.5	95.5	75.1	75.7
130	38053	8752	17526	5088	5304	84.8	97.1	75.1	73.3
140	38889	8223	17782	5139	5219	79.7	98.5	75.9	72.1
150	39686	7925	17912	5211	5149	76.8	99.3	76.9	71.2
160	40080	7268	17886	5175	4964	70.4	99.1	76.4	68.6
170	40772	6576	18008	5225	4845	63.7	99.8	77.2	67.0
175	41110	6410	18047	5261	4798	62.1	100.0	77.7	66.3

Table D-16. Weighted usable area (WUA) versus discharge relationships for steelhead at Middle Fork John Day River- Caribou Creek to Vincent Creek.

Discharge	Total	WUA (ft^2)/1000 ft			Percent of maximum habitat		
(cfs)	(ft^2)/1000 ft	Spawning	Fry	Juvenile	Spawning	Fry	Juvenile
6	23124	1949	7836	5067	17.5	98.6	54.0
10	24086	4105	7879	5805	36.9	99.1	61.8
20	26006	7351	7931	6888	66.1	99.8	73.4
30	27641	9558	7901	7457	86.0	99.4	79.4
40	29236	10100	7933	7828	90.9	99.8	83.4
50	30860	10633	7948	8260	95.7	100.0	88.0
60	31670	10832	7774	8685	97.5	97.8	92.5
70	32440	10937	7522	8942	98.4	94.6	95.2
80	33467	11029	7363	9209	99.2	92.6	98.1
90	34387	11115	7251	9307	100.0	91.2	99.1
100	35264	11043	7185	9390	99.3	90.4	100.0
110	36100	10992	7136	9371	98.9	89.8	99.8
120	37104	10917	7159	9293	98.2	90.1	99.0
130	38053	10738	7178	9269	96.6	90.3	98.7
140	38889	10539	7242	9180	94.8	91.1	97.8
150	39686	10385	7339	9133	93.4	92.3	97.3
160	40080	10099	7254	8889	90.9	91.3	94.7
170	40772	9683	7232	8618	87.1	91.0	91.8
175	41110	9575	7243	8515	86.1	91.1	90.7

Table D-17. Weighted usable area (WUA) versus discharge relationships for fluvial spawning and resident spawning bull trout at Granite Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Fluvial spawning	WUA (ft^2)/1000 ft Resident spawning	Percent of maximum habitat Fluvial spawning	Percent of maximum habitat Resident spawning
2	12572	52	44	3.6	6.7
3	13858	94	81	6.5	12.2
4	15081	123	103	8.5	15.6
6	16290	213	150	14.8	22.7
8	17142	343	221	23.8	33.4
10	17727	463	287	32.2	43.4
12	18108	638	351	44.4	53.0
14	18492	796	409	55.4	61.9
16	18772	907	462	63.0	69.8
18	19070	973	477	67.6	72.0
20	19514	1020	490	70.9	74.0
22	19978	1054	506	73.2	76.5
24	20417	1134	521	78.8	78.8
26	20833	1196	533	83.1	80.6
28	21166	1261	544	87.6	82.3
30	21326	1311	553	91.1	83.5
32	21492	1377	564	95.7	85.2
34	21656	1406	574	97.7	86.7
35	21744	1420	578	98.7	87.3
36	21823	1426	589	99.1	89.0
38	21983	1435	604	99.7	91.4
40	22142	1439	619	100.0	93.5
42	22305	1437	629	99.8	95.0
44	22510	1433	639	99.6	96.6
46	22710	1414	646	98.3	97.7
50	23081	1344	656	93.4	99.2
52	23260	1322	657	91.9	99.3
54	23433	1298	662	90.2	100.0

Table D-18. Weighted usable area (WUA) versus discharge relationships for bull trout fry, juveniles, and adults at Granite Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Fry	WUA Juvenile and adult resident	WUA Adult fluvial	Percent of maximum habitat Fry	Percent Juvenile and adult resident	Percent Adult fluvial
2	12572	2949	1839	1142	76.4	55.5	39.9
3	13858	3102	2149	1467	80.4	64.9	51.3
4	15081	3497	2364	1650	90.6	71.3	57.7
6	16290	3790	2819	2022	98.2	85.1	70.7
8	17142	3861	3100	2390	100.0	93.6	83.5
10	17727	3815	3184	2530	98.8	96.1	88.4
12	18108	3724	3255	2593	96.5	98.2	90.6
14	18492	3625	3204	2678	93.9	96.7	93.6
16	18772	3488	3100	2638	90.3	93.6	92.2
18	19070	3424	3124	2635	88.7	94.3	92.1
20	19514	3445	3144	2636	89.2	94.9	92.1
22	19978	3507	3222	2683	90.8	97.2	93.8
24	20417	3562	3276	2756	92.3	98.9	96.3
26	20833	3615	3314	2838	93.7	100.0	99.2
28	21166	3605	3270	2861	93.4	98.7	100.0
30	21326	3542	3163	2840	91.7	95.5	99.3
32	21492	3436	3059	2825	89.0	92.3	98.7
34	21656	3341	2979	2791	86.6	89.9	97.6
35	21744	3242	2888	2740	84.0	87.2	95.8
36	21823	3205	2843	2704	83.0	85.8	94.5
38	21983	3213	2813	2695	83.2	84.9	94.2
40	22142	3235	2828	2715	83.8	85.3	94.9
42	22305	3224	2802	2698	83.5	84.5	94.3
44	22510	3261	2872	2708	84.5	86.7	94.6
46	22710	3303	2922	2708	85.5	88.2	94.6
50	23081	3348	2964	2696	86.7	89.4	94.2
52	23260	3377	2982	2705	87.5	90.0	94.5
54	23433	3398	2992	2730	88.0	90.3	95.4

Table D-19. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Granite Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Spawning	Holding	Fry	Juvenile	Percent of maximum habitat Spawning	Holding	Fry	Juvenile
2	12572	0	788	2806	1900	0.0	12.3	76.7	46.2
3	13858	14	1086	2990	2348	0.6	16.9	81.8	57.0
4	15081	17	1275	3263	2750	0.7	19.8	89.2	66.8
6	16290	20	1691	3529	3341	0.9	26.3	96.5	81.2
8	17142	105	2246	3632	3747	4.5	35.0	99.3	91.0
10	17727	131	2703	3657	3980	5.5	42.1	100.0	96.7
12	18108	153	3055	3582	4117	6.5	47.5	98.0	100.0
14	18492	256	3480	3406	4024	10.9	54.2	93.2	97.8
16	18772	939	3838	3277	3875	39.7	59.7	89.6	94.1
18	19070	1095	4164	3280	3932	46.4	64.8	89.7	95.5
20	19514	1361	4475	3295	3849	57.7	69.6	90.1	93.5
22	19978	1456	4755	3338	3826	61.7	74.0	91.3	92.9
24	20417	1560	5014	3368	3838	66.1	78.0	92.1	93.2
26	20833	1699	5265	3387	3758	71.9	81.9	92.6	91.3
28	21166	1943	5469	3412	3662	82.3	85.1	93.3	89.0
30	21326	2146	5706	3352	3564	90.9	88.8	91.7	86.6
32	21492	2269	5874	3271	3457	96.1	91.4	89.5	84.0
34	21656	2202	5997	3098	3273	93.2	93.3	84.7	79.5
35	21744	2361	6053	3018	3129	100.0	94.2	82.5	76.0
36	21823	2362	6093	3020	3022	100.0	94.8	82.6	73.4
38	21983	2327	6182	3027	2964	98.6	96.2	82.8	72.0
40	22142	2324	6279	3041	2899	98.4	97.7	83.2	70.4
42	22305	2168	6335	3056	2863	91.8	98.6	83.6	69.5
44	22510	2110	6406	3086	2815	89.3	99.7	84.4	68.4
46	22710	2090	6425	3106	2779	88.5	100.0	84.9	67.5
50	23081	1965	6426	3170	2822	83.2	100.0	86.7	68.6
52	23260	1921	6383	3202	2819	81.3	99.3	87.6	68.5
54	23433	1804	6346	3242	2845	76.4	98.8	88.7	69.1

Table D-20. Weighted usable area (WUA) versus discharge relationships for steelhead at Granite Boulder Creek.

