RECLAMATION

Managing Water in the West

Technical Memorandum No. 86-68290-03-07

Klamath River Tributary Fish Passage Surveys

U.S. Department of the Interior
Bureau of Reclamation

October 2007

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October 2007

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Technical Service Center, Denver, Colorado
Fisheries and Wildlife Resources Group, 86-68290

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U.S. Department of the Interior
Bureau of Reclamation
Klamath Falls Area Office
Klamath Falls, Oregon

Ron Sutton — 11-5-07

Prepared: Ron Sutton — Date
Fishery Biologist, Fisheries and Wildlife Resources Group 86-68290

Jon Hicks — 10-30-07

Peer Review: Jon Hicks — Date
Water Conservation Specialist, Bureau of Reclamation Klamath Falls Area Office KO-300

10.31.07

Peer Review: Keith Schultz — Date
Fishery Biologist, Bureau of Reclamation Klamath Falls Area Office KO-700

86-68290 — 12-3-2007

Technical and Managerial Approval: Steve Hiebert — Date
Manager, Fisheries and Wildlife Resources Group 86-68290

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Prepared for:
Bureau of Reclamation
Klamath Basin Area Office
Klamath Falls, Oregon

by:
Ron Sutton
Bureau of ReclamationTechnical Service Center
Fisheries and Wildlife Resources Group
Denver, Colorado

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Summary

The objective of this study was to determine how Klamath River main stem flows interact with tributaries to allow passage for juvenile and adult salmonids. Reclamation's Technical Service Center (TSC) conducted surveys at the mouths of the following tributaries, from July 9 through July 13, 2007:

Beaver Creek (RM 163);
Horse Creek (RM 150);
Cade Creek (RM 110); and,
Sandy Bar Creek (RM 70

Results indicated that tributary passage for juvenile and adult salmonids is highly dependent on tributary flows and current channel configuration. Increasing main stem Klamath River flows provided limited improvement to tributary access, depending on the hydraulic slope and flow in each tributary. Annual channel maintenance (create step pools and "slots") in tributaries with high gradients at their mouth would be a more cost-effective strategy to improve passage conditions than main stem flow management. While increased main stem flows, step pools or pocket water may provide improved access to tributary areas closest to the main stem, tributary flows will continue to be the limiting factor for salmonids seeking tributary access and thermal refugia.

Introduction

One issue in the Klamath River, downstream from Iron Gate Dam, is whether main stem Klamath River flows create a barrier to tributary access for juvenile and adult salmonids, particularly coho salmon (*Oncorhynchus kitsutch*). In the fall, adult coho salmon typically spawn in small streams or in side channels to larger rivers (Lestelle 2007). During summer, high water temperatures in the main stem Klamath River can trigger movement of juvenile salmonids as they seek refuge from the warm water (Sutton et al. 2007). It is likely that some juveniles enter cooler tributaries during this time. The objective of this study was to determine how main stem flows interact with Klamath River tributaries to allow passage for juvenile and adult salmonids. Reclamation's Technical Service Center (TSC) conducted surveys at the mouths of the following tributaries, from July 9 through July 13, 2007:

Beaver Creek (RM 163);
Horse Creek (RM 150);
Cade Creek (RM 110); and,
Sandy Bar Creek (RM 70).

Methods

Field surveying was conducted as follows:

- a three-person crew and a boat were used to assist with the surveys;
- one person operated a total station[1] from shore and all coordinates were referenced to a local benchmark (rebar);
- benchmark coordinates (North American Datum (NAD) 83) recorded using a handheld Global Positioning System (GPS) unit;
- two transects were placed across the Klamath River at the mouth of each tributary site and bed elevations (cross-sectional profile). With the exception at the Beaver Creek site, water surface elevations were measured across each transect with total station and prism. At Beaver Creek an automatic level and survey rod were used when the total station failed to work in the hot weather;
- two transects were placed in each creek near the mouth and surveyed for bed elevations and water surface elevations;
- main stem discharge was determined either across one of the transects using a Marsh McBirney Model 2000 Flomate meter and top-set wading rod or from the nearest USGS gage; and,
- discharge in each creek was measured using a Marsh McBirney Model 2000 Flomate meter and top-set wading rod.

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[1] A **total station** is an optical instrument used in modern surveying. It is a combination of an electronic theodolite (transit), an electronic distance measuring device (EDM) and software running on an external computer.With a total station one may determine angles and distances from the instrument to points to be surveyed. With the aid of trigonometry, the angles and distances may be used to calculate the coordinates of actual positions of surveyed points, or the position of the instrument from known points, in absolute terms.

Survey data were analyzed using the Manning's equation in a model called MANSQ[2], which is included in a suite of models within the Physical Habitat Simulation System (PHABSIM)[3] (Waddle 2001).

The MANSQ model uses Manning's equation in the form:

$$Q = (1.49/n * S^{1/2}) * A * R^{2/3}$$

and simplifies it to:

$$Q = K * A * R^{2/3}$$

where:

Q = discharge in cubic feet per second (cfs)
1.49 = English units correction (cube root of 3.28 feet per meter)
R = hydraulic radius, in feet
S = slope of energy grade line
n = coefficient of roughness, referred to as Manning's n[4]
A = cross section area of flow in the channel in square feet.
K = is determined from one set of measured discharge and water surface elevation pairs and measured channel geometry at a cross section.

The model was calibrated by comparing simulated to measured water surface elevations. After calibration, additional water surface elevations were simulated at various flows. It should be noted that typically three or more flows are measured (e.g., low, medium, high) to improve model calibration (Waddle 2001). With only one flow measurement at two transects located in the main stem at the tributary mouths and no hydraulic controls measured downstream, calibration techniques were limited and flow estimates for passage were likely overestimated because the backwater effects from downstream controls were not taken into account (Bob Milhous, Hydraulic Engineer, U.S. Geological Survey (USGS), personal communication, October 30, 2007). The main stem and creek transects were simulated separately to allow a comparison of combinations of tributary and main stem flows to determine which combinations provided enough water depth (using water surface elevations and depth profiles) to allow access into the tributaries.

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[2] The MANSQ program utilizes Manning's equation to calculate water surface elevations on a cross section by cross section basis and therefore treats each cross section as independent. Model calibration is accomplished by a trial and error procedure to select a β coefficient that minimizes the error between observed and simulated water surface elevations at all measured discharges.
[3] PHABSIM: (pronounced P-HAB-SIM) - the Physical Habitat Simulation System. Computes a relationship between streamflow and physical habitat for various life stages of an aquatic organism or a recreational activity.
[4] MANNING'S ROUGHNESS or MANNING's n: A factor used when computing the average velocity of flow of water in a channel that represents the effect of roughness of the confining material upon the energy losses in the flowing water. Also referred to as "n" or roughness coefficient.

Suggested passage criteria for adult coho salmon followed guidelines adopted by Oregon Department of Fish and Wildlife and taken from Thompson (1972). To determine the recommended flow for passage, the two transects in the tributaries were set in shallow areas judged to be the most critical to passage of adult fish near the confluence with the Klamath River, and linear transects was measured which followed the shallowest course from bank to bank. For each transect, a flow was computed for conditions which met the minimum depth criterium of 0.6 ft for coho salmon, where at least 25% of the total transect width and a continuous portion equaling at least 10% of its total width, equal to or greater than the minimum depth, was maintained (Thompson 1972). Both width criteria must be met to insure passage. For juvenile salmon, NMFS (2000) guideline for minimum depth at low flow in non-embedded culverts is 0.5 ft. This guideline was applied using the same width/depth criteria (i.e., 25% and 10%) discussed for adult passage. I assumed that this was a very conservative approach for juvenile passage in the Klamath River basin since depths suitable for juvenile salmonid passage may be as low as 0.1 ft (Toz Soto, Karuk Fishery Biologist, personal communication, May, 2007). The AVDEPTH[5] model of PHABSIM was used to simulate flows that met these criteria at the shallowest transect of each tributary.

Results

The discharges (cfs) for the main stem Klamath River and the tributary at each study site are listed in Table 1. Benchmark coordinates for each site were as follows:

- Beaver Creek - N41°52’09.8” W122º49’02.6”
- Horse Creek - N41°49’21.6” W123º00’17.9”
- Cade Creek - N41°48’23.9” W123º21’03.2”
- Sandy Bar Creek - N41°29’02.2” W123º31’06.2”

Hydraulic slope measurements (change in water surface elevations between two cross sections, divided by the distance between cross sections) for the main stem Klamath River and tributaries are summarized in Table 2. Tributaries had higher slopes than the main stem and Cade Creek and Sandy Bar Creek had the highest tributary slopes measured. Simulated water surface elevations calibrated to within 0.05 ft of observed water surface elevations (Table 3). Model calibration could be improved with additional flow measurements. Model outputs were analyzed and flows and water surface elevations needed for adult and juvenile passage are summarized in Table 4 for each tributary.

[5] AVDEPTH /AVPERM, calculates a variety of hydraulic characteristics for each cross section in addition to a study site average view. These include wetted width, wetted perimeter, and wetted surface area, cross sectional area, mean channel velocity, and average depths. They can also be utilized to determine the width of a stream with water that is over some arbitrary depth(s) specified by the user. These programs provide a wealth of information at a cross section or a study site level aggregate and should be examined in most applications.

Table 1 Discharge (cfs) measurements at study locations for Klamath passage study.

		Discharge (cfs)		
Date	Klamath River		Tributaries	
July 10, 2007	At Beaver Creek	1020[1]	Beaver Creek	43
July 12, 2007	At Horse Creek	1100	Horse Creek	21
July 11, 2007	At Cade Creek	1230[2]	Cade Creek	1
July 13, 2007	at Sandy Bar Creek	1669	Sandy Bar Creek	1

[1] Iron Gate Dam USGS gage (RM 190)
[2] Seiad USGS gage (RM 129)

Table 2 Hydraulic slope measurements at study locations for Klamath passage study.

		Slope		
Date	Klamath River		Tributaries	
July 10, 2007	At Beaver Creek	0.0035	Beaver Creek	0.010
July 12, 2007	At Horse Creek	0.0070	Horse Creek	0.014
July 11, 2007	At Cade Creek	0.0012	Cade Creek	0.140
July 13, 2007	at Sandy Bar Creek	0.0014	Sandy Bar Creek	0.170

Table 3 Water surface elevation calibration results for Klamath passage study.

