WASHINGTON STATE
DEPARTMENT OF
ECOLOGY

Open File Technical Report

Kalama River
Fish Habitat Analysis Using the Instream Flow Incremental Methodology

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Kalama River Fish Habitat Analysis Using the Instream Flow Incremental Methodology

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SUMMARY

The Washington State Department of Ecology (Ecology) conducted an instream flow study on the Kalama River using the Instream Flow Incremental Methodology (IFIM). This study provides information about the relationship between streamflow and fish habitat, which can be used in developing minimum instream flow requirements for fish in the Kalama River. Two sites, composed of five transects, was chosen. The site was located at approximately river mile (RM) 4.3 near the overhead gas pipeline at Mahaffey's and at RM 5.2, upstream of the lower salmon hatchery. Streamflow measurements and substrate information were recorded at high, medium and low flows. This information was entered into the IFG4 hydraulic model to simulate the distribution of water depths and velocities with respect to substrate and cover under a variety of flows. Using the HABTAT model, the simulated information was then used to generate an index of change in available habitat relative to changes in flow; this index is referred to as "weighted usable area" (WUA).

Determination of a minimum instream flows for the Kalama River will require setting priorities for river reaches, fish species and lifestages. Different fish species and lifestages exist simultaneously in the river and each has a different flow requirement. There is no single flow that will simultaneously provide optimum habitat for all fish species and lifestages.

In addition, minimum instream flows must include flows necessary for incubation of fish eggs, smolt out-migration, fish passage to spawning grounds, and prevention of stranding fry and juveniles. Other variables to be considered include water temperature, water quality, and sediment load. These variables were not addressed in this study.

No instream flow recommendations were made in this report. Those recommendations would be the next step after this study. Instream flow determinations would require an evaluation of the environmental variables listed above combined with the long-range fishery management objectives of the state and federal natural resource agencies and affected Tribes. Some results of the IFIM study are portrayed in the table below:

Flow and Habitat Relationships for the Kalama River

Species	Instream Flow Which Provides Maximum Spawning Habitat	Instream Flow Which Provides Maximum Juvenile Habitat
Chinook	1050 cfs	600 cfs
Steelhead	950 cfs	900 cfs
Coho	900 cfs	N/A

ACKNOWLEDGEMENTS

I want to thank Joshua Husseman (Ecology), Jeff Marti (Ecology), Clay Keown (Ecology), and Cynthia Pratt (Fish and Wildlife) for having provided valuable assistance in gathering field data.

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Introduction

The Washington State Department of Ecology (Ecology) is mandated by the 1971 Water Resources Act (Chapter 90.54 RCW) to maintain instream flows necessary to provide for preservation of wildlife, fish, scenic, aesthetic and other environmental values. As part of Ecology's commitment to the Lower Columbia Steelhead Conservation Initiative to provide more protection for salmonids after the listing of steelhead as a threatened species in the lower Columbia River in March 1998, Ecology agreed to conduct instream flow studies to provide information for determining instream flows. To determine appropriate minimum instream flows for fish habitat, one tool Ecology often uses is the Instream Flow Incremental Methodology (IFIM) to generate some of the necessary information. The minimum flows determined by Ecology cannot take away any existing water rights and serve to protect existing water right users by restricting new upstream diversions if the river is already experiencing low flows. This information may be used by Ecology to determine the impact of future water appropriations on fish habitat or to condition new water rights to protect instream flows for fish habitat.

Study participants included staff from Ecology and Washington State Department of Fish and Wildlife (WDFW).

Project Background: Location and Description

The Kalama River is located in southwestern Washington in Cowlitz and Skamania counties. The Kalama River basin originates on the southwest slopes of Mount St. Helens and flows southwesterly about 44 miles to its confluence with the Columbia River at RM 73 (WDF et al., 1993). Major tributaries within the 205 square mile basin include Fossil Creek, North Fork, Langdon Creek, Gobar Creek, Wildhorse Creek, and Hatchery Creek among others. Elevations within the basin range from less than 100 feet in the lower reaches near the river's mouth to 5,000 - 6,000 feet in the upper basin.