Discharge	Total	WUA (ft^2)/1000 ft			Percent of maximum habitat		
(cfs)	(ft^2)/1000 ft	Spawning	Fry	Juvenile	Spawning	Fry	Juvenile
2	12572	0	3778	1901	0.0	70.9	30.1
3	13858	56	4122	2573	1.3	77.4	40.8
4	15081	56	4537	3082	1.3	85.2	48.9
6	16290	119	4952	3893	2.8	93.0	61.7
8	17142	926	5205	4518	22.1	97.7	71.6
10	17727	1303	5327	4989	31.0	100.0	79.1
12	18108	1498	5297	5363	35.7	99.4	85.0
14	18492	1986	5146	5617	47.3	96.6	89.0
16	18772	2441	4924	5785	58.1	92.4	91.7
18	19070	2735	4916	5950	65.1	92.3	94.3
20	19514	2980	4867	6131	71.0	91.4	97.2
22	19978	3022	4881	6259	72.0	91.6	99.2
24	20417	3075	4915	6308	73.2	92.3	100.0
26	20833	3153	4895	6304	75.1	91.9	99.9
28	21166	3408	4844	6203	81.2	90.9	98.3
30	21326	3526	4765	6131	84.0	89.5	97.2
32	21492	3487	4694	6005	83.1	88.1	95.2
34	21656	3494	4575	5898	83.2	85.9	93.5
35	21744	3478	4465	5797	82.8	83.8	91.9
36	21823	3459	4403	5713	82.4	82.7	90.6
38	21983	3612	4383	5583	86.0	82.3	88.5
40	22142	3748	4373	5496	89.3	82.1	87.1
42	22305	4004	4379	5430	95.4	82.2	86.1
44	22510	4029	4377	5354	96.0	82.2	84.9
46	22710	4198	4404	5294	100.0	82.7	83.9
50	23081	4105	4414	5257	97.8	82.9	83.3
52	23260	4087	4453	5166	97.4	83.6	81.9
54	23433	4035	4441	5110	96.1	84.3	81.0

Table D-21. Weighted usable area (WUA) versus discharge relationships for fluvial spawning and resident spawning bull trout at Dad's Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft		Percent of maximum habitat	
		Fluvial spawning	Resident spawning	Fluvial spawning	Resident spawning
0.1	5611	0	0	0.0	0.0
0.5	6518	0	2	0.0	0.6
1	6920	0	8	0.0	1.7
1.5	7070	26	31	6.6	7.2
2	7189	69	68	17.3	15.8
2.5	7294	106	99	26.7	22.8
3	7391	161	145	40.6	33.6
3.5	7477	215	192	54.1	44.4
4	7556	262	230	66.0	53.1
4.5	7646	288	256	72.3	59.2
5	7859	316	287	79.4	66.4
5.5	7970	332	309	83.6	71.4
6	8682	346	325	87.1	75.2
6.5	8795	360	340	90.6	78.6
7	8899	378	357	95.0	82.6
7.5	8999	391	371	98.3	85.8
8	9094	397	378	99.8	87.5
8.5	9184	398	383	100.0	88.5
9	9269	394	397	99.1	91.8
9.5	9352	389	407	97.9	94.1
10	9429	384	414	96.5	95.8
10.5	9505	375	418	94.3	96.7
11	9580	373	423	93.7	97.8
11.5	9650	369	429	92.8	99.1
12	9720	366	432	92.0	100.0
12.5	9786	359	430	90.3	99.4
13	9870	353	428	88.7	99.0
13.5	9951	340	426	85.6	98.5
14	10031	322	421	80.9	97.5
14.5	10108	303	412	76.2	95.2

Table D-22. Weighted usable area (WUA) versus discharge relationships for bull trout fry, juveniles, and adults at Dad's Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Fry	Juvenile and adult resident	Adult fluvial	Percent of maximum habitat Fry	Juvenile and adult resident	Adult fluvial
0.5	6518	2439	460	118	96.7	50.3	25.2
1	6920	2523	595	224	100.0	65.0	47.9
1.5	7070	2428	729	260	96.2	79.7	55.7
2	7189	2328	751	275	92.3	82.1	58.9
2.5	7294	2155	896	402	85.4	97.9	86.0
3	7391	2016	915	425	79.9	100.0	91.1
3.5	7477	1846	867	467	73.1	94.8	100.0
4	7556	1676	783	431	66.4	85.6	92.2
4.5	7646	1560	715	413	61.8	78.1	88.4
5	7859	1406	621	344	55.7	67.9	73.7
5.5	7970	1353	570	296	53.6	62.3	63.4
6	8682	1579	606	269	62.6	66.3	57.6
6.5	8795	1607	618	290	63.7	67.5	62.1
7	8899	1615	604	287	64.0	66.0	61.4
7.5	8999	1602	582	278	63.5	63.6	59.6
8	9094	1612	567	304	63.9	62.0	65.1
8.5	9184	1639	560	312	65.0	61.2	66.7
9	9269	1648	542	309	65.3	59.3	66.2
9.5	9352	1678	537	325	66.5	58.7	69.5
10	9429	1694	522	326	67.1	57.1	69.8
10.5	9505	1720	513	325	68.2	56.1	69.6
11	9580	1741	500	323	69.0	54.7	69.2
11.5	9650	1767	496	321	70.0	54.2	68.7
12	9720	1790	487	317	71.0	53.3	67.8
12.5	9786	1812	478	307	71.8	52.3	65.8
13	9870	1845	504	309	73.1	55.0	66.2
13.5	9951	1874	540	323	74.3	59.0	69.1
14	10031	1903	556	326	75.4	60.8	69.8
14.5	10108	1931	569	335	76.5	62.2	71.7

Table D-23. Weighted usable area (WUA) versus discharge relationships for Chinook salmon at Dad's Creek.