Transect	Distance to next downstream transect (ft)	Observed elevation (ft)	Simulated elevation (ft)	Difference (ft)
Klamath River at Beaver Creek				
Discharge - 1020 cfs				
1	0	95.660	95.655	-0.005
2	48	95.830	95.830	0
Beaver Creek				
Discharge – 43 cfs				
1	0	95.840	95.835	-0.005
2	31.5	96.160	96.160	0
Klamath River at Horse Creek				
Discharge - 1100 cfs				
1	0	98.280	98.280	0
2	71.5	98.780	98.775	-0.005
Horse Creek				
Discharge - 21 cfs				
1	0	99.080	99.080	0
2	57	99.870	99.865	-0.005
Klamath River at Cade Creek				
Discharge - 1230 cfs				
1	0	97.640	97.635	-0.005
2	30	97.690	97.685	-0.005
Cade Creek				
Discharge - 1 cfs				
1	0	99.670	99.670	0
2	17	102.060	102.055	-0.005
Klamath River at Sandy Bar Creek				
Discharge - 1669 cfs				
1	0	93.140	93.135	-0.005
2	65.5	93.230	93.230	0
Sandy Bar Creek				
Discharge - 1 cfs				
1	0	94.190	94.140	-0.05
2	32	99.590	99.640	0.05

Table 4 Flows and water surface elevations needed to meet tributary passage criteria for juvenile and adult salmonids at selected tributaries in the Klamath River.

	Juveniles				Adults			
Tributary confluence	**Discharge (cfs)**		**Water surface elevation (ft)**		**Discharge (cfs)**		**Water surface elevation (ft)**	
	Tributary	Main stem	Tributary	Main stem[1]	Tributary	Main stem	Tributary	Main stem[1]
Beaver Cr	5	770	95.40[2]	95.40	8	850	95.51[2]	95.51
Horse Cr	25	1600	99.12[3]	99.14	40	1700	99.23[3]	99.26
Cade Cr	5	>3600	102.34[2]	>100.5	7	>3600	102.44[2]	>100.5
Sandy Bar Cr	>10	>4200	>99.9[2]	>95.36	>10	>4200	>99.9[2]	>95.36

[1] Average of main stem Klamath River transects 1 and 2.
[2] Transect 2
[3] Transect 1

Each tributary is discussed separately in the following sections.

Beaver Creek

Transect locations at the Beaver Creek site are diagrammed in Figure 1. Photos of Beaver Creek as it enters the Klamath River are shown in Figures 2 and 3. Cross sectional profiles of each transect (main stem and tributary) and measured water surface elevations are shown in Figures 4 to 7. A plot of flow versus wetted width shown in Figure 8 illustrates adult passage flow needed to meet depth and width criteria at transect 2 in Beaver Creek.

As illustrated in Figure 8, a flow of 8 cfs in Beaver Creek meets both passage criteria for adult coho salmon and steelhead at transect 2. For juveniles, a flow of 5 cfs meets both criteria. Based on information collected, main stem flows of 770 and 850 cfs would meet juvenile and adult salmonid passage needs into Beaver Creek, respectively.

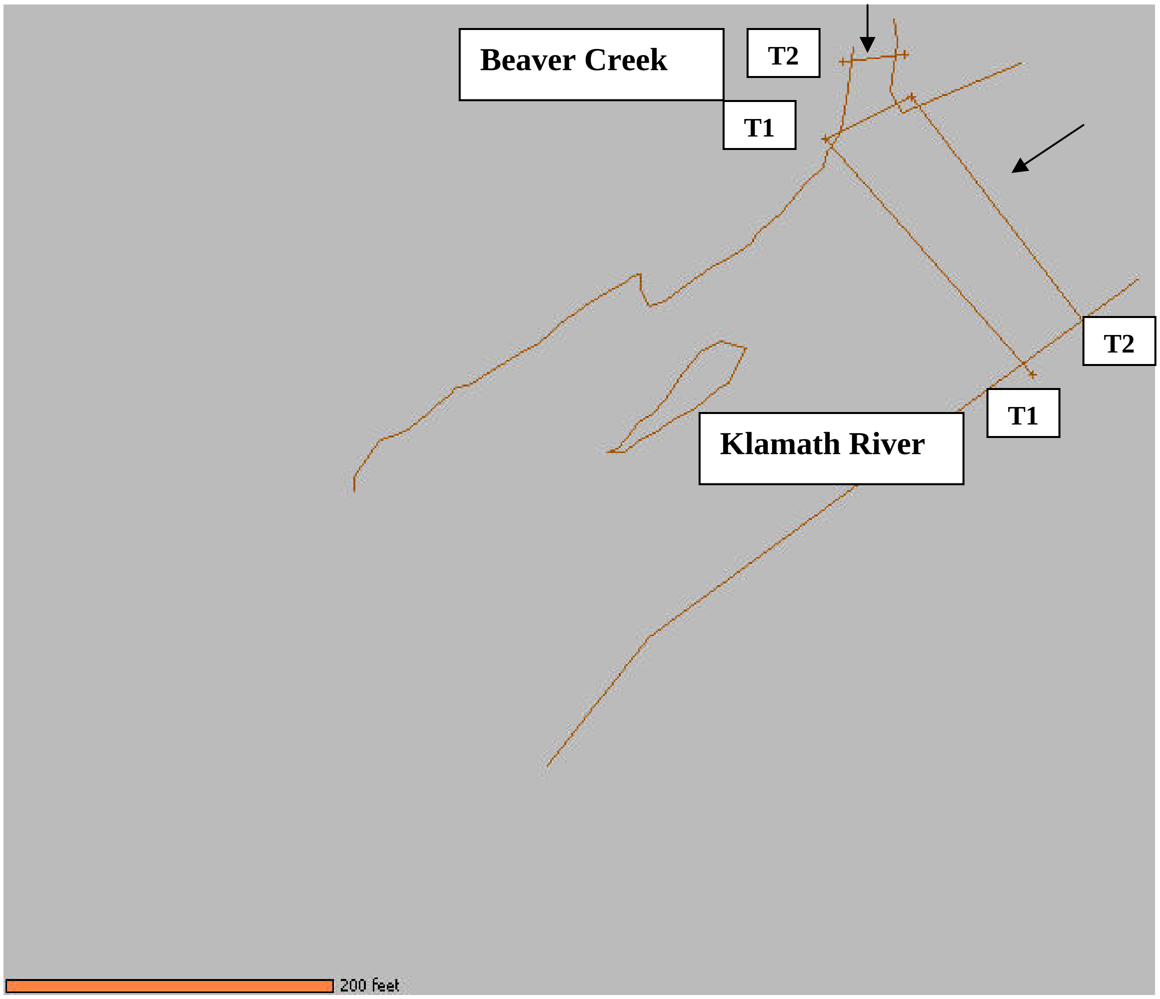

Figure 1 Beaver Creek confluence with Klamath River and transect locations.

Figure 2 Beaver Creek confluence with Klamath River looking upstream, July 10, 2007.

Figure 3 Beaver Creek looking upstream towards transect 2, July 10, 2007.

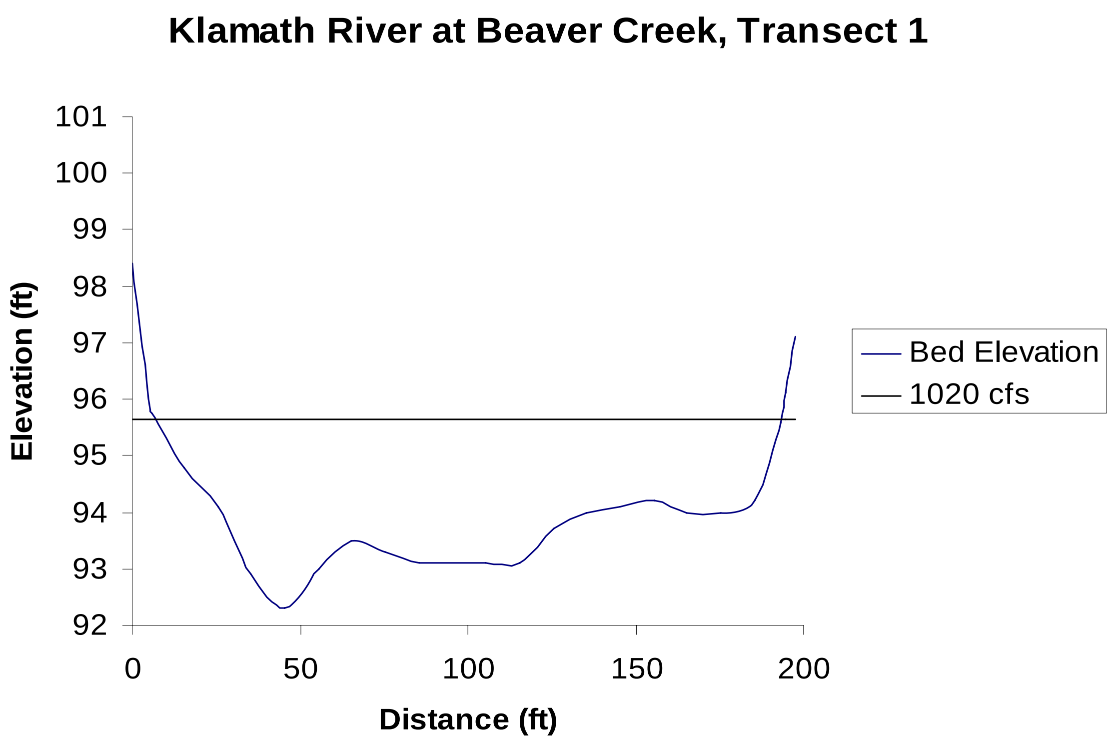

Figure 4 Klamath River transect 1 profile and water surface elevations at Beaver Creek.