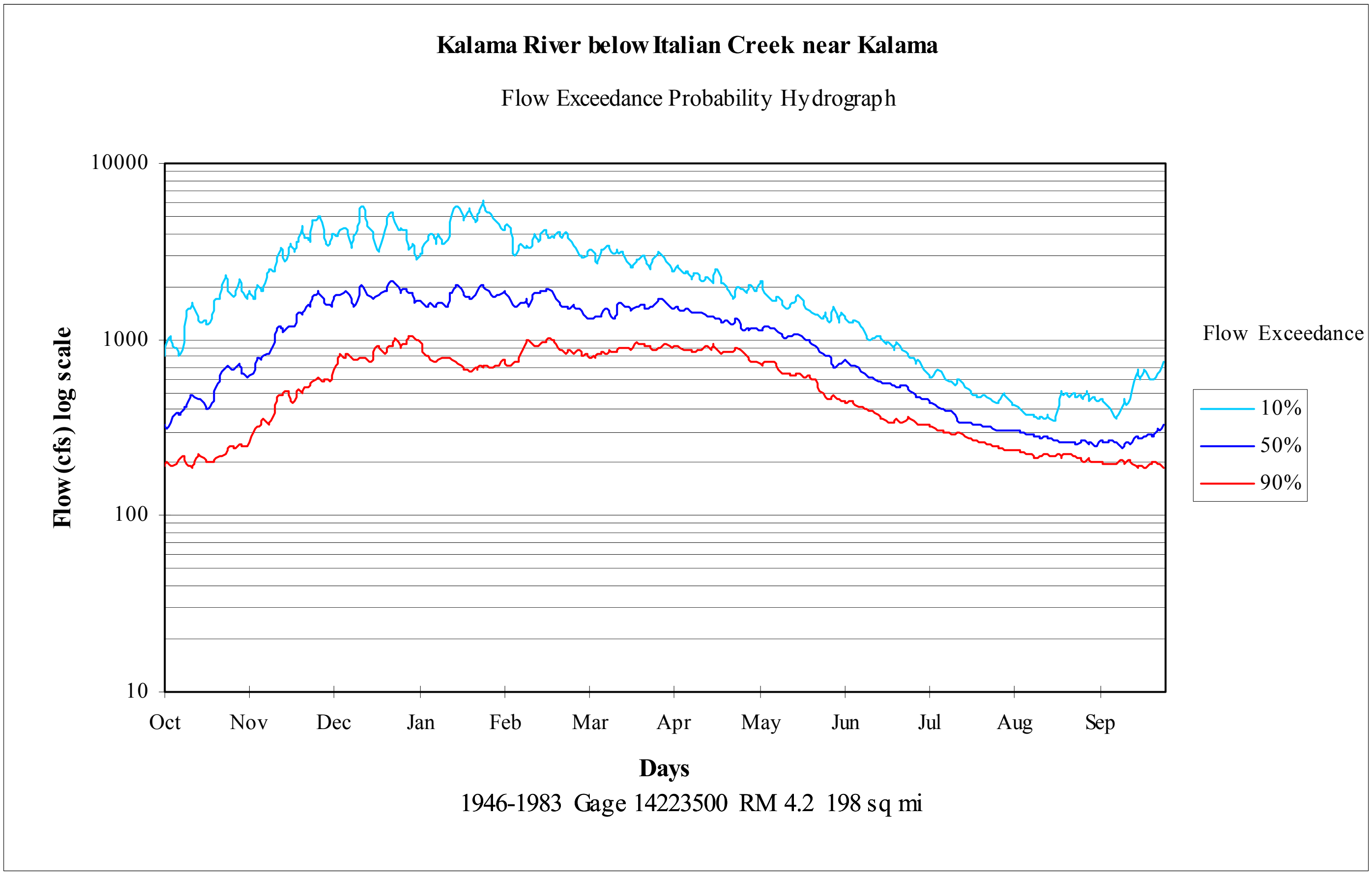
Private timber companies own and manage approximately 96 percent of the Kalama watershed. The Washington Department of Natural Resources manages a few sections in the basin and the U.S. Forest Service owns a limited number of parcels in the upper portion of the watershed. (WDFW, 1998).

The quality of fish habitat in the Kalama River watershed is largely a function of forest practices in the upper reaches of the watershed. Exposing large quantities of soil through the logging process (e.g. tractor skidding) and deficient road building results in ditch erosion and cut bank failures. The consequences of these activities include changes in water quality and quantity, changes in streamflow extremes, increases in sedimentation and destabilization of the streambed. Habitat in the lower reaches are impacted by farming and livestock grazing of riparian vegetation along with non-point source pollution from agricultural land uses and increased urban development. Contamination by septic systems, fertilizers, herbicides and pesticides are all areas of concern as is excessive water withdrawal (WDFW, 1998).

Hydrology

The daily exceedance flows for the Kalama River are portrayed in Figure 1. This graph is based upon daily average flows from 1946-1983 obtained from the U.S. Geological Survey (USGS) gage 5.7 miles downstream of Italian Creek near the city of Kalama at RM 4.2. This exceedance graph is useful in assessing variances in streamflows at certain times of the year rather than relying on a single number such as mean monthly flow.

Figure 1. Hydrograph of the Kalama River.



The exceedance graph shows the range of flows one might expect on a given day.