Discharge	Total	WUA (ft^2)/1000 ft				Percent of maximum habitat			
(cfs)	(ft^2)/1000 ft	Spawning	Holding	Fry	Juvenile	Spawning	Holding	Fry	Juvenile
0.1	5611	0	29	1353	230	0.0	1.9	61.8	14.4
0.5	6518	0	77	1900	646	0.0	4.9	86.8	40.5
1	6920	7	150	2155	1014	0.7	9.6	98.4	63.6
1.5	7070	26	178	2190	1246	2.5	11.4	100.0	78.1
2	7189	52	195	2173	1345	4.9	12.5	99.2	84.3
2.5	7294	128	318	2086	1501	12.1	20.4	95.2	94.0
3	7391	143	362	1967	1576	13.6	23.2	89.8	98.8
3.5	7477	294	426	1823	1596	27.9	27.3	83.2	100.0
4	7556	301	462	1697	1588	28.5	29.6	77.5	99.5
4.5	7646	301	500	1585	1543	28.5	32.0	72.4	96.7
5	7859	301	572	1506	1436	28.5	36.6	68.8	90.0
5.5	7970	301	602	1451	1338	28.5	38.5	66.2	83.9
6	8682	304	709	1604	1356	28.8	45.3	73.2	85.0
6.5	8795	363	796	1591	1307	34.4	50.9	72.7	81.9
7	8899	541	842	1559	1253	51.2	53.9	71.2	78.5
7.5	8999	576	875	1528	1176	54.6	56.0	69.8	73.7
8	9094	608	986	1520	1080	57.6	63.1	69.4	67.7
8.5	9184	682	1036	1513	1009	64.6	66.3	69.1	63.2
9	9269	669	1205	1500	972	63.4	77.1	68.5	60.9
9.5	9352	740	1314	1511	924	70.1	84.1	69.0	57.9
10	9429	898	1381	1515	908	85.1	88.4	69.2	56.9
10.5	9505	826	1425	1530	881	78.2	91.2	69.9	55.2
11	9580	842	1453	1537	876	79.8	92.9	70.2	54.9
11.5	9650	816	1479	1553	916	77.3	94.7	70.9	57.4
12	9720	911	1509	1571	929	86.3	96.5	71.8	58.2
12.5	9786	889	1520	1588	935	84.3	97.3	72.5	58.6
13	9870	869	1548	1615	943	82.3	99.0	73.7	59.1
13.5	9951	841	1563	1633	935	79.7	100.0	74.6	58.6
14	10031	1055	1562	1658	938	100.0	99.9	75.7	58.8
14.5	10108	1020	1550	1677	933	96.7	99.2	76.6	58.5

Table D-24. Weighted usable area (WUA) versus discharge relationships for steelhead at Dad's Creek.

Discharge	Total	WUA (ft^2)/1000 ft			Percent of maximum habitat		
(cfs)	(ft^2)/1000 ft	Spawning	Fry	Juvenile	Spawning	Fry	Juvenile
0.1	5611	0	1990	180	0.0	69.0	7.2
0.5	6518	0	2559	739	0.0	88.8	29.8
1	6920	123	2790	1189	4.8	96.8	48.0
1.5	7070	223	2860	1520	8.6	99.2	61.3
2	7189	455	2884	1660	17.6	100.0	67.0
2.5	7294	570	2872	1878	22.1	99.6	75.8
3	7391	634	2842	2016	24.6	98.5	81.4
3.5	7477	732	2788	2112	28.4	96.7	85.2
4	7556	804	2704	2215	31.1	93.8	89.4
4.5	7646	876	2596	2272	33.9	90.0	91.7
5	7859	914	2470	2316	35.4	85.7	93.4
5.5	7970	962	2382	2346	37.3	82.6	94.7
6	8682	1372	2569	2456	53.1	89.1	99.1
6.5	8795	1510	2533	2478	58.4	87.8	100.0
7	8899	1510	2485	2475	58.4	86.2	99.9
7.5	8999	1767	2424	2459	68.4	84.1	99.2
8	9094	1788	2336	2413	69.2	81.0	97.4
8.5	9184	2388	2287	2370	92.5	79.3	95.6
9	9269	2491	2249	2374	96.5	78.0	95.8
9.5	9352	2583	2196	2339	100.0	76.2	94.4
10	9429	2536	2194	2289	98.2	76.1	92.4
10.5	9505	2519	2183	2209	97.5	75.7	89.1
11	9580	2554	2200	2176	98.9	76.3	87.8
11.5	9650	2537	2186	2183	98.2	75.8	88.1
12	9720	2482	2197	2159	96.1	76.2	87.1
12.5	9786	2476	2207	2150	95.9	76.6	86.8
13	9870	2476	2229	2144	95.9	77.3	86.5
13.5	9951	2443	2241	2119	94.6	77.7	85.5
14	10031	2440	2261	2087	94.4	78.4	84.2
14.5	10108	2495	2268	2035	96.6	78.7	82.1

Appendix E – Weighted Usable Area (WUA) Versus Discharge Relationships for Fry and Juveniles using Klamath River Escape Cover Coding System

Table E-1. Weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at upper John Day River – Cottonwood Galley.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout fry	Chinook salmon fry	Steelhead fry	Percent of maximum habitat Bull trout fry	Chinook salmon fry	Steelhead fry
20	29895	2605	2461	3190	44.1	37.8	35.6
30	32911	3289	3137	4053	55.7	48.2	45.3
40	34563	3907	3718	4859	66.1	57.1	54.3
44	35026	4021	3906	5104	68.1	60.0	57.0
50	35553	4262	4158	5450	72.1	63.9	60.9
60	36313	4597	4502	5906	77.8	69.2	66.0
70	37071	4741	4671	6187	80.3	71.8	69.1
80	37802	4596	4712	6400	77.8	72.4	71.5
90	38829	4909	4945	6809	83.1	76.0	76.0
100	40491	5609	5536	7589	95.0	85.1	84.7
110	41193	5907	5895	8065	100.0	90.6	90.1
120	41599	5843	6076	8360	98.9	93.4	93.4
130	42197	5839	6255	8596	98.9	96.2	96.0
140	42662	5815	6347	8729	98.4	97.6	97.5
150	43487	5826	6505	8927	98.6	100.0	99.7
160	43960	5784	6487	8955	97.9	99.7	100.0
170	44302	5753	6374	8766	97.4	98.0	97.9
175	44600	5867	6437	8830	99.3	98.9	98.6

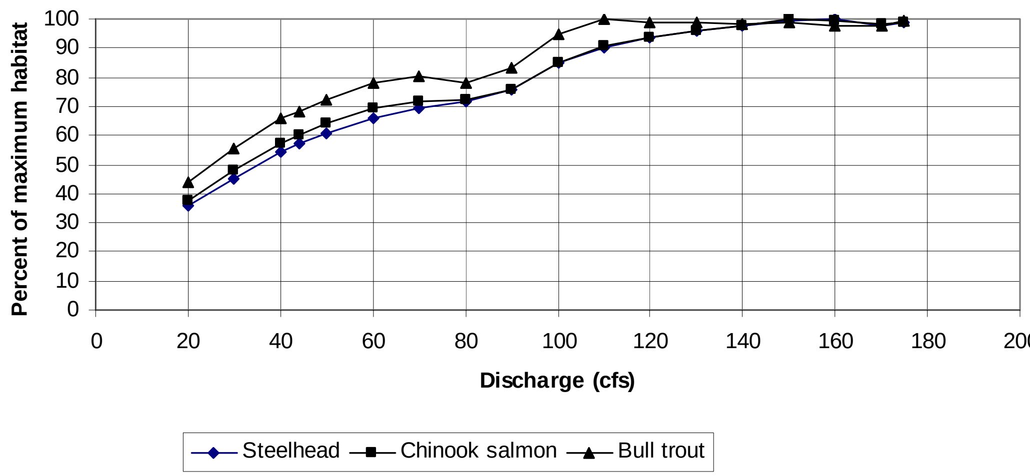

Figure E-1. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at upper John Day River – Cottonwood galley.