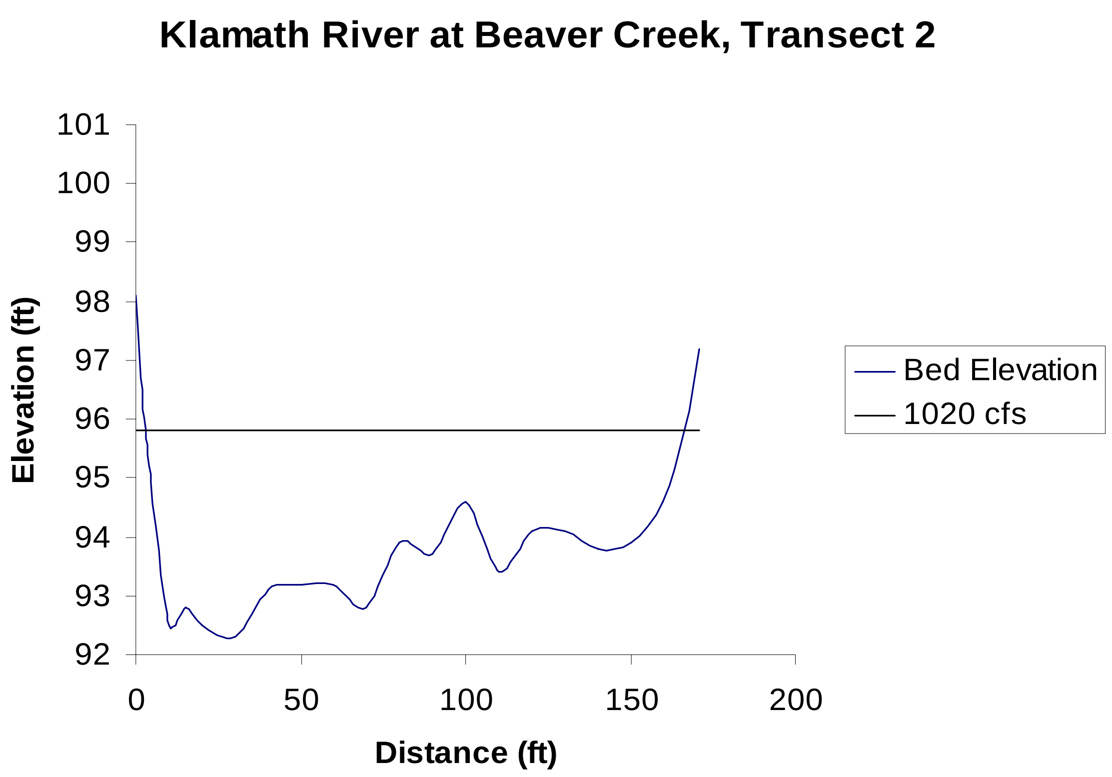

Figure 5 Klamath River transect 2 profile and water surface elevation at Beaver Creek.

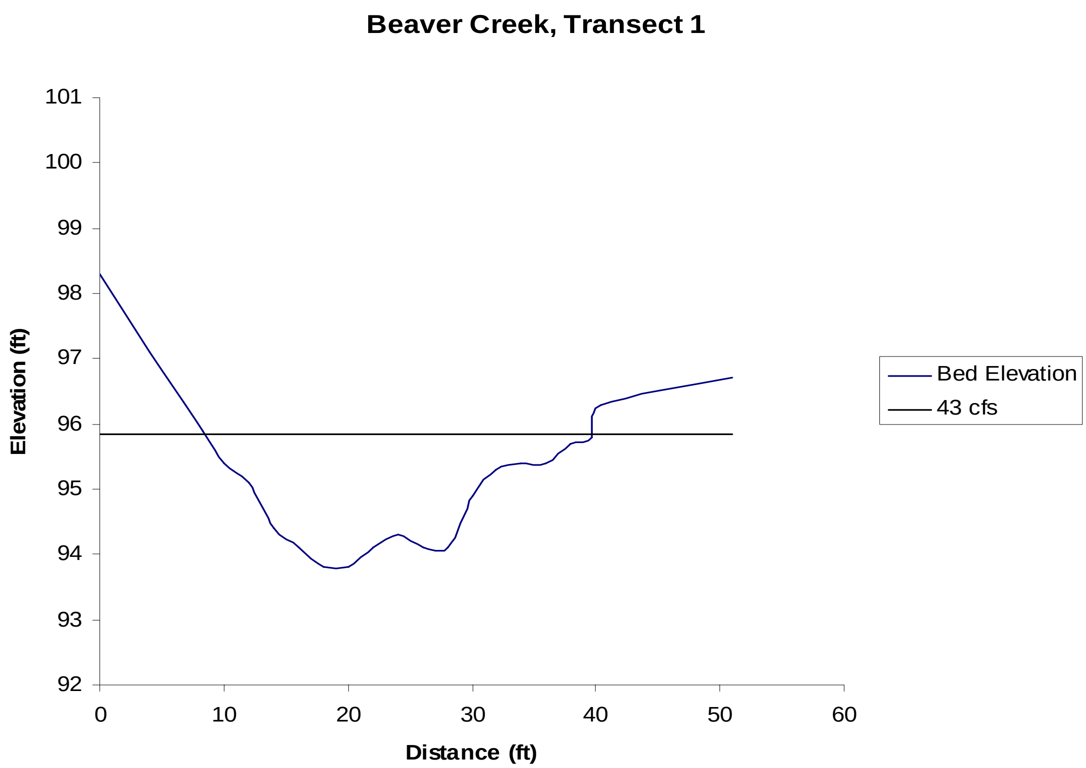

Figure 6 Beaver Creek transect 1 profile and water surface elevation.

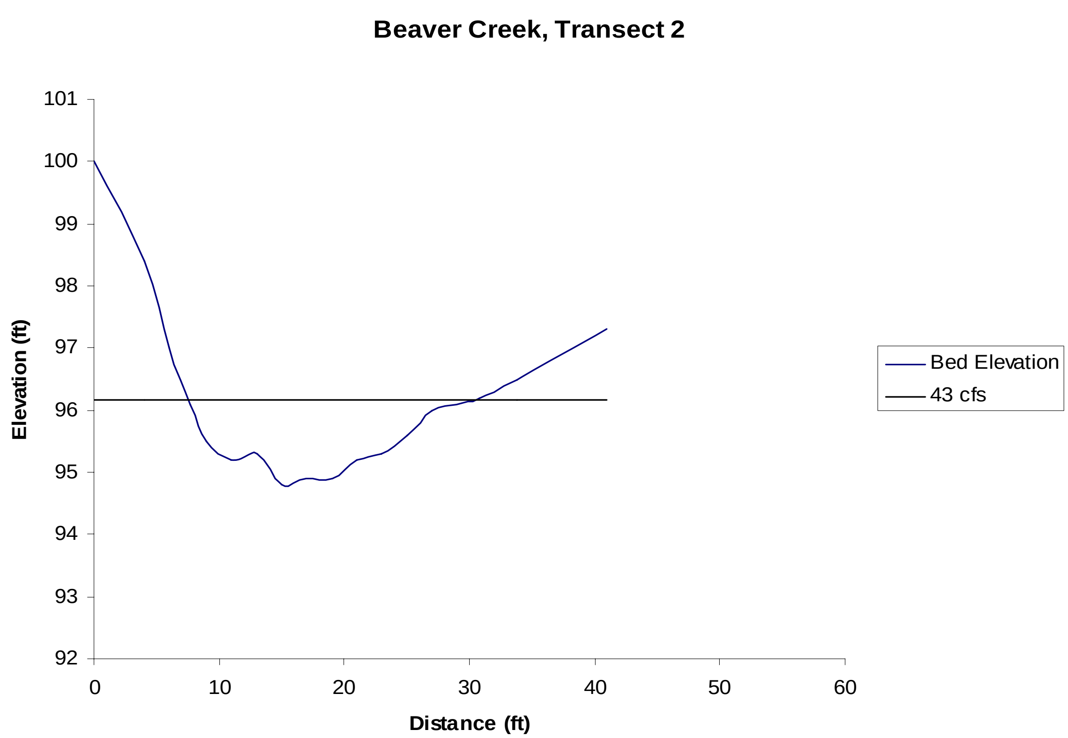

Figure 7 Beaver Creek transect 2 profile and water surface elevation.

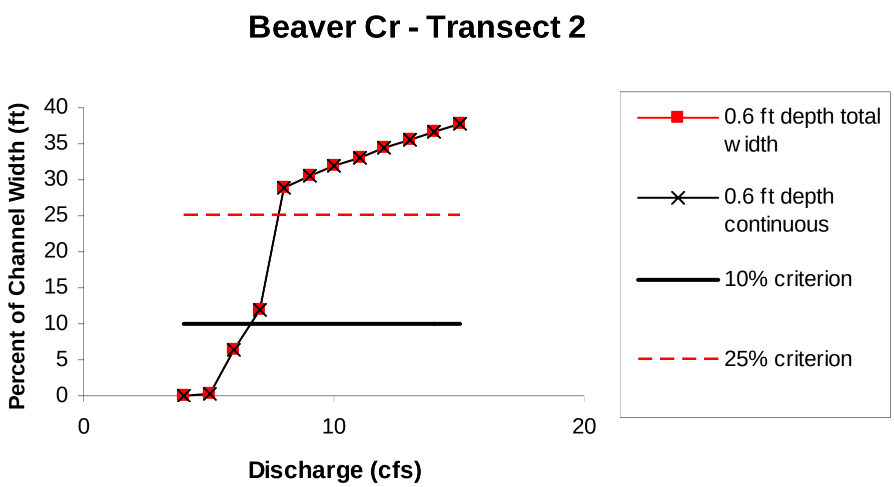

Figure 8 Discharge required to meet adult passage criteria at Beaver Creek.

Horse Creek

Transect locations at the Horse Creek site are diagrammed in Figure 9. Photos of Horse Creek as it enters the Klamath River are shown in Figures 10 and 11. Cross sectional profiles of each transect (main stem and tributary) and measured water surface elevations are shown in Figures 12 to 15. A plot of flow versus wetted width shown in Figure 16 illustrates adult passage flow needed to meet depth and width criteria at transect 2 in Horse Creek.

As illustrated in Figure 16, a flow of 40 cfs in Horse Creek meets both passage criteria (i.e., 10 and 25%) for adult coho salmon and steelhead at transect 1. For juveniles, a flow of 25 cfs meets both criteria. Main stem Klamath River discharge needed to achieve passage criteria at the mouth of Horse Creek were 1,600 and 1,700 cfs for juvenile and adult salmonids, respectively (Table 4) under current measured Horse Creek channel morphology. When sufficient Klamath River flows of 1,600 cfs and 1,700 cfs are not available, access to the mouth of Horse Creek could be improved through annual minor physical movement of the substrate (i.e., creation of pocketwater and “slots”).