When a single number is used to describe the flow in a stream, such as average monthly flow, it gives a very distorted idea of the normal flow in the stream. A range, such as the 10% to 90% flow exceedance values, best describes streamflow. This flow range describes the flow one would expect to see 80% of the time in the stream. The 10% exceedance value can be viewed as the quantity of flow in the stream on a specific day that reaches that flow level or higher one out of every 10 years. The 50% exceedance flow value is the median flow: over all the years of record, half of the time on that day the flow was higher and half of the time the flow was lower. The 90% exceedance level means the flow is that level or higher in 9 out of 10 years on that day.

For example: in August in the Kalama River the ninety percent exceedance flow is about 220 cfs, the fifty percent exceedance flow is approximately 280 cfs, and the ten percent exceedance flow is about 410 cfs. During August one would expect to see flows from 220 to 410 cfs about eighty percent of the time. In January one would expect to see flows ranging from 760 to 4660 cfs about eighty percent of the time.

The 10% exceedance flow level is not an unusual flow in the stream. Streamflow in a certain year in not at the 10%, 50%, or 90% level on a consistent basis. Rather, flow normally jumps back and forth on a daily or weekly basis from the 10% to 90% exceedance level and sometimes from the 5% to 95% exceedence levels. Usually the reason for this flow behavior is either it's raining and streamflows are very high, or it has stopped raining for a week and streamflows are now very low.

The hydrograph does not include water diverted for irrigation or other purposes and used consumptively. This diverted water would need to be added to the hydrograph to determine the natural flow in the stream.

Water Quality Standards

Monitoring of water quality on the Kalama River has indicated excursions (a situation where water quality conditions do not meet state water quality standards) for temperature and pH. The Department of Ecology has conducted monitoring of the river since 1970 at ambient monitoring station 27B070 located 2.3 miles northeast of Kalama on Kalama River Road. Because of these excursions, the Kalama River is listed on the Washington State Department of Ecology's 303(d) list of water bodies that fail to meet state water quality standards (Ecology, 1996).

Fish Use and Status

The Kalama River basin is in the area for three different fish species listed as threatened under the Endangered Species Act: steelhead were listed in March, 1998 for the Lower Columbia River ESU; chinook salmon were listed in March, 1999 for the Lower Columbia River ESU; and chum salmon were listed in March, 1999 for the Columbia River ESU. Coho salmon are still being studied as a candidate species. Maps of these ESU areas are in Appendix A.

As part of the 1992 Salmon and Steelhead Stock Inventory (SASSI), the Washington State Department of Fisheries and Department of Wildlife identified summer steelhead and coho stocks as being "depressed" (WDF et al., 1993). The rating "depressed" means a stock of fish whose production is below expected levels based on available habitat and natural variations in survival rates, but above the level where permanent damage to the stock is likely.

Chinook

Fall chinook salmon in the Kalama River spawn primarily in an 8.7 mile stretch from Italian Creek (RM 9.9) downstream to the I-5 bridge (RM 1.2). There is no upstream migration beyond the Kalama Falls Hatchery (RM 10) unless surplus fish are released upstream of the hatchery. Fall chinook migrate upriver from August through September and spawn from late September to November (WDF et al., 1993). Natural production of fall chinook which are indigenous to the Kalama River has decreased from historic levels primarily due to habitat degradation (WDFW, 1998). Natural spawning escapements from 1967-1991 averaged 6448 fish. According to the SASSI, this stock is healthy although escapements since 1989 have been below average probably due to natural fluctuations (WDF et al., 1993).

Spring chinook in the Kalama River are managed as a hatchery stock. Historically spring chinook have been native to the Kalama River, however by the 1950's spawning escapements were fewer than 100 fish. Spring chinook hatchery stock were introduced at the Kalama Falls Hatchery in 1959. Spawning occurs between the Lower Kalama Hatchery (RM 4.8) and the Kalama Falls Hatchery (RM 10). In surplus years, spawning releases are made upstream of the upper hatchery though a natural barrier at RM 36.8 blocks migration. Spring chinook typically migrate upriver from March through July and spawn from mid-August through early October. Escapements from 1980-1991 averaged 602 fish. The status of the spring chinook stock is reported as healthy in the 1992 SASSI report (WDF et al., 1993).

Steelhead

Summer steelhead in the Kalama River generally migrate upriver from early June through October and spawn from mid-January through April (WDF et al., 1993). Few summer steelhead spawn below the Kalama Falls Hatchery (RM10), most spawning occurs from upstream of the hatchery to the upper falls (RM36.8) (WDFW, 1998). The wild summer steelhead escapement goal is 1000 fish. Adjusted trap counts ranged from 188 to 764 summer steelhead from 1976-1990.

According to the SASSI report the status of the summer steelhead stock is depressed (WDF et al., 1993). Overharvesting, genetic impacts of hatchery steelhead, urbanization of the riparian zone adjacent to the river, and past forest practices are factors responsible for depressed summer runs. Past logging operations were often concentrated on individual tributaries resulting in decreased riparian cover and increases in temperature and sedimentation along with changes in flow regimes. These tributaries, particularly Gobar Creek, Wildhorse Creek, and the North Fork Kalama among others accounted for up to 50 percent of steelhead spawning escapements during redd surveys from 1988-90 (WDFW, 1998).