Table E-2. Weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at upper John Day River – Cottonwood Galley.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile	Percent of maximum habitat Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile
20	29895	2685	2797	2913	40.7	40.4	32.7
30	32911	3483	3583	3996	52.8	51.8	44.9
40	34563	4041	4219	4810	61.2	61.0	54.0
44	35026	4294	4482	5103	65.0	64.8	57.3
50	35553	4535	4843	5520	68.7	70.0	62.0
60	36313	4869	5437	6206	73.7	78.6	69.7
70	37071	5324	5701	6819	80.6	82.4	76.6
80	37802	5443	5701	7194	82.4	82.4	80.8
90	38829	5674	5745	7502	85.9	83.0	84.3
100	40491	5826	5969	7852	88.2	86.3	88.2
110	41193	5987	6061	8151	90.7	87.6	91.6
120	41599	6155	6353	8500	93.2	91.8	95.5
130	42197	6262	6566	8685	94.8	94.9	97.6
140	42662	6330	6749	8678	95.9	97.5	97.5
150	43487	6587	6919	8830	99.8	100.0	99.2
160	43960	6509	6800	8900	98.6	98.3	100.0
170	44302	6369	6409	8859	96.5	92.6	99.5
175	44600	6603	6388	8840	100.0	92.3	99.3

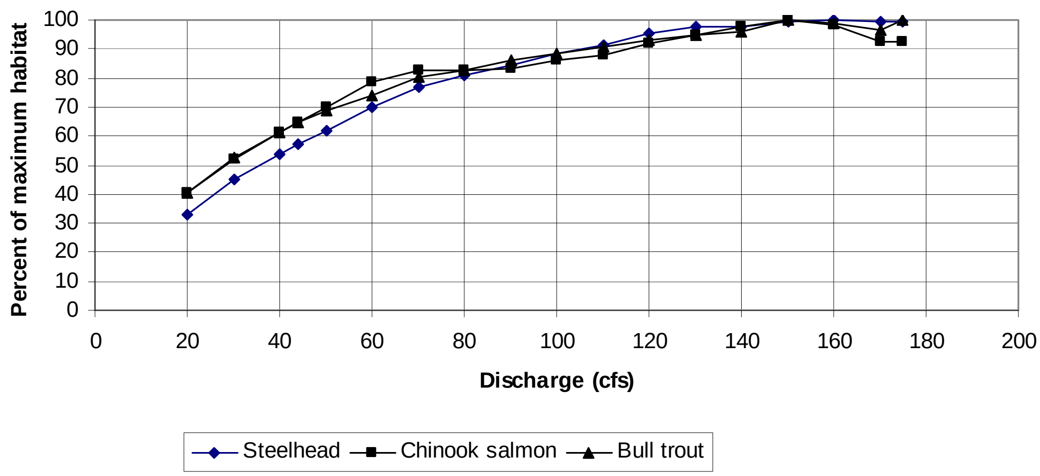

Figure E-2. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at upper John Day River – Cottonwood galley.

Table E-3. Weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Reynolds Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout fry	Chinook salmon fry	Steelhead fry	Percent of maximum habitat Bull trout fry	Chinook salmon fry	Steelhead fry
8	18293	4319	4598	6104	91.7	97.4	92.1
10	19170	4426	4621	6236	94.0	97.9	94.1
12	20211	4589	4652	6410	97.4	98.5	96.7
14	20727	4662	4656	6490	99.0	98.6	97.9
16	21099	4710	4721	6630	100.0	100.0	100.0
18	21381	4400	4431	6480	93.4	93.9	97.7
20	21681	4409	4505	6490	93.6	95.4	97.9
22	21897	4279	4493	6488	90.9	95.2	97.9
24	22290	4247	4443	6422	90.2	94.1	96.9
26	22600	4211	4432	6425	89.4	93.9	96.9
28	22837	4250	4354	6353	90.2	92.2	95.8
30	23102	4282	4258	6285	90.9	90.2	94.8
32	23369	4248	4169	6177	90.2	88.3	93.2
34	23600	4195	4191	6147	89.1	88.8	92.7
36	23761	4125	4183	6140	87.6	88.6	92.6
38	24407	3969	4157	6110	84.3	88.0	92.2
40	24559	3949	4186	6079	83.8	88.7	91.7
42	24709	3941	4199	6058	83.7	88.9	91.4
44	24857	3920	4208	6016	83.2	89.1	90.7
46	24999	3890	4223	5973	82.6	89.5	90.1

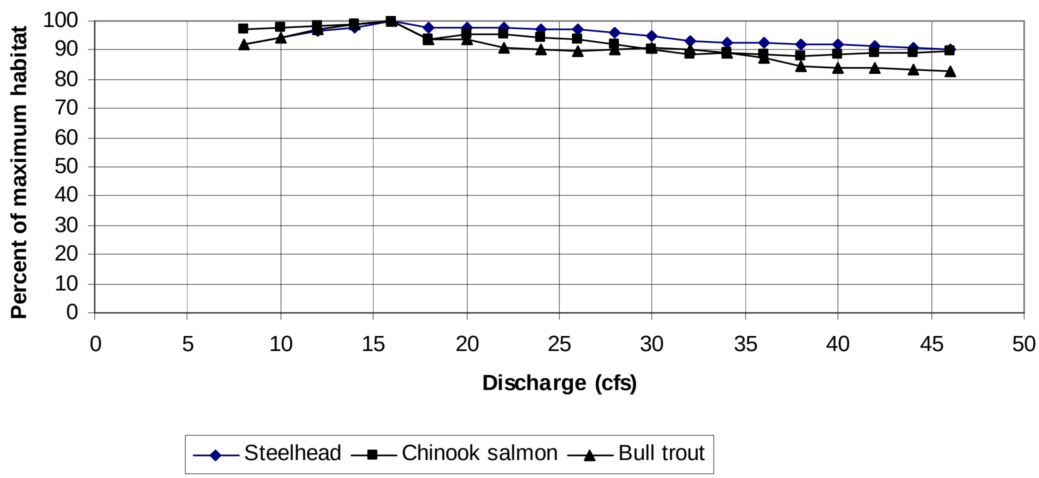

Figure E-3. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Reynolds Creek.

Table E-4. Weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Reynolds Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile	Percent of maximum habitat Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile
8	18293	3792	4465	5334	78.8	77.2	64.5
10	19170	3918	4780	5993	81.5	82.7	72.5
12	20211	4024	5029	6507	83.7	87.0	78.7
14	20727	4154	5136	6813	86.4	88.8	82.4
16	21099	4484	5386	6990	93.2	93.1	84.5
18	21381	4486	5478	7463	93.3	94.7	90.2
20	21681	4613	5598	7708	95.9	96.8	93.2
22	21897	4661	5715	7872	96.9	98.8	95.2
24	22290	4724	5744	8035	98.2	99.3	97.1
26	22600	4697	5783	8189	97.7	100.0	99.0
28	22837	4757	5745	8254	98.9	99.3	99.8
30	23102	4810	5674	8272	100.0	98.1	100.0
32	23369	4739	5495	8213	98.5	95.0	99.3
34	23600	4694	5450	8179	97.6	94.2	98.9
36	23761	4632	5439	8160	96.3	94.0	98.6
38	24407	4464	5411	8178	92.8	93.6	98.9
40	24559	4391	5337	8175	91.3	92.3	98.8
42	24709	4343	5322	8165	90.3	92.0	98.7
44	24857	4341	5332	8129	90.3	92.2	98.3
46	24999	4325	5304	8087	89.9	91.7	97.8