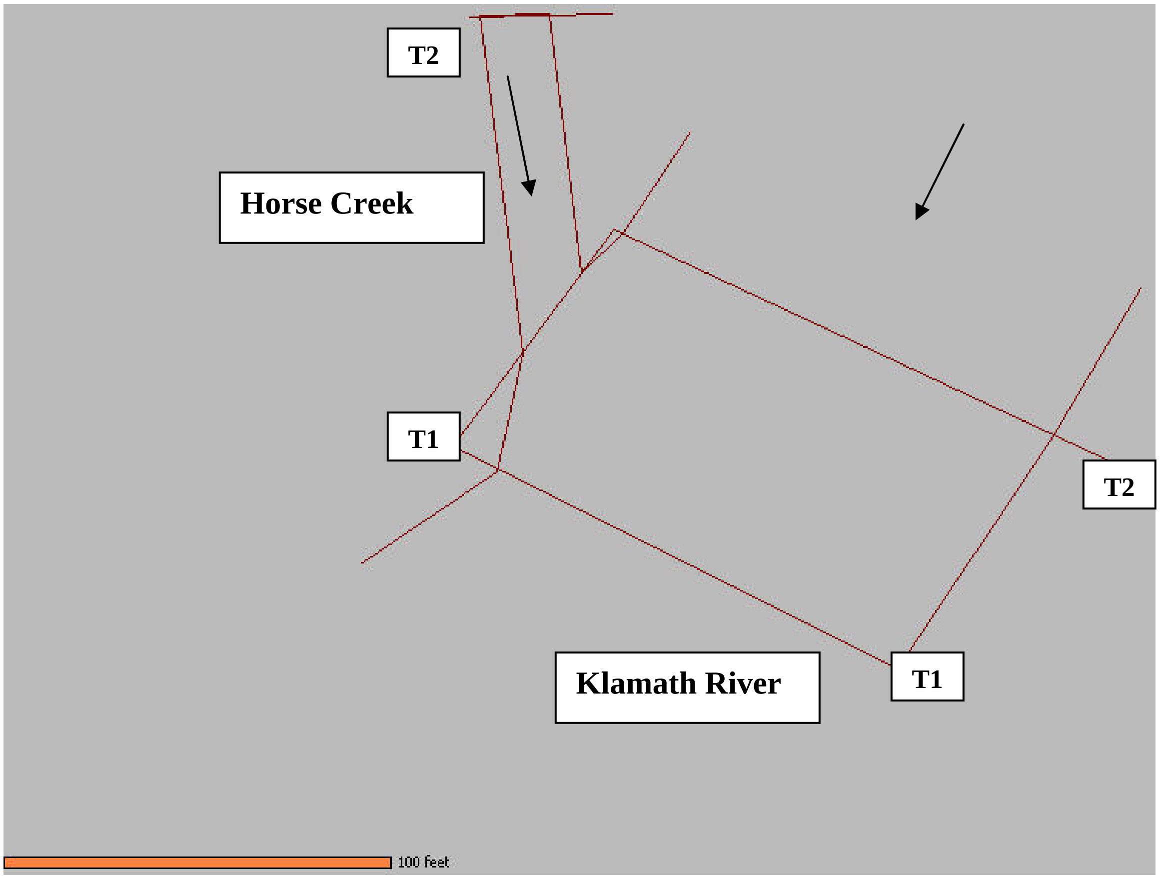

Figure 9 Horse Creek confluence with Klamath River and transect locations.

Figure 10 Horse Creek transect 1 at Klamath River confluence, July 12, 2007.

Figure 11 Horse Creek confluence (opposite bank) with Klamath River and Klamath River transect 1, July 12, 2007.

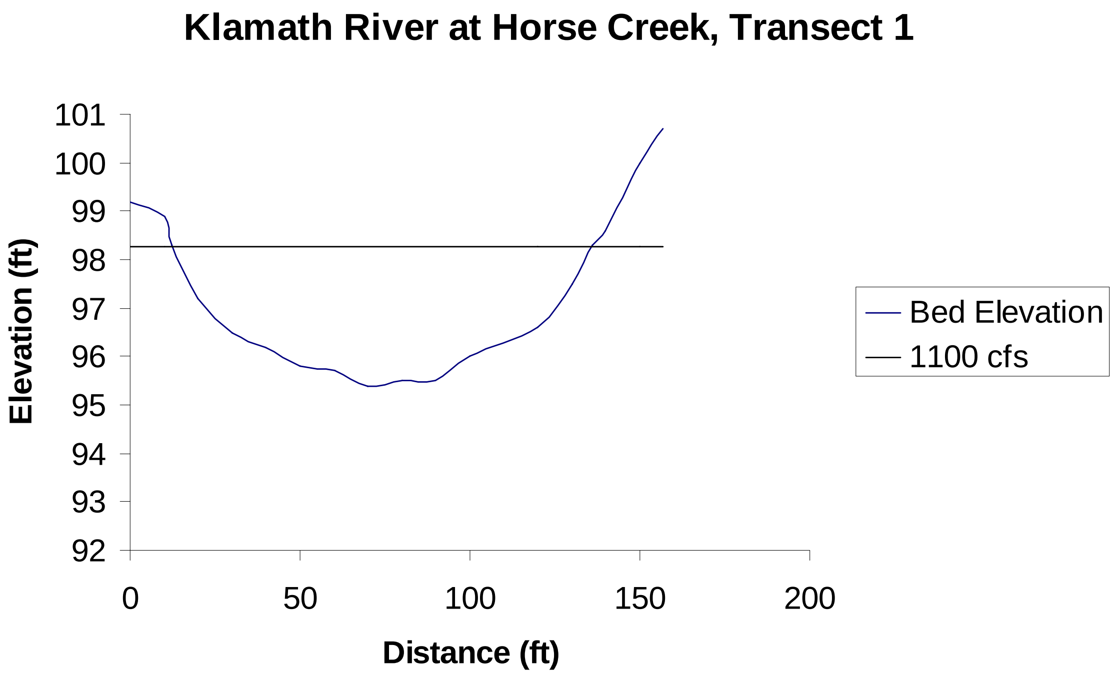

Figure 12 Klamath River transect 1 profile and water surface elevation at Horse Creek.

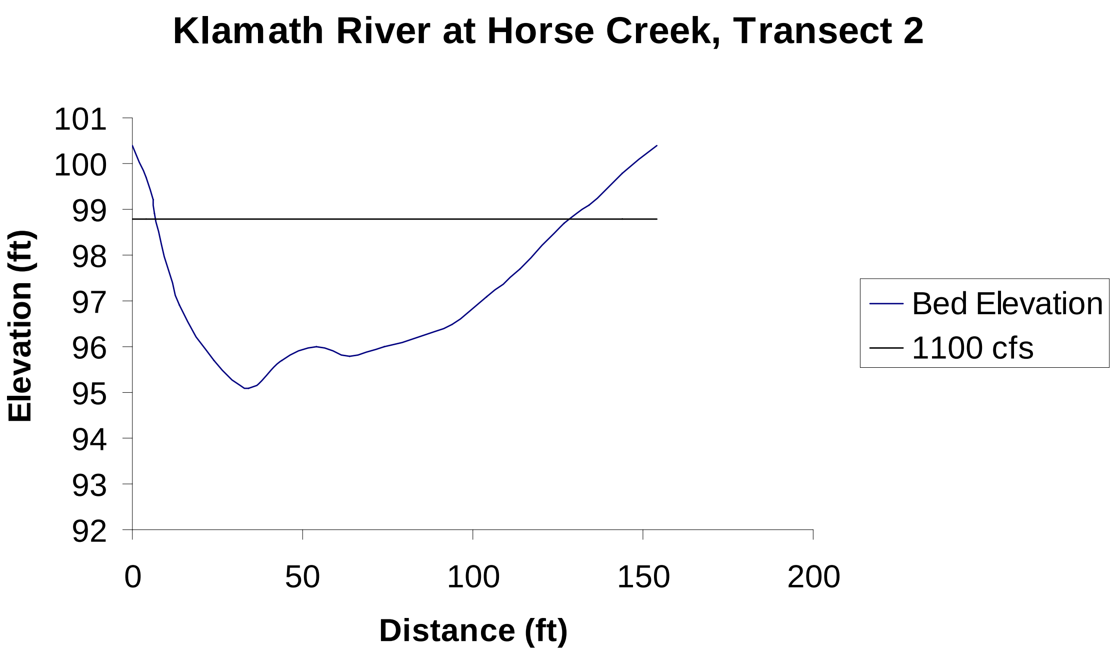

Figure 13 Klamath River transect 2 profile and water surface elevation at Horse Creek.

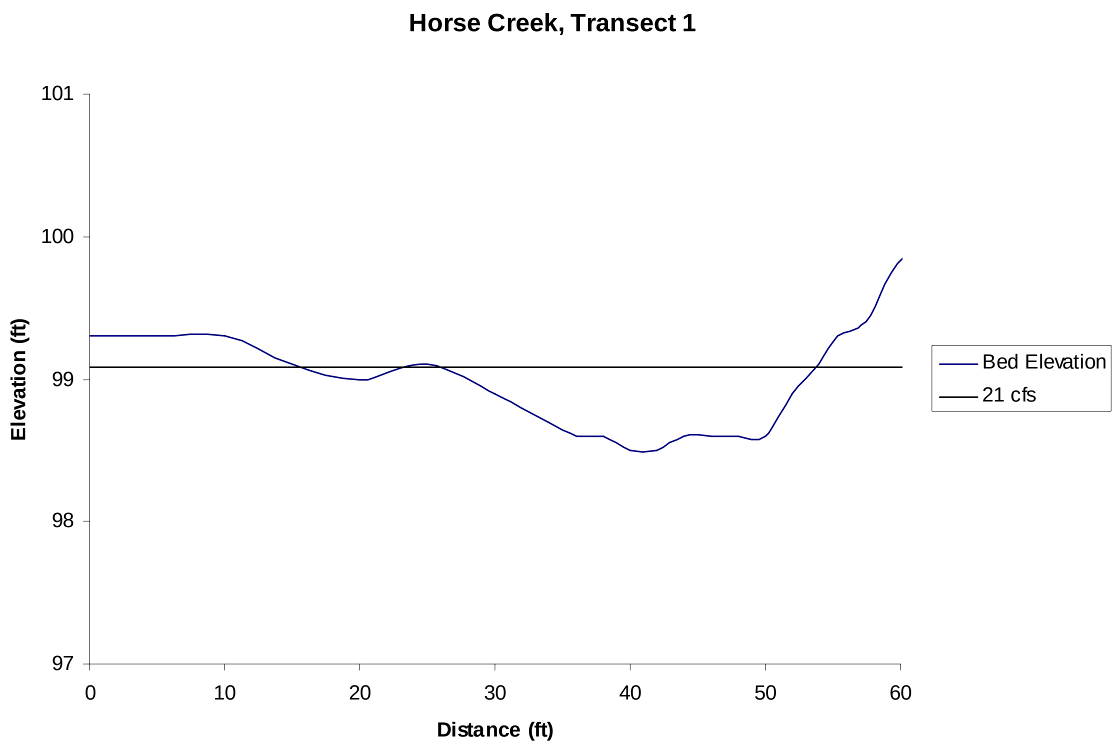

Figure 14 Horse Creek transect 1 profile and water surface elevation.