Winter steelhead migrate upriver from November through April with spawning occurring from early January to early June. The falls at the Kalama Falls Hatchery is a barrier to winter steelhead migration so, unlike summer steelhead, most winter steelhead spawning occurs below the Kalama Hatchery. Winter steelhead stock status is listed as healthy in the SASSI report. The spawning escapement goal is 1000 wild winter steelhead and the average escapement from 1983-1992 was 1157 (WDFW, 1998).

Coho
Wild coho may comprise only 5 to 10 percent of the total Kalama basin produced coho stock (WDFW, 1998). The native population of coho in the Kalama River was estimated to be about 3000 fish in 1951. Hatchery coho have been planted from the Lower Kalama Hatchery since 1942 (WDF et al., 1993). These natural stocks have been declining since the middle of this century due to habitat degradation from agriculture, logging, urbanization and high harvest rates in the fisheries (WDFW, 1998).

Coho usually migrate upriver into the Kalama River in early September through February with spawning occurring from mid-October through February. Until a fish ladder was constructed in 1936, coho were confined to areas below the lower Kalama Falls (WDFW, 1998). Though escapement figures are unknown, coho are thought to spawn in all available Kalama River tributaries. Coho return as two-year-old jacks and three-year-old adults. The SASSI Report lists the stock status of coho in the Kalama as depressed based on chronically low production (WDF et al., 1993).

Study Methods

Instream Flow Incremental Methodology (IFIM)

IFIM was selected as the best available method for predicting how the quantity of available fish habitat changes in response to incremental changes in streamflow. The U.S. Fish and Wildlife Service in the late 1970s (Bovee, 1982) developed this methodology. The IFIM involves putting site-specific streamflow and habitat data into a group of models collectively called PHABSIM (physical habitat simulation). The most common model is IFG4, which uses multiple transects to predict depths and velocities in a river over a range of flows. IFG4 creates a cell for each measured point along the transect or cross-section. Each cell has an average water depth and water velocity associated with a type of substrate or cover for a particular flow. The cell's area is measured in square feet. Fish habitat is defined in the computer model by the variables of velocity, depth, substrate, and/or cover. These are important habitat variables that can be measured, quantified, and predicted.

The IFIM is used nationwide and is accepted by most resource managers as the best available tool for determining the relationship between flows and fish habitat. However, the methodology only uses four variables in hydraulic simulation. At certain flows, such as extreme low flows, other variables such as fish passage, food supply (aquatic insects), competition between fish species, and predators (birds, larger fish, etc.) may be of overriding importance. In addition to the PHABSIM models, IFIM may include reviewing water quality, sediment, channel stability, temperature, hydrology, and other variables that affect fish production. These additional variables are not analyzed in this report.

After the IFG4 model is calibrated and run, its output is entered into another model (HABTAT) with data describing fish habitat preferences in terms of depth, velocity, substrate, and cover. These preferences vary according to fish species and life-stage (adult spawning and juvenile rearing).

The output of the HABTAT model is an index of fish habitat known as Weighted Useable Area (WUA). The preference factor for each variable at a cell is multiplied by the other variables to arrive at a composite, weighted preference factor for that cell. For example: a velocity preference of 1.0 multiplied by a depth preference of 0.9, then multiplied by a substrate preference of 0.8 equals a composite factor of 0.72 for that cell. This composite-preference factor is multiplied by the number of square feet of area in that cell.

A summation of all the transect cells' areas results in the total number of square feet of preferred habitat available at a specified flow. This quantity is normalized to 1,000 feet of stream or river. The final model result is a listing of fish habitat values (WUA) in units of square feet per 1,000 feet of stream. The WUA values are listed with their corresponding flows (given in cubic feet per second).

Study Site and Transect Selection

A preliminary study site was selected for the IFIM study by reviewing topographic maps. Actual site selection was done during field visits. Four transects were chosen around RM 4.3 and one transect at RM 5.2 (see Figure 2) to represent the lower river. These transect sites are shown in the table below.

Kalama River Transects

Transect #	Location
1	River Mile 4.3
2	230 feet upstream of Transect 1
3	118 feet upstream of Transect 2
4	50 feet upstream of Transect 3
5	River Mile 5.2

Field Procedures

IFIM measurements were taken on May 14, 1998 at 828 cfs; June 10, 1998 at 690 cfs; August 3, 1998 at 262 cfs, and on September 17, 1998 at 190 cfs.

A temporary gage at each site was used to verify that streamflow at each transect remained steady during measurement. Transects were marked using survey hubs and flagging. Water velocity was measured using standard USGS methods with a calibrated Swoffer velocity meter mounted on a top-set wading rod.