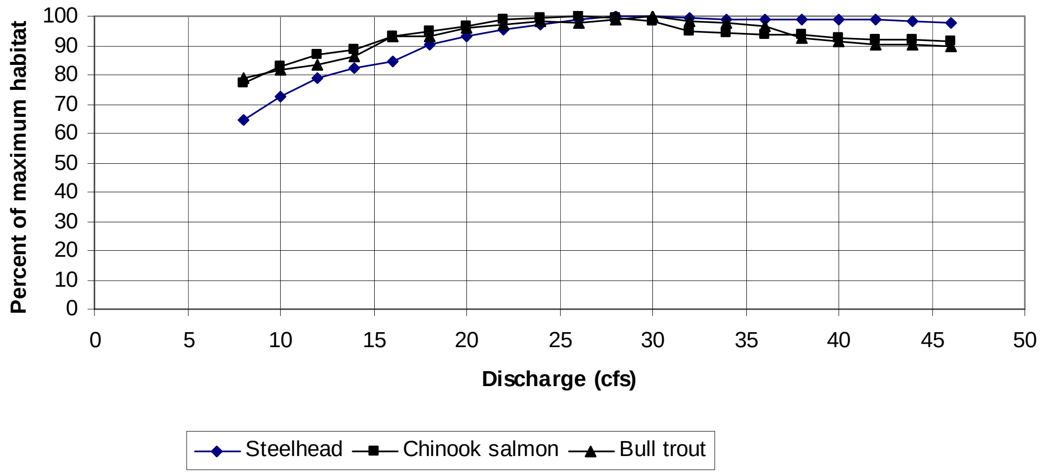

Figure E-4. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Reynolds Creek.

Table E-5. Weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Middle Fork John Day River, Camp Creek to Big Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout fry	Chinook salmon fry	Steelhead fry	Percent of maximum habitat Bull trout fry	Chinook salmon fry	Steelhead fry
10	33530	2365	2162	2719	30.6	26.5	23.6
20	38774	3569	3273	4178	46.1	40.1	36.2
29	42974	4707	4289	5566	60.9	52.5	48.2
30	43300	4859	4435	5759	62.8	54.3	49.9
40	45510	5798	5406	6934	75.0	66.2	60.1
50	46874	6214	6124	7727	80.3	75.0	67.0
60	48151	6138	6418	8344	79.4	78.6	72.3
63	48549	6116	6480	8511	79.1	79.3	73.8
80	50344	7073	7285	9563	91.5	89.2	82.9
100	51487	7533	7778	10167	97.4	95.2	88.1
120	52488	7734	8082	10500	100.0	98.9	91.0
140	53462	7562	8133	10721	97.8	99.6	92.9
160	54662	7397	8114	11051	95.6	99.3	95.8
180	55868	7234	8169	11373	93.5	100.0	98.6
200	56748	7073	8043	11537	91.4	98.5	100.0
220	57677	6992	7963	11475	90.4	97.5	99.5
240	58476	6977	7829	11293	90.2	95.8	97.9
260	59214	6974	7673	11024	90.2	93.9	95.6
280	60007	6995	7556	10749	90.4	92.5	93.2

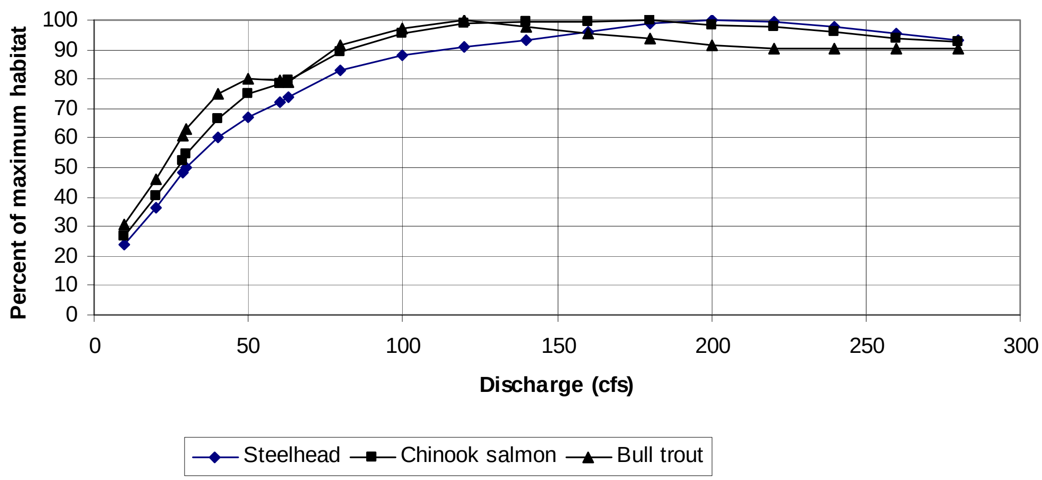

Figure E-5. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Middle Fork John Day River, Camp Creek to Big Boulder Creek.

Table E-6. Weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Middle Fork John Day River, Camp Creek to Big Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile	Percent of maximum habitat Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile
10	33530	2871	3138	3260	23.9	25.2	17.6
20	38774	4512	4673	4993	37.5	37.5	27.0
29	42974	5228	5840	6224	43.5	46.9	33.6
30	43300	5468	6074	6477	45.5	48.7	35.0
40	45510	6656	7697	8155	55.4	61.8	44.1
50	46874	8069	8930	10095	67.1	71.6	54.6
60	48151	8413	9654	11432	70.0	77.5	61.8
63	48549	8391	9725	11747	69.8	78.0	63.5
80	50344	9409	10811	13371	78.3	86.7	72.3
100	51487	10422	11671	14809	86.7	93.6	80.1
120	52488	11327	12178	16114	94.2	97.7	87.1
140	53462	11816	12463	16980	98.3	100.0	91.8
160	54662	12023	12423	17422	100.0	99.7	94.2
180	55868	11778	12268	17899	98.0	98.4	96.8
200	56748	11292	12195	18274	93.9	97.8	98.8
220	57677	10828	11803	18499	90.1	94.7	100.0
240	58476	10503	11230	18454	87.4	90.1	99.8
260	59214	10131	10435	18274	84.3	83.7	98.8
280	60007	9695	9914	18012	80.6	79.5	97.4

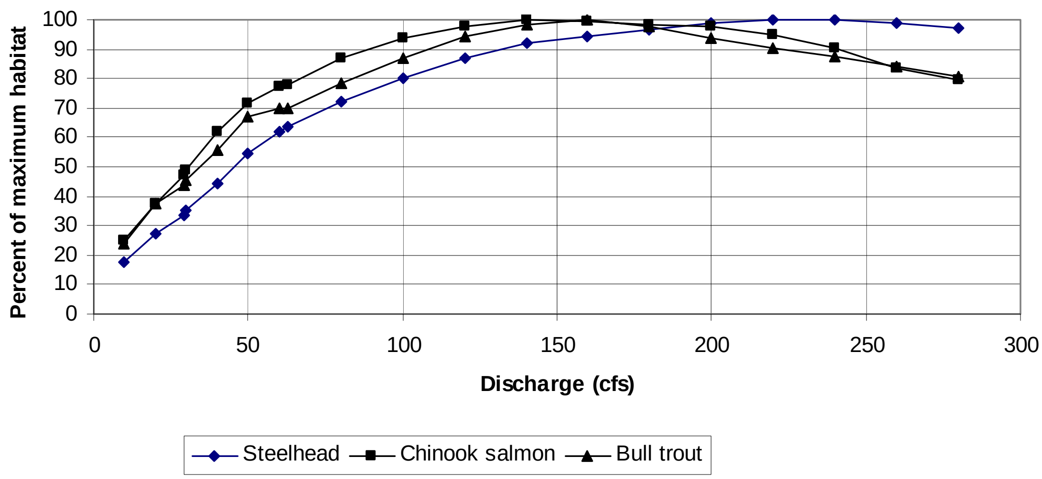

Figure E-6. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Middle Fork John Day River, Camp Creek to Big Boulder Creek.