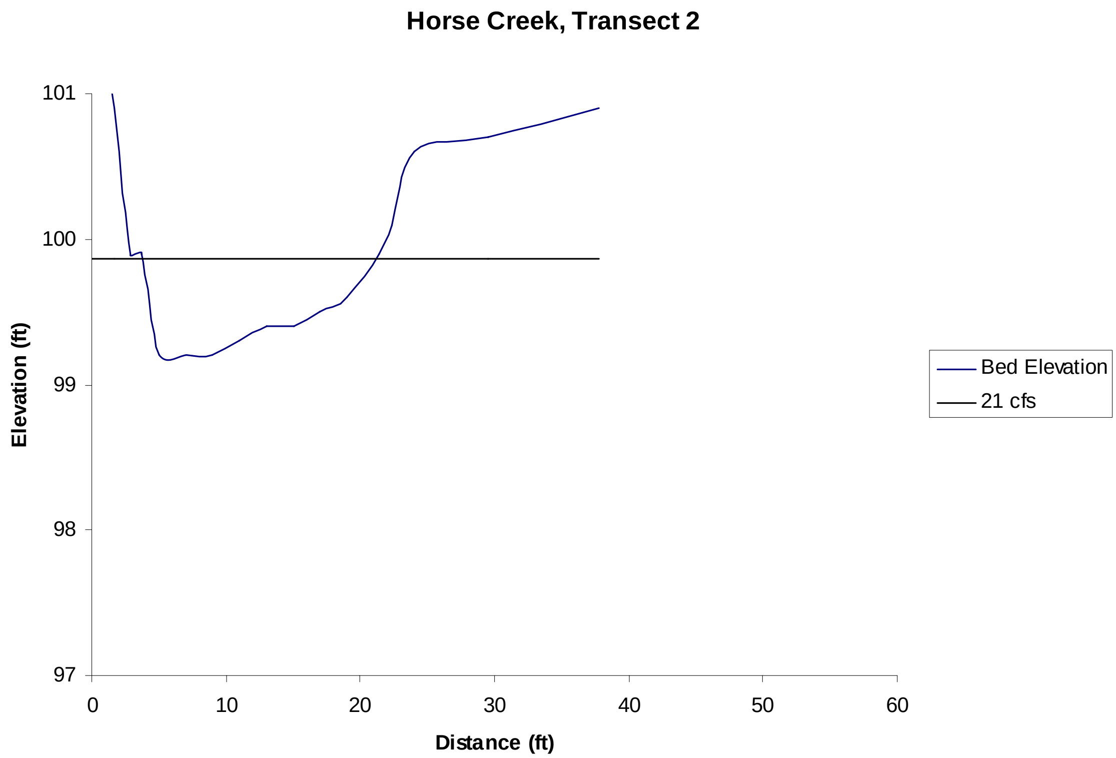

Figure 15 Horse Creek transect 2 profile and water surface elevation.

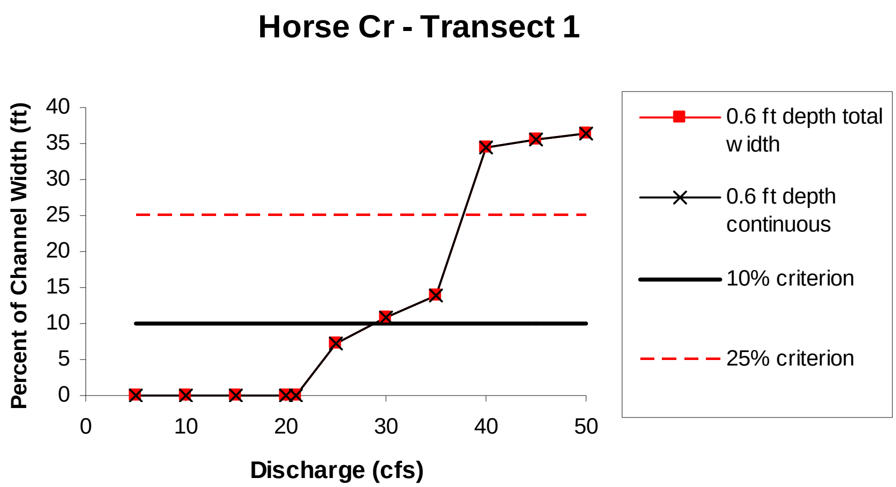

Figure 16 Discharge required to meet adult passage criteria at Horse Creek.

Cade Creek

Transect locations at the Cade Creek site are diagrammed in Figure 17. Photos of Cade Creek as it enters the Klamath River are shown in Figure 18. Cross sectional profiles of each transect (main stem and tributary) and measured water surface elevations are shown in Figures 19 to 22. A plot of flow versus wetted width shown in Figure 23 illustrates adult passage flow needed to meet depth and width criteria at transect 2 in Horse Creek.

Cade Creek is perched above the Klamath main stem stream channel just upstream of where it enters the Klamath River, resulting in a very steep slope at the confluence (Figure 18). As a result, there is a dramatic water surface elevation difference (>2 ft) between the top of the slope at the mouth of Cade Creek and the Klamath River, even at main stem flows >3,600 cfs (Table 4). During the survey at Cade Creek on July 11, 2007, juvenile salmonids were observed attempting unsuccessfully to jump into the tributary from the main stem, possibly trying to escape the warm main stem water temperatures. The main stem water temperature was 25.5 ºC (77.9 ºF) while the Cade Creek temperature was 21.5 ºC (70.7 ºF) at 1300 hours. A minor stream restoration effort to create pocketwater habitat in lower Cade Creek would allow easier access for juvenile salmonids to enter Cade Creek.

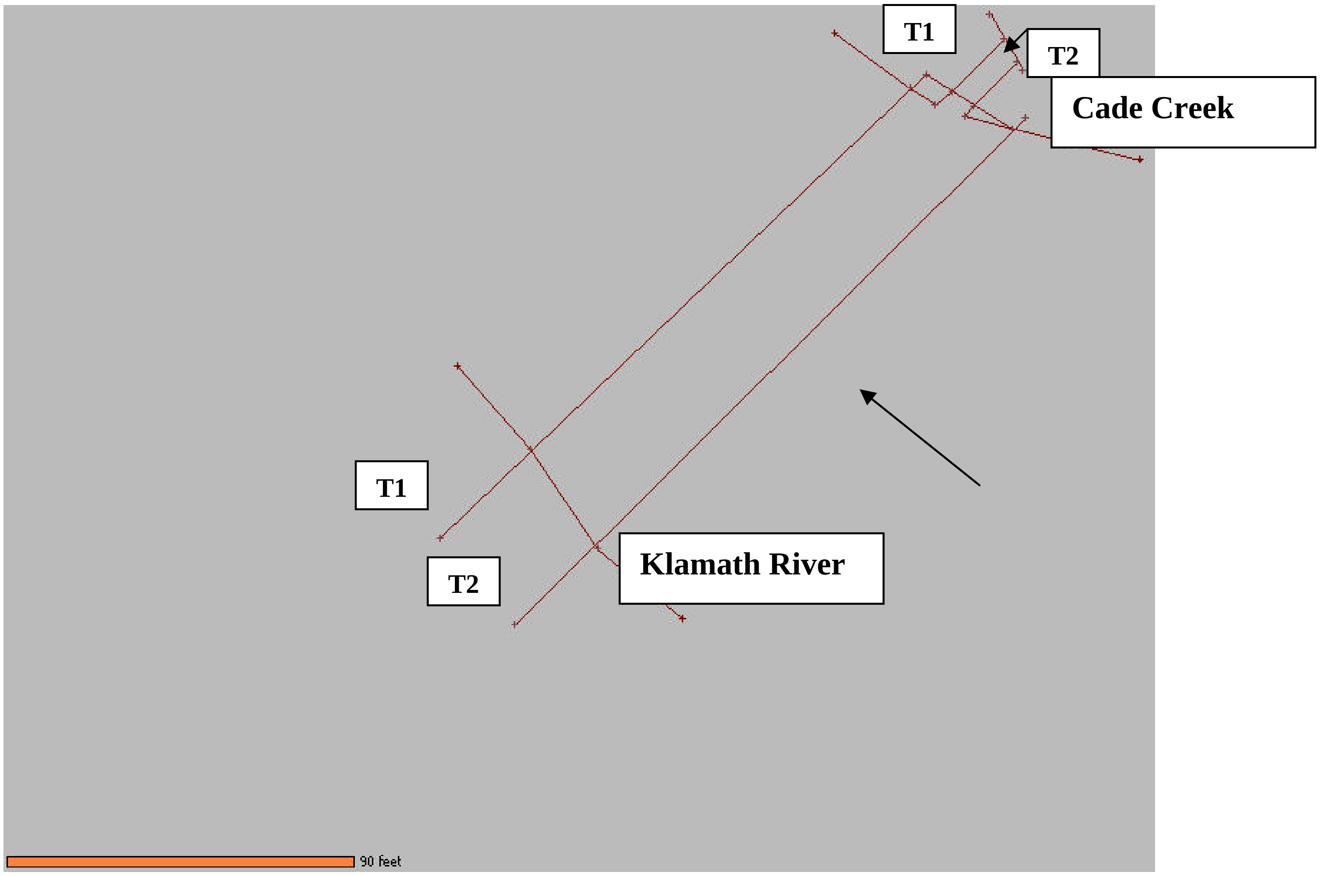

Figure 17 Cade Creek confluence with Klamath River and transect locations.