Water surface elevations and stream-bank profiles were surveyed with a survey level and stadia rod. These points were referenced to an arbitrary, fixed benchmark. Substrate composition and cover were assessed by visually estimating the percent of the two main particle size classes and type of cover according to a scale recommended by the Washington Departments of Fisheries and Wildlife. This scale is included as Appendix E.

Hydraulic Model

Calibration Philosophy

Calibration of the hydraulic model involved checking the velocities and depths predicted by the model against velocities and depths measured in the field. This included examining indicators of the model's accuracy such as mean error and Velocity Adjustment Factor (VAF). The calibration philosophy was to change data or to

manipulate data using a computer calibration option only when doing so would improve the model's ability to extrapolate without reducing the accuracy of predicted depths and velocities at the measured calibration flows.

Calibration of the IFG4 model was done cell by cell for each transect to decide whether the predicted cell velocities adequately represented measured velocities. Generally, if the predicted cell velocity at the calibration flow was within 0.2 feet per second (fps) of the measured cell velocity, the predicted velocity was considered adequate. Any change to a calibration velocity was limited to a change of 0.2 fps. The 0.2-fps change limit was thought to be reasonable considering the normal range of velocity measurement error. All cell velocities were reviewed at the highest and lowest extrapolated flows to ensure that extreme cell velocities were not predicted.

Indicators of Model Accuracy

Two indicators of the IFG4 model's accuracy in predicting depths and velocities are the mean error and the Velocity Adjustment Factor (VAF). See Appendix C for mean errors and VAFS for each transect at each site.

The mean error is the ratio of the calculated flow (from depths and velocities at the measured flows) to the predicted flow (from depth and velocity regressions). As a rule of thumb, the mean error for the calculated discharge should be less than 10 percent.

The Velocity Adjustment Factor (VAF) for a three-flow IFG4 hydraulic model indicates whether the flow predicted from the velocity/discharge regressions matches the flow predicted from the stage/discharge regressions. The velocities predicted from the velocity/discharge regressions for a transect are all multiplied by the same VAF to achieve the flow predicted from the stage/discharge regression. Calculating and comparing the flows predicted from two different regressions gives an indication as to whether or not some of the model's assumptions are being met.

A range in the VAF value of 0.9 to 1.1 is considered good, 0.85 to 0.9 and 1.1 to 1.15 fair, 0.8 to 0.85 and 1.15 to 1.20 marginal, and less than 0.8 and more than 1.2 poor (Milhous, 1984). The standard extrapolation range is 0.4 times the low calibration flow and 2.5 times the high calibration flow. The extrapolation range of the model is usually limited when two or more transects have VAFs which fall below 0.8 or above 1.2.

Options in IFG4 Model

Several options are available in the IFG4 hydraulic model (Milhous, 1989). Ecology's standard method is to set all the options to zero except for option 8 which is set at 2, and option 13 to 1 to get a summary of the velocity adjustment factors. The standard options were used for the models in this study.

Site Specific Calibration

A three-flow IFG4 model with five transects was run for the Kalama site. The IFG4 input file, a summary of the calibration details, data changes, and the velocity adjustment factors are included as Appendix C. The mean errors ranged from 0.49 to 6.42 percent. The velocity adjustment factors ranged from 0.86 to 1.02 allowing an extrapolation range from 100 to 2050 cfs.

Transect Weighting

The table below lists the percent weighting each transect received relative to the whole site. Transect weighting is determined one of two ways: either the model automatically determines weighting for each transect by using the distance between the transects or transect weight is set to predetermined levels by specifying distances between transects and upstream weighting (referred to as composite weighting). Composite weighting is done when the transects are located far apart and the distances between the transects would create incorrect weighing, or the investigator wants to increase the weight of a particular type of fish habitat for that site. Transect weighting for the Kalama River sites was done using the distances between transects and composite weighting for transect 5 at RM 5.2..

Transect Weighting for the Kalama River Site

Transect #	1	2	3	4	5
Percent of Total Site	21.7	32.8	15.85	17.2	12.45

Agency Approval of the Hydraulic Model

Brad Caldwell of the Department of Ecology and Hal Beecher of the Department of Fish and Wildlife met December 3, 1998 and after reviewing the calibration details decided the hydraulic models were adequate for the extrapolation range listed above.

Habitat Use Model (HABTAT)

Options Used in HABTAT

The HABTAT program combines the depths and velocities predicted from the IFG4 hydraulic model with the depths, velocities, cover, and substrate preferences from the habitat-use curves. The HABTAT program calculates WUA for each flow modeled. The IOC options used in HABTAT were IOC 00000 00101 00000 000.