Table E-7. Weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Middle Fork John Day River, Caribou Creek to Vincent Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout fry	Chinook salmon fry	Steelhead fry	Percent of maximum habitat Bull trout fry	Chinook salmon fry	Steelhead fry
6	23124	4391	5488	6596	57.0	64.7	56.0
10	24086	4376	5829	6938	56.8	68.7	58.9
20	26006	4318	6257	7763	56.0	73.8	65.9
30	27641	4616	6397	8438	59.9	75.4	71.6
40	29236	5132	6976	9201	66.6	82.3	78.1
50	30860	5572	7547	9887	72.3	89.0	83.9
60	31670	5668	7871	10232	73.6	92.8	86.9
70	32440	5444	7967	10374	70.7	93.9	88.1
80	33467	5699	8139	10573	74.0	96.0	89.8
90	34387	5735	8186	10763	74.4	96.5	91.4
100	35264	5940	8242	10953	77.1	97.2	93.0
110	36100	6169	8200	11100	80.1	96.7	94.2
120	37104	6438	8164	11302	83.6	96.3	95.9
130	38053	6685	8197	11441	86.8	96.6	97.1
140	38889	7047	8291	11600	91.5	97.8	98.5
150	39686	7347	8407	11780	95.3	99.1	100.0
160	40080	7394	8343	11658	96.0	98.4	99.0
170	40772	7653	8425	11623	99.3	99.3	98.7
175	41110	7699	8481	11644	100.0	100.0	98.8

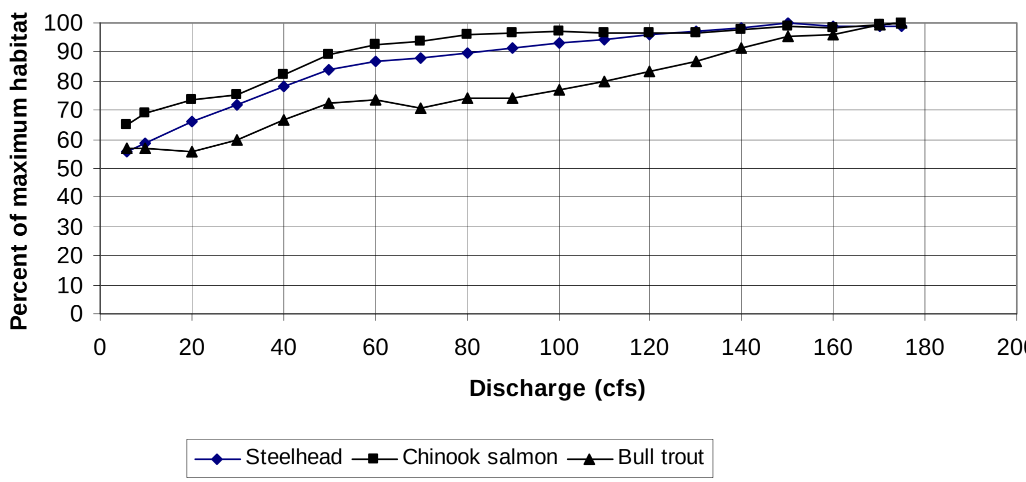

Figure E-7. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Middle Fork John Day River, Caribou Creek to Vincent Creek.

Table E-8. Weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Middle Fork John Day River, Caribou Creek to Vincent Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile	Percent of maximum habitat Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile
6	23124	9322	8031	7033	71.7	68.3	41.5
10	24086	10273	9338	8222	79.0	79.4	48.5
20	26006	11352	10723	10091	87.3	91.2	59.5
30	27641	11685	11115	11169	89.9	94.5	65.9
40	29236	11932	11497	11997	91.8	97.8	70.8
50	30860	12466	11685	12923	95.9	99.4	76.2
60	31670	12719	11761	13928	97.9	100.0	82.2
70	32440	12873	11530	14642	99.0	98.0	86.4
80	33467	12926	11357	15364	99.5	96.6	90.6
90	34387	12997	11216	15800	100.0	95.4	93.2
100	35264	12920	11103	16178	99.4	94.4	95.4
110	36100	12750	10847	16373	98.1	92.2	96.6
120	37104	12534	10651	16458	96.4	90.6	97.1
130	38053	12383	10440	16731	95.3	88.8	98.7
140	38889	12281	10328	16832	94.5	87.8	99.3
150	39686	12096	10260	16951	93.1	87.2	100.0
160	40080	11612	9888	16644	89.3	84.1	98.2
170	40772	11328	9628	16279	87.2	81.9	96.0
175	41110	11150	9531	16143	85.8	81.0	95.2

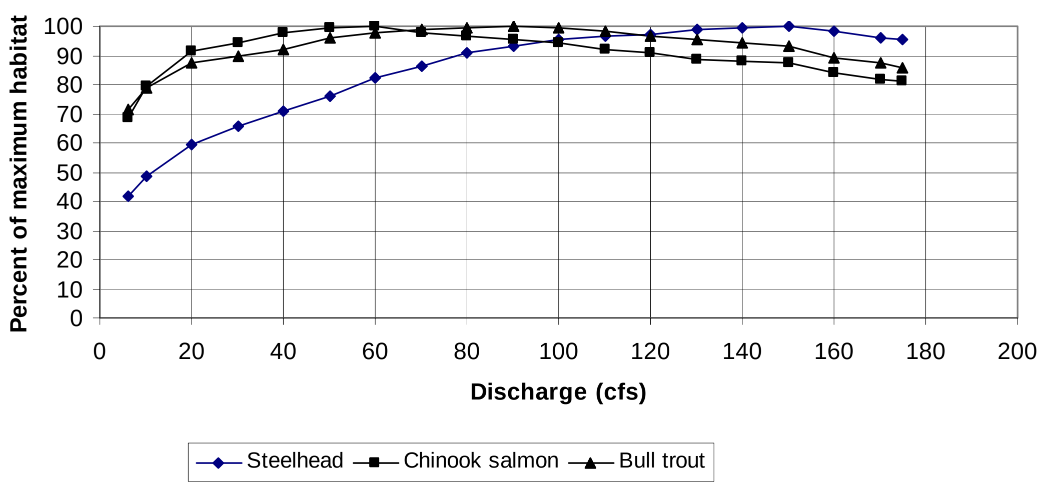

Figure E-8. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Middle Fork John Day River, Caribou Creek to Vincent Creek.