Figure 18 Cade Creek confluence with Klamath River, July 11, 2007.

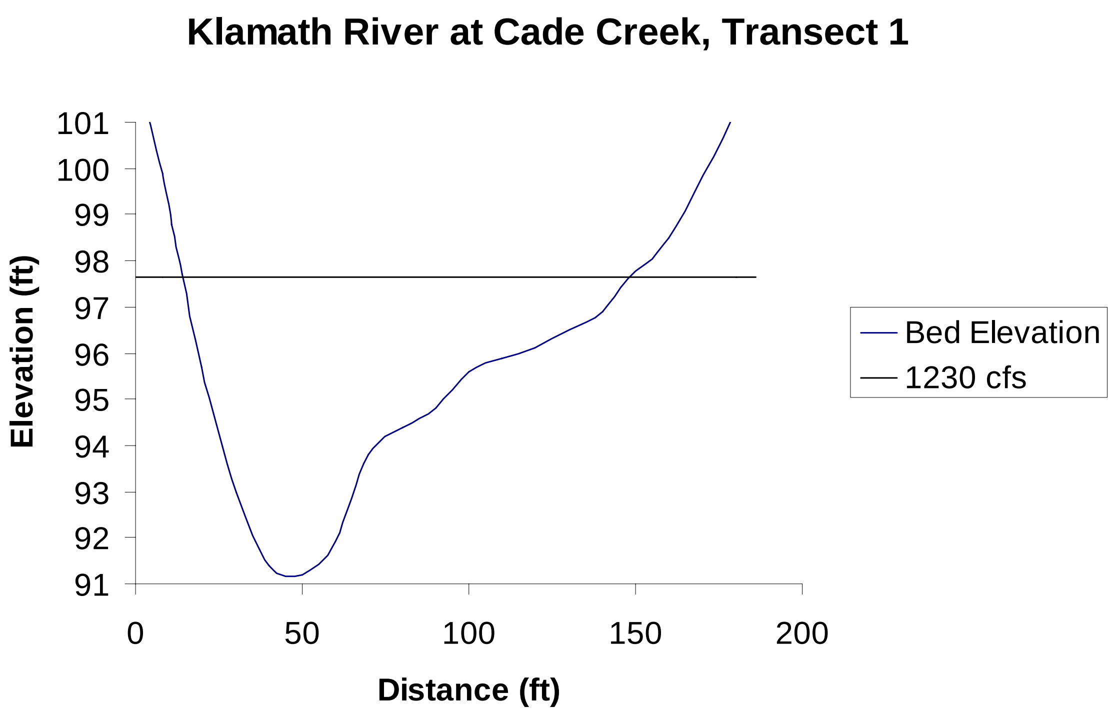

Figure 19 Klamath River transect 1 profile and water surface elevation at Cade Creek.

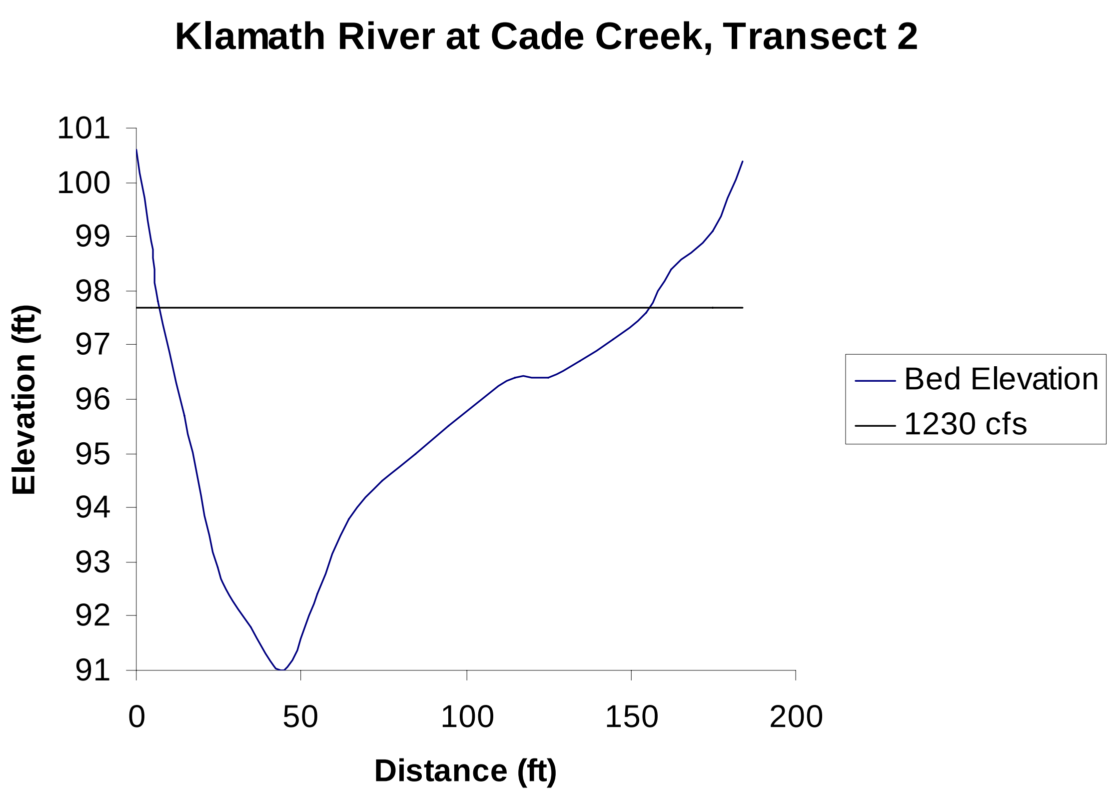

Figure 20 Klamath River transect 2 profile and water surface elevation at Cade Creek.

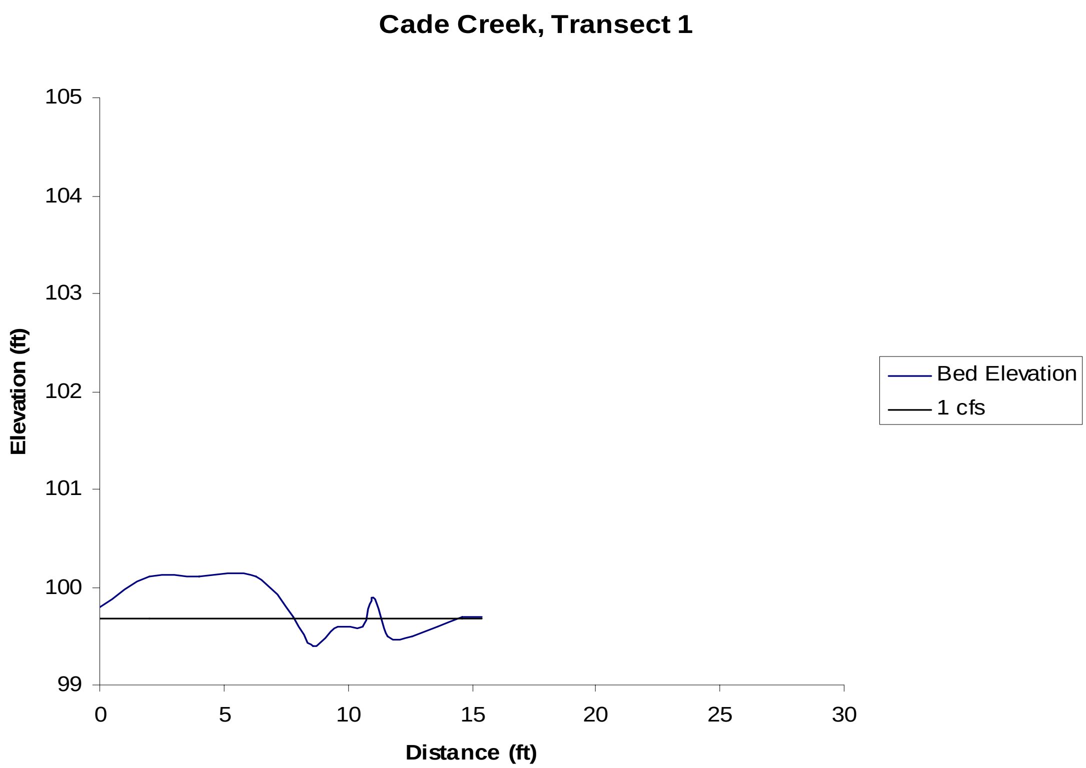

Figure 21 Cade Creek transect 1 profile and water surface elevation.

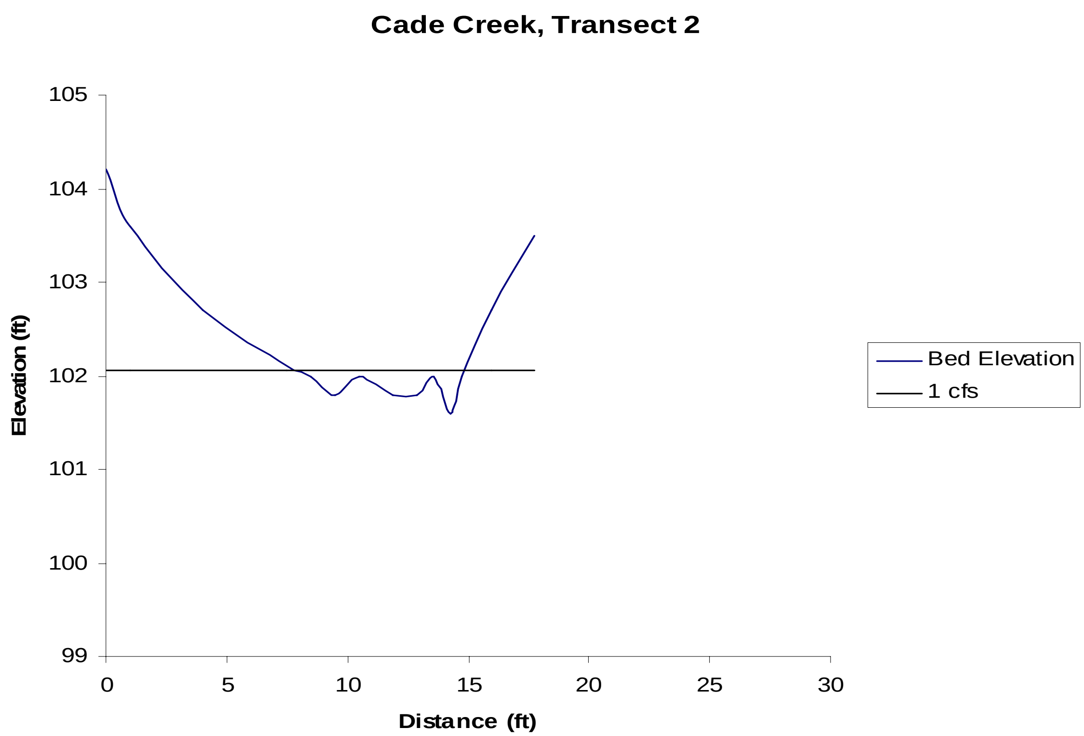

Figure 22 Cade Creek transect 2 profile and water surface elevation.