Habitat Preference Curves

Fish preference curves for the Kalama River were agreed to by Brad Caldwell for the Department of Ecology and by Hal Beecher for the Department of Fish and Wildlife at a December 3, 1998 meeting. Existing agency preference curves were used for chinook, coho, and steelhead. These preference curves are listed in Appendix D. The substrate and cover codes are listed in Appendix E.

Observations on use by juvenile salmonids of water depth, velocity, substrate, and cover were gathered by Department of Fish and Wildlife biologist Hal Beecher. These observations are in Appendix B.

Results and Discussion

The results are the fish habitat versus flow curves in Figure 3. Figure 4 shows how the wetted area changes with flow. The total area number can be divided by 1,000 to calculate the average wetted width for any flow from 100 to 2050 cfs. Table 1 shows what percent of optimum habitat is available for each species at a given flow.

These results can be interpreted by biologists to determine a minimum flow regime to protect and preserve instream flow for fish under Washington State law.

Factors To Consider When Developing A Minimum Insteam Flow

Determining a minimum instream flow for a river or stream requires more than choosing the peak WUA flow for one lifestage of one species at one reach from the IFIM study. Because multiple lifestages existing simultaneously in a river, no specific flow will provide an optimum flow for all lifestages and species. Setting a minimum instream flow requires ranking the importance of each fish species and lifestage. This ranking requires considering long-range management plans for the fishery resources as determined by the state and federal natural resource agencies and the affected Tribes.

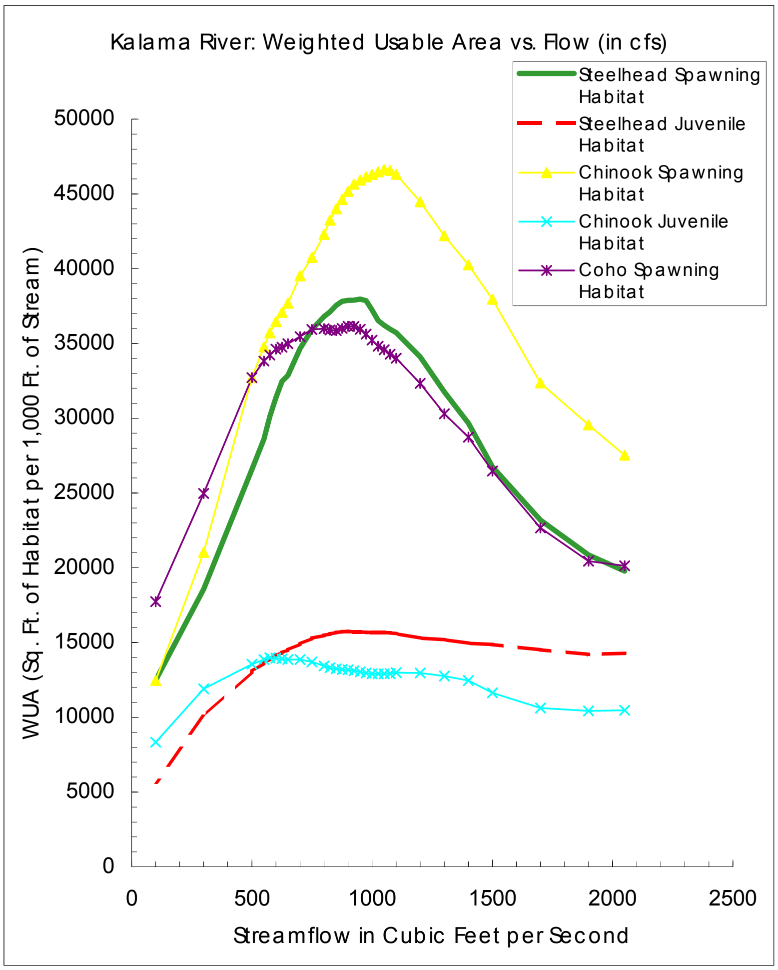
In addition, minimum instream flows must include flows necessary for incubation of fish eggs, smolt out-migration, fish passage to spawning grounds, and prevention of stranding of fry and juveniles. Other variables, which have to be considered, include water temperature, water quality, and sediment load. None of these variables were measured in this IFIM study. Therefore, reaching a conclusion about an appropriate minimum instream flow involves integrating the results of the IFIM study with consideration of these additional variables.

It's important to know that under a minimum instream flow under Washington State's laws is not the minimum flow that must be in the stream. No one has to stop using an existing water right to meet the minimum instream flow set by rule. The minimum instream flow only applies to new water rights issued after the date the rule was adopted. The minimum instream flow is the flow at which water is unneeded for the protection and preservation of fish and therefore new water rights can be given to anyone who requests since there is surplus water available.

Setting the minimum instream flow at the monthly mean during the low flow month sounds reasonable, but under State law it means that one-half of the flow during the low flow month is now available for new diversions. This is because the flow in the stream is higher than the mean about 50% of the time.

Figure 3. WUA vs Flow for Kalama River.