Table E-9. Weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Granite Boulder Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout fry	Chinook salmon fry	Steelhead fry	Percent of maximum habitat Bull trout fry	Chinook salmon fry	Steelhead fry
2	12572	1655	1377	1855	33.0	30.8	30.2
3	13858	1799	1564	2107	35.8	35.0	34.3
4	15081	2240	1846	2508	44.6	41.3	40.8
6	16290	2687	2173	2932	53.5	48.6	47.8
8	17142	3013	2442	3283	60.0	54.6	53.5
10	17727	3306	2669	3618	65.9	59.6	58.9
12	18108	3492	2800	3841	69.6	62.6	62.6
14	18492	3621	2885	4036	72.1	64.5	65.7
16	18772	3679	2958	4171	73.3	66.1	67.9
18	19070	3810	3101	4346	75.9	69.3	70.8
20	19514	3995	3272	4537	79.6	73.1	73.9
22	19978	4195	3464	4769	83.6	77.4	77.7
24	20417	4369	3655	5003	87.0	81.7	81.5
26	20833	4560	3829	5204	90.9	85.6	84.8
28	21166	4698	4005	5360	93.6	89.5	87.3
30	21326	4729	4037	5428	94.2	90.2	88.4
32	21492	4680	4024	5483	93.2	89.9	89.3
34	21656	4632	3903	5459	92.3	87.2	88.9
35	21744	4534	3858	5432	90.3	86.2	88.5
36	21823	4502	3888	5435	89.7	86.9	88.5
38	21983	4564	3942	5527	90.9	88.1	90.0
40	22142	4618	4004	5591	92.0	89.5	91.1
42	22305	4645	4072	5680	92.5	91.0	92.5
44	22510	4719	4141	5768	94.0	92.5	93.9
46	22710	4794	4199	5867	95.5	93.8	95.6
50	23081	4907	4334	5973	97.8	96.9	97.3
52	23260	4976	4399	6062	99.1	98.3	98.7
54	23433	5020	4474	6140	100.0	100.0	100.0

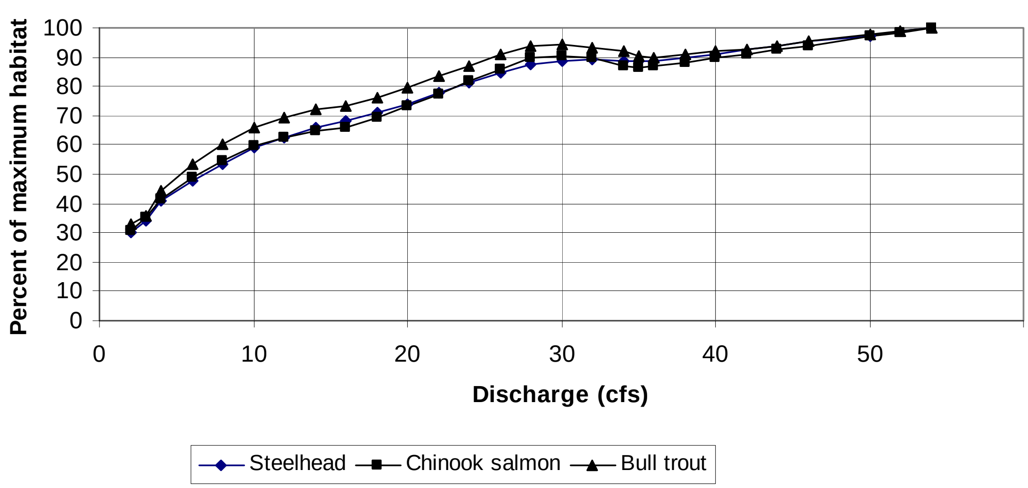

Figure E-9. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Granite Boulder Creek.

Table E-10. Weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Granite Boulder Creek.

Discharge	Total	WUA (ft^2)/1000 ft			Percent of maximum habitat		
(cfs)	(ft^2)/1000 ft	Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile	Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile
2	12572	1596	1925	2181	46.6	40.7	27.8
3	13858	1919	2438	2915	56.0	51.6	37.1
4	15081	2166	2887	3476	63.2	61.0	44.3
6	16290	2611	3557	4322	76.2	75.2	55.0
8	17142	2926	4061	5004	85.4	85.9	63.7
10	17727	2927	4369	5543	85.4	92.4	70.6
12	18108	3014	4620	6088	87.9	97.7	77.5
14	18492	2987	4610	6463	87.2	97.5	82.3
16	18772	2860	4464	6743	83.4	94.4	85.9
18	19070	2971	4598	6985	86.7	97.2	89.0
20	19514	3070	4566	7325	89.6	96.5	93.3
22	19978	3247	4641	7602	94.7	98.1	96.8
24	20417	3357	4730	7763	97.9	100.0	98.9
26	20833	3427	4687	7846	100.0	99.1	99.9
28	21166	3401	4647	7852	99.2	98.3	100.0
30	21326	3318	4558	7845	96.8	96.4	99.9
32	21492	3177	4491	7738	92.7	94.9	98.5
34	21656	3066	4259	7634	89.5	90.0	97.2
35	21744	2928	4065	7545	85.4	85.9	96.1
36	21823	2852	3907	7469	83.2	82.6	95.1
38	21983	2812	3833	7355	82.0	81.0	93.7
40	22142	2861	3741	7274	83.5	79.1	92.6
42	22305	2810	3696	7178	82.0	78.1	91.4
44	22510	2959	3639	7076	86.3	76.9	90.1
46	22710	3044	3617	7038	88.8	76.5	89.6
50	23081	3168	3853	7221	92.4	81.5	92.0
52	23260	3230	3888	7141	94.2	82.2	90.9
54	23433	3259	3946	7124	95.1	83.4	90.7

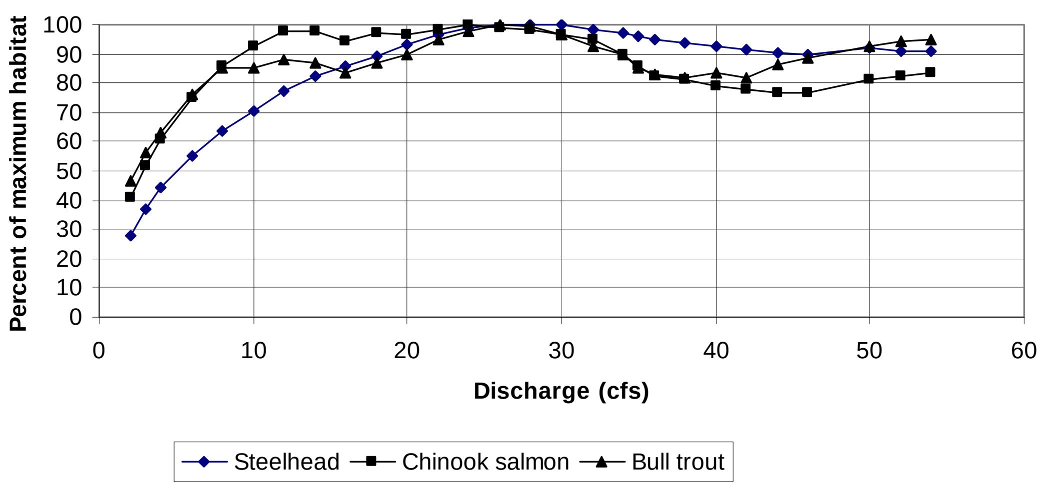

Figure E-10. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Granite Boulder Creek.