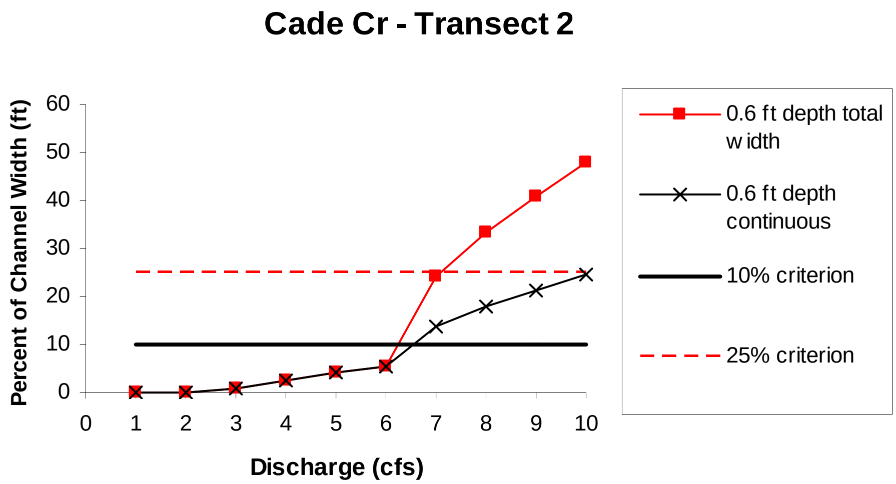

Figure 23 Discharge required to meet adult passage criteria at Cade Creek.

Sandy Bar Creek

Transect locations at the Sandy Bar Creek site are diagrammed in Figure 24. Photos of Sandy Bar Creek as it enters the Klamath River are shown in Figures 25 and 26. Cross sectional profiles of each transect (main stem and tributary) and measured water surface elevations are shown in Figures 27 to 30. Flows needed for juvenile and adult passage in Sandy Bar Creek exceeded the upper modeled creek flow of 10 cfs (Figure 31). I would prefer modeling higher flows with additional surveys at flows higher than 1 cfs in Sandy Bar Creek. Similar to Cade Creek, Sandy Bar Creek is perched above the Klamath River and enters the main stem at a very steep slope, resulting in a dramatic water surface elevation difference (>4.5 ft) between the top of the slope and the Klamath River, even at main stem flows >4,200 cfs (Table 4). This steep drop in elevation at the confluence makes passage improbable for juvenile salmonids. However, a recent stream restoration effort conducted by the Karuk tribe (see Figure 25) has created pocketwater habitat to allow juvenile salmonids to pass into the tributary.

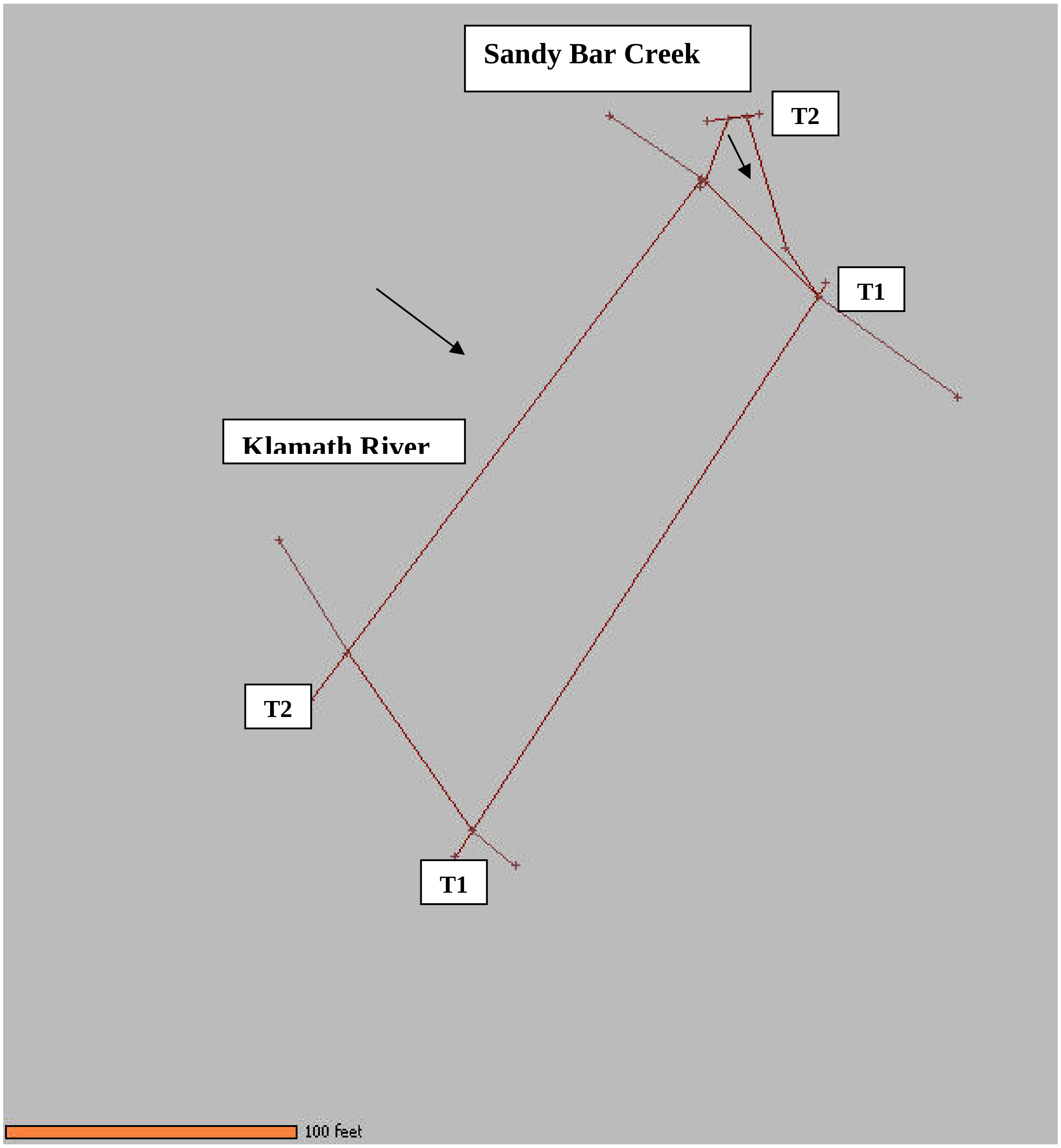

Figure 24 Sand Bar Creek confluence with Klamath River and transect locations.

Figure 25 Sandy Bar Creek looking upstream at stream restoration, July 13, 2007.

Figure 26 Sandy Bar Creek confluence with Klamath River looking downstream, July 13, 2007.

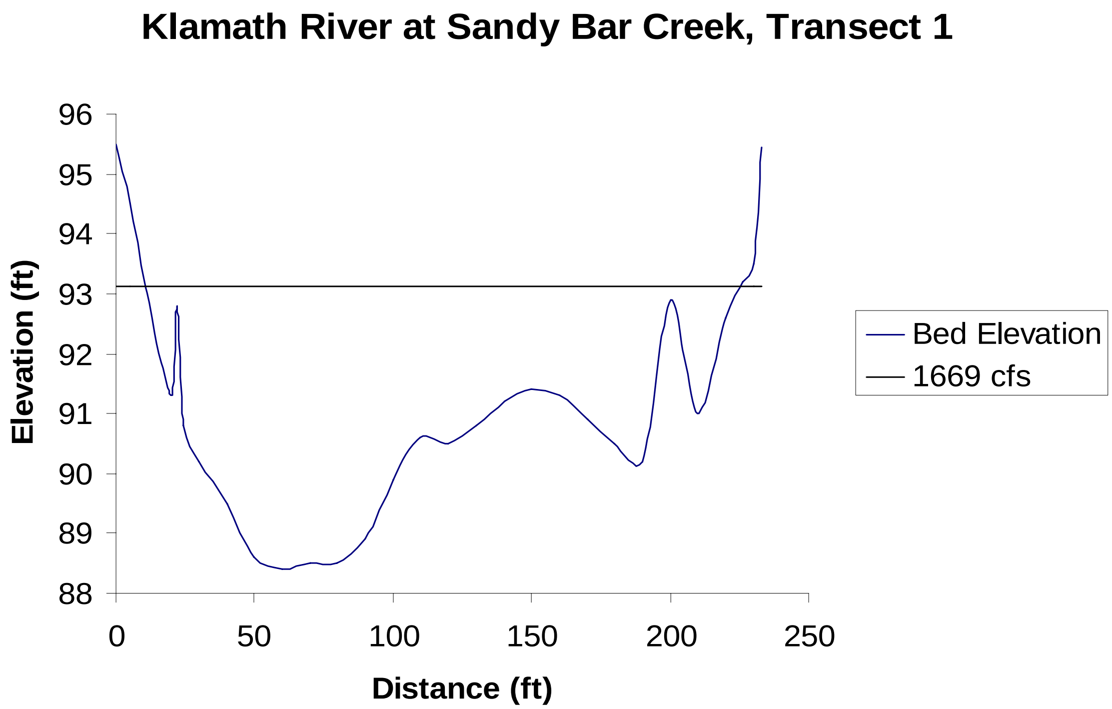

Figure 27 Klamath River transect 1 profile and water surface elevation at Sandy Bar Creek.