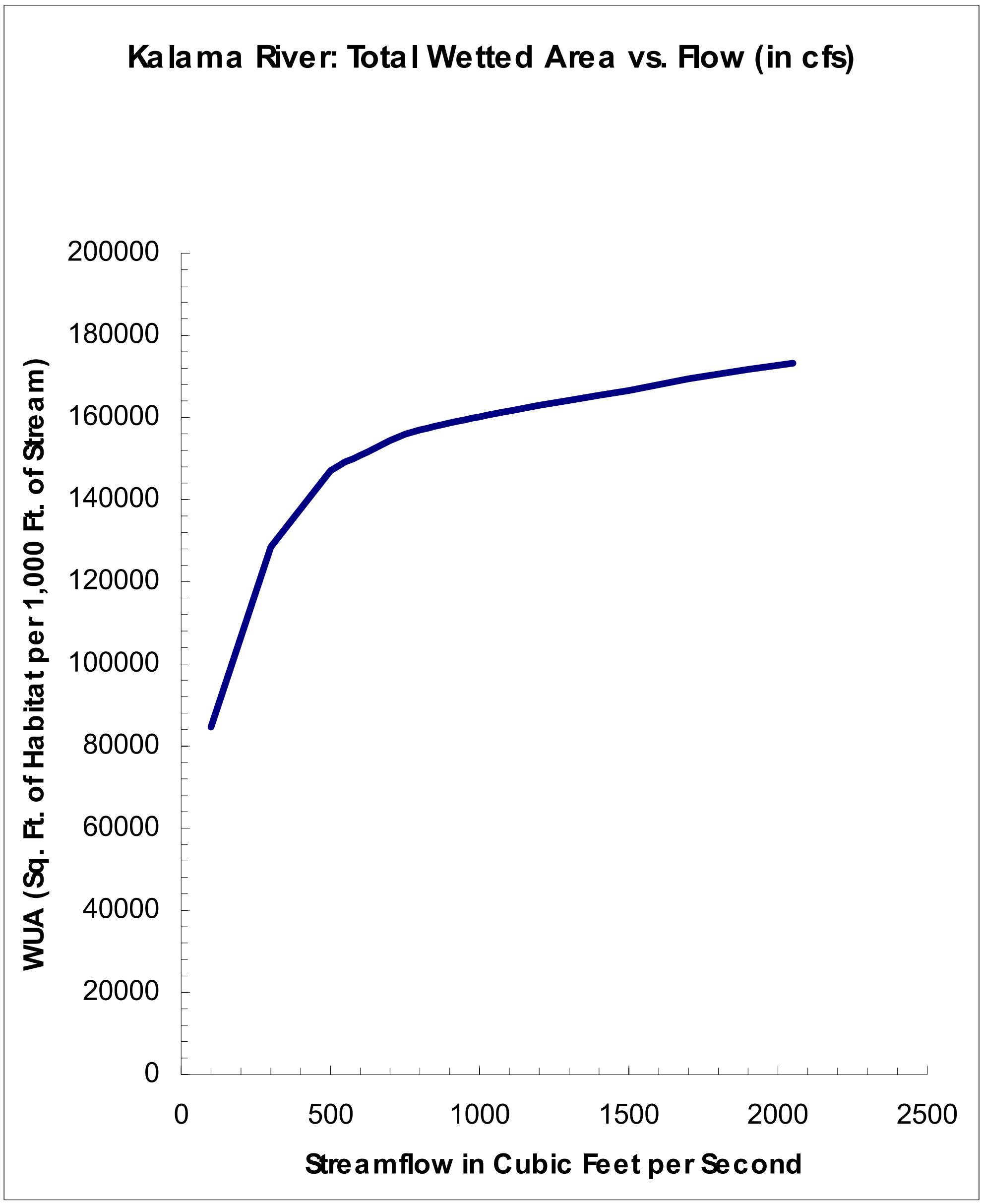
Kalama River Fish Habitat: Weighted Usable Area vs. Flow (in cfs)



Flow in cfs	Steelhead Spawning Habitat	Steelhead Juvenile Habitat	Chinook Spawning Habitat	Chinook Juvenile Habitat	Coho Spawning Habitat
2050	19775	14274	27521	10475	20137
1900	20849	14199	29559	10433	20440
1700	23193	14512	32358	10616	22670
1500	26753	14862	37943	11634	26467
1400	29665	14961	40256	12470	28732
1300	31748	15197	42193	12765	30299
1200	34095	15289	44474	12963	32324
1100	35716	15588	46308	12972	34019
1075	35960	15643	46557	12928	34274
1050	36204	15670	46619	12899	34575
1025	36540	15669	46476	12903	34811
1000	37244	15663	46296	12911	35215
975	37866	15685	46136	12959	35621
950	37964	15708	45919	13045	35950
925	37886	15713	45651	13119	36130
900	37878	15736	45166	13173	36145
875	37823	15729	44610	13208	36004
850	37551	15669	44001	13242	35850
825	37114	15571	43252	13318	35893
800	36798	15466	42289	13437	35991
750	35926	15277	40753	13705	35929
700	34667	14896	39520	13858	35462
650	32856	14497	37688	13864	34992
625	32458	14319	37082	13916	34747
600	31367	14126	36466	13952	34619
575	30124	13899	35709	13978	34224
550	28596	13628	34759	13863	33821
500	26572	13064	32710	13550	32711
300	18565	10044	21030	11902	24969
100	12474	5671	12467	8339	17729

Figure 4. Wetted Area vs Flow.

Kalama River: Total Wetted Area vs. Flow (in cfs)



Flow in cfs	Total Area
2050	173191
1900	171724
1700	169407
1500	166547
1400	165420
1300	164195
1200	162924
1100	161592
1075	161246
1050	160894
1025	160535
1000	160171
975	159799
950	159421
925	159036
900	158643
875	158242
850	157832
825	157394
800	156930
750	155956
700	154358
650	152516
625	151604
600	150753
575	149906
550	149191
500	147022
300	128429
100	84611

Table 1. Habitat as a percent of optimum.

Flow in cfs	Steelhead Spawning Habitat (Percent of Optimum)	Steelhead Juvenile Habitat (Percent of Optimum)	Chinook Spawning Habitat (Percent of Optimum)	Chinook Juvenile Habitat (Percent of Optimum)	Coho Spawning Habitat (Percent of Optimum)
2050	52%	91%	59%	75%	56%
1900	55%	90%	63%	75%	57%
1700	61%	92%	69%	76%	63%
1500	70%	94%	81%	83%	73%
1400	78%	95%	86%	89%	79%
1300	84%	97%	91%	91%	84%
1200	90%	97%	95%	93%	89%
1100	94%	99%	99%	93%	94%
1075	95%	99%	100%	92%	95%
1050	95%	100%	100%	92%	96%
1025	96%	100%	100%	92%	96%
1000	98%	100%	99%	92%	97%
975	100%	100%	99%	93%	99%
950	100%	100%	98%	93%	99%
925	100%	100%	98%	94%	100%
900	100%	100%	97%	94%	100%
875	100%	100%	96%	94%	100%
850	99%	100%	94%	95%	99%
825	98%	99%	93%	95%	99%
800	97%	98%	91%	96%	100%
750	95%	97%	87%	98%	99%
700	91%	95%	85%	99%	98%
650	87%	92%	81%	99%	97%
625	85%	91%	80%	100%	96%
600	83%	90%	78%	100%	96%
575	79%	88%	77%	100%	95%
550	75%	87%	75%	99%	94%
500	70%	83%	70%	97%	90%
300	49%	64%	45%	85%	69%
100	33%	36%	27%	60%	49%

Literature Cited

Bovee, K.D. 1982. A Guide to Stream Habitat Analysis using the Instream Flow Incremental Methodology. Instream Flow Paper 12. U.S. Fish and Wildlife Service, Fort Collins, Colorado. FWS/OBS-82/26.

Milhous, R.T., et al. 1984. User's Guide to the Physical Habitat Simulation System. Instream Flow Paper 11. Revised. U.S. Fish and Wildlife Service, Fort Collins, Colorado. FWS/OBS-81/43.

Milhous, R.T., et al. 1989. Physical Habitat Simulation System Reference Manual – Version II. Instream Flow Information Paper No. 26, U.S. Fish and Wildlife Service, Biological Report 89(16), Fort Collins, Colorado.

Washington Department of Ecology. 1996. Water Quality in Washington State (Section 303d of the Federal Clean Water Act). Washington State Department of Ecology F-WQ-95-84, Olympia, Washington.

Washington Department of Fisheries, et al. March, 1993. 1992 Washington State Salmon and Steelhead Stock Inventory. Olympia, Washington.

Washington Department of Fish and Wildlife, et al. July, 1998. Integrated Landscape Management Plan for Fish and Wildlife: A Pilot Project in the Lewis-Kalama River Watershed WRIA #27 Volume 1-Appendices. Olympia, Washington.

Appendix A. Maps of Chinook, Steelhead, and Chum ESUs in the Kalama River Basin

Appendix B. Snorkeling Observations in the Kalama River

Snorkel observations **KALAMA RIVER** 8/3/98 p.m. Hal Beecher (observer) & Cynthia Pratt

IFIM Study Sites

T1 sandy shallow RB with eddy, deep sandy pool on LB to bedrock cliff - several adult suckers, in possible breeding colors and 1 juvenile steelhead (about 9") near bedrock cliff

T2 main (right) channel: head of riffle, swift - 3 juvenile steelhead near turbulence near RB, only sculpins in swift water of main channel
LB side