Table E-11. Weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Dad's Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout fry	Chinook salmon fry	Steelhead fry	Percent of maximum habitat Bull trout fry	Chinook salmon fry	Steelhead fry
0.1	5611	1204	772	1213	55.0	40.9	47.9
0.5	6518	1842	1299	1886	84.1	68.8	74.5
1	6920	2027	1579	2143	92.6	83.6	84.7
1.5	7070	2097	1728	2260	95.8	91.5	89.3
2	7189	2131	1792	2335	97.4	94.9	92.3
2.5	7294	2104	1824	2379	96.1	96.6	94.0
3	7391	2047	1800	2409	93.5	95.3	95.2
3.5	7477	1953	1724	2424	89.2	91.3	95.8
4	7556	1847	1645	2418	84.4	87.1	95.5
4.5	7646	1777	1581	2401	81.2	83.7	94.9
5	7859	1656	1565	2412	75.7	82.9	95.3
5.5	7970	1624	1579	2424	74.2	83.6	95.8
6	8682	1712	1652	2527	78.2	87.5	99.8
6.5	8795	1747	1646	2531	79.8	87.2	100.0
7	8899	1773	1645	2501	81.0	87.2	98.8
7.5	8999	1756	1636	2494	80.2	86.6	98.6
8	9094	1760	1648	2440	80.4	87.3	96.4
8.5	9184	1792	1657	2438	81.8	87.8	96.4
9	9269	1797	1644	2428	82.1	87.1	96.0
9.5	9352	1836	1663	2368	83.9	88.1	93.6
10	9429	1865	1668	2377	85.2	88.3	93.9
10.5	9505	1897	1689	2364	86.6	89.4	93.4
11	9580	1919	1699	2383	87.7	90.0	94.2
11.5	9650	1956	1726	2367	89.3	91.4	93.5
12	9720	1992	1749	2395	91.0	92.6	94.6
12.5	9786	2026	1771	2418	92.5	93.8	95.6
13	9870	2071	1808	2452	94.6	95.8	96.9
13.5	9951	2111	1827	2480	96.4	96.8	98.0
14	10031	2152	1862	2509	98.3	98.6	99.2
14.5	10108	2189	1888	2517	100.0	100.0	99.5

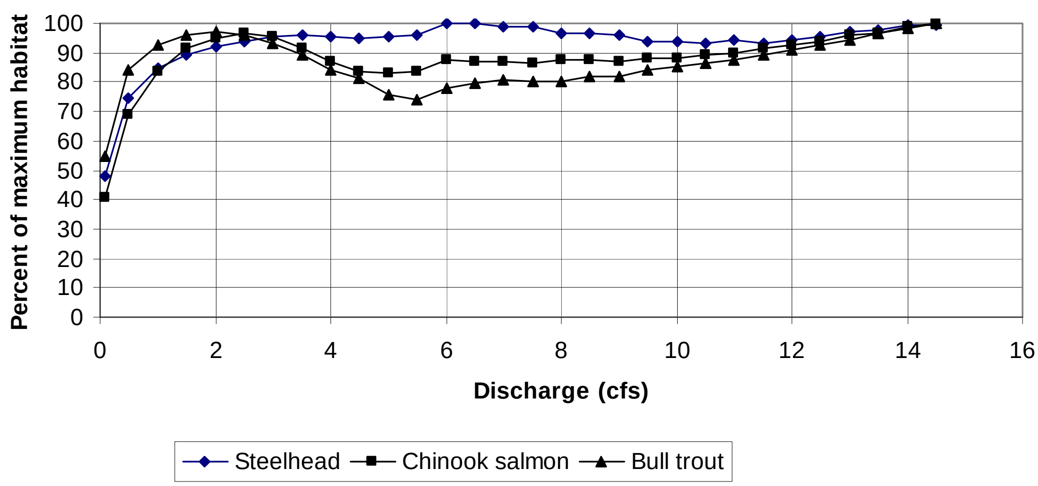

Figure E-11. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for fry using Klamath River escape cover coding at Dad's Creek.

Table E-12. Weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Dad's Creek.

Discharge (cfs)	Total (ft^2)/1000 ft	WUA (ft^2)/1000 ft Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile	Percent of maximum habitat Bull trout juvenile	Chinook salmon juvenile	Steelhead juvenile
0.1	5611	85	212	193	8.1	12.6	7.3
0.5	6518	394	459	467	37.8	27.3	17.6
1	6920	489	911	986	46.9	54.2	37.2
1.5	7070	596	1231	1480	57.1	73.3	55.8
2	7189	632	1360	1642	60.6	81.0	61.9
2.5	7294	989	1524	1845	94.7	90.8	69.6
3	7391	1044	1604	1968	100.0	95.5	74.2
3.5	7477	1013	1654	2072	97.0	98.5	78.1
4	7556	955	1679	2180	91.4	100.0	82.2
4.5	7646	897	1671	2245	85.9	99.5	84.6
5	7859	747	1610	2309	71.5	95.9	87.1
5.5	7970	677	1573	2366	64.9	93.7	89.2
6	8682	666	1607	2504	63.8	95.7	94.4
6.5	8795	700	1584	2564	67.0	94.3	96.7
7	8899	692	1522	2589	66.3	90.7	97.6
7.5	8999	685	1467	2599	65.6	87.4	98.0
8	9094	655	1342	2587	62.7	79.9	97.5
8.5	9184	647	1294	2543	62.0	77.1	95.9
9	9269	619	1268	2611	59.3	75.5	98.4
9.5	9352	620	1209	2645	59.4	72.0	99.7
10	9429	614	1208	2652	58.8	71.9	100.0
10.5	9505	606	1176	2637	58.0	70.0	99.4
11	9580	590	1175	2633	56.5	70.0	99.3
11.5	9650	591	1166	2637	56.6	69.4	99.4
12	9720	591	1177	2625	56.6	70.1	99.0
12.5	9786	589	1181	2612	56.4	70.3	98.5
13	9870	634	1187	2599	60.7	70.7	98.0
13.5	9951	699	1183	2560	67.0	70.5	96.5
14	10031	731	1181	2539	70.0	70.3	95.7
14.5	10108	754	1158	2504	72.2	69.0	94.4

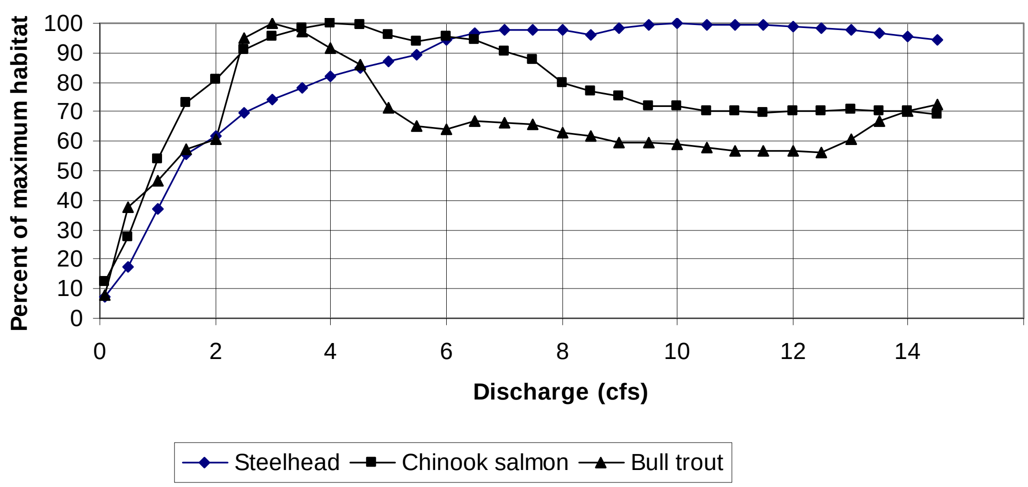

Figure E-12. Normalized (% of maximum habitat) weighted usable area (WUA) versus discharge relationships for juveniles using Klamath River escape cover coding at Dad's Creek.