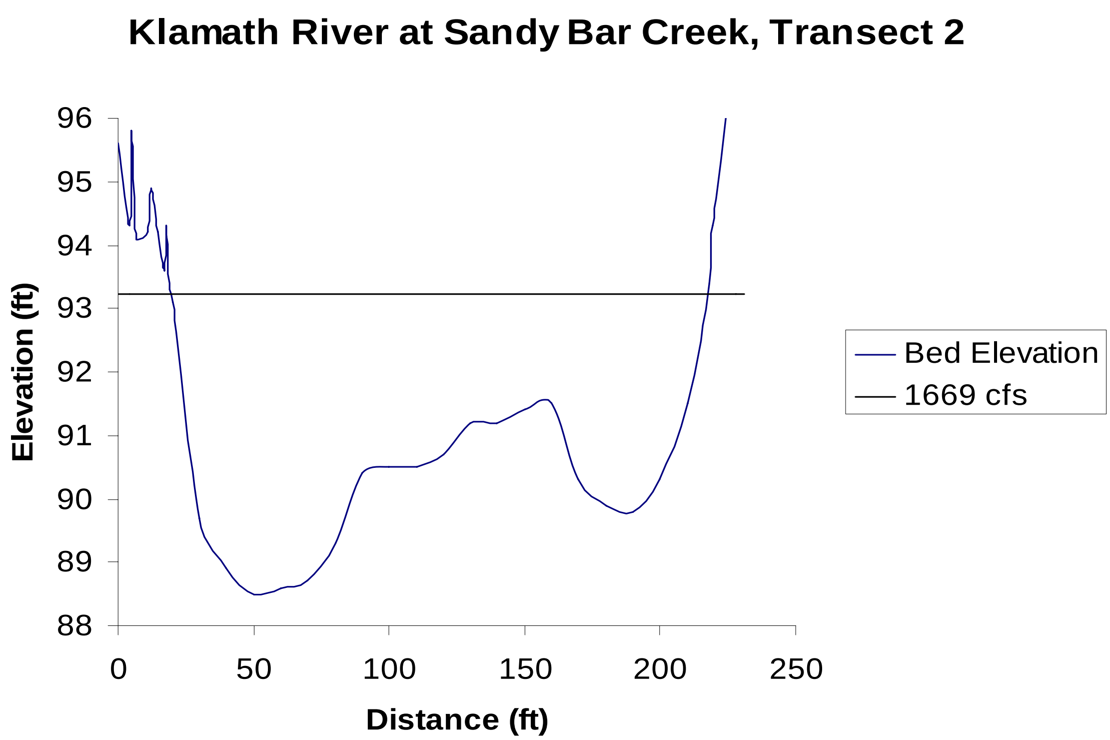

Figure 28 Klamath River transect 2 profile and water surface elevation at Sandy Bar Creek.

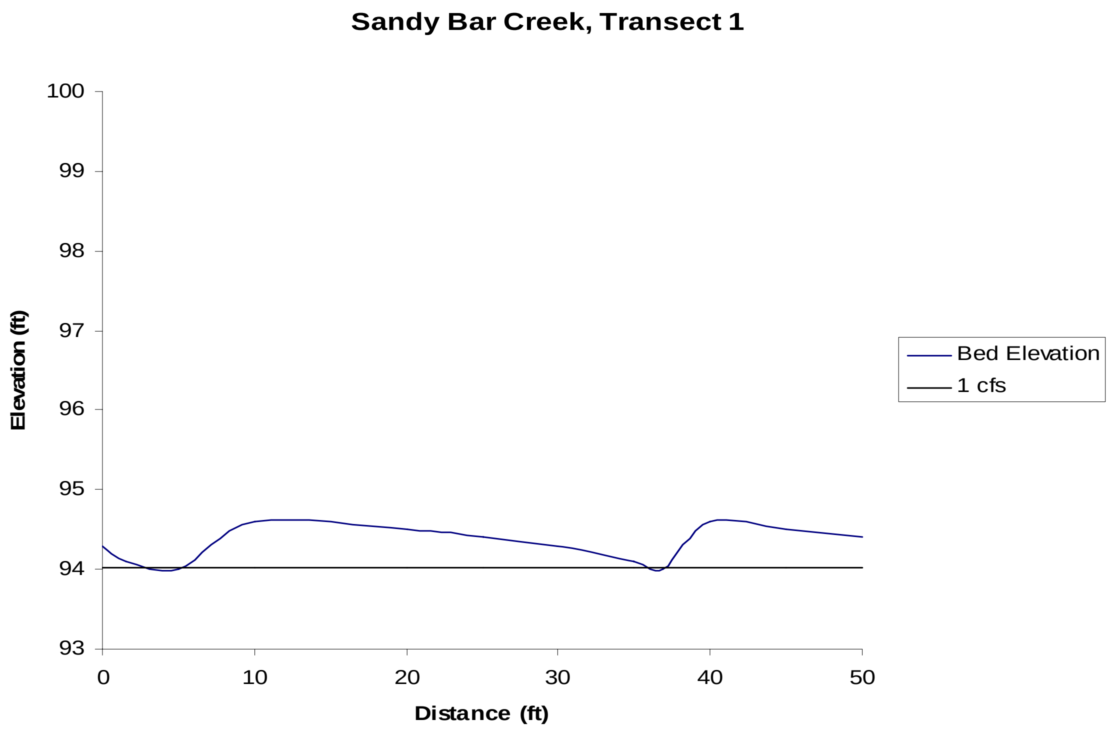

Figure 29 Sandy Bar Creek transect 1 profile and water surface elevation.

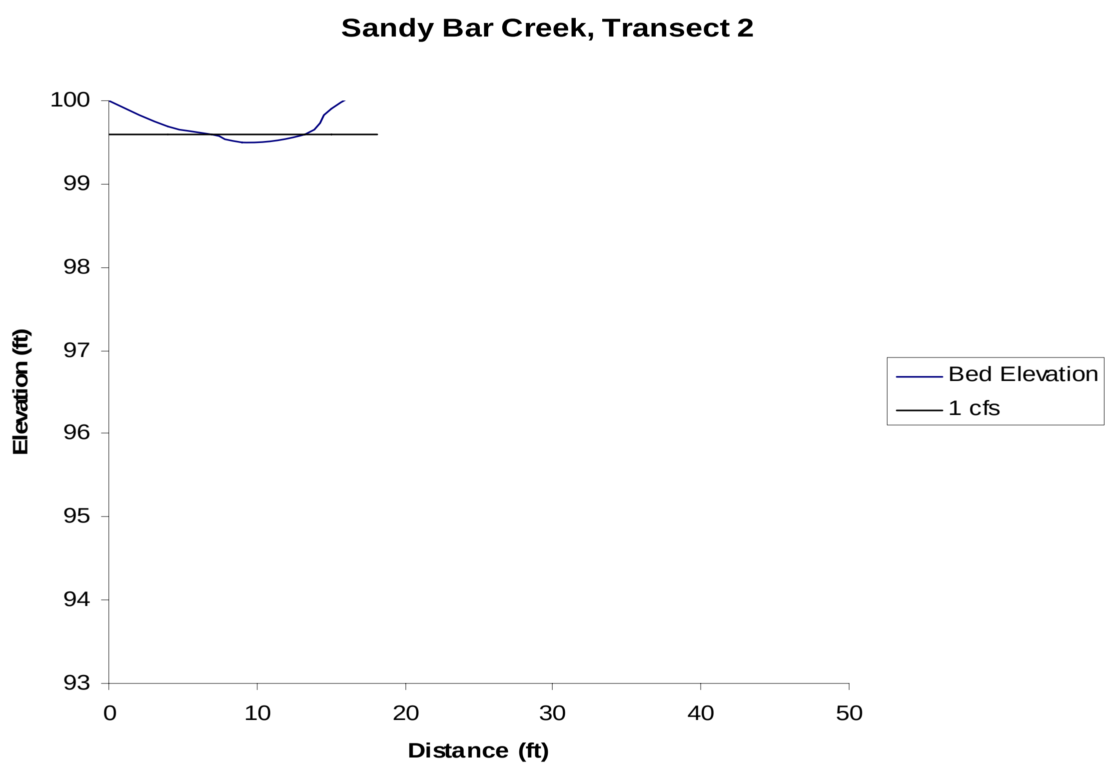

Figure 30 Sandy Bar Creek transect 2 profile and water surface elevation.

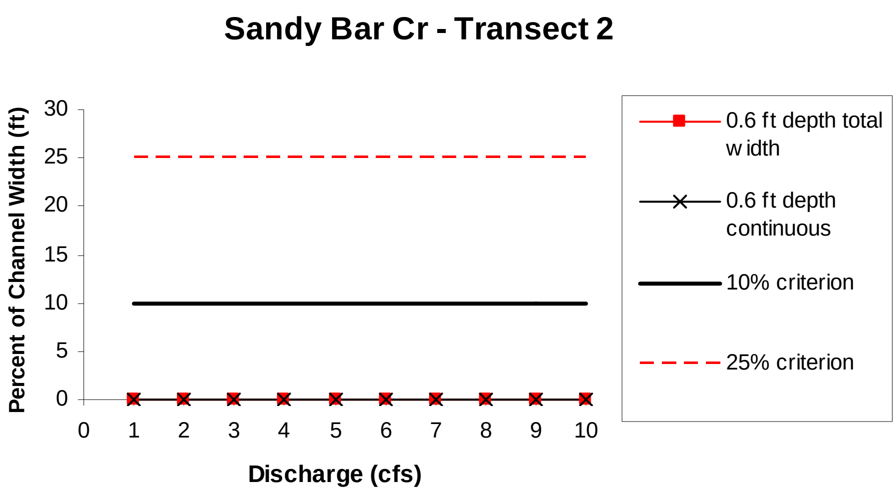

Figure 31 Discharge required to meet adult passage criteria at Sandy Bar Creek.

Recommendations

The following suggestions would help improve this study:

1. Since fall adult movement into tributaries is affected primarily by tributary freshets, I suggest a re-survey of the tributary transects and any downstream main stem hydraulic controls during mid and high flows to improve model calibration and to better assess the range of flows that may affect adult migration into the tributaries.
2. Surveys on additional tributaries would provide more clarity on the ability of main stem flows to meet tributary passage requirements.
3. Small tributaries that are "perched" above the main stem Klamath River, such as Cade Creek and Sandy Bar Creek, should be targeted for annual stream restoration to create pocketwaters that allow juvenile salmonids to move more easily between the main stem and the tributary. To test this hypothesis, juveniles could be trapped or observed by snorkeling at the mouth of one of these tributaries and in the tributaries before and after the restoration to determine its effectiveness.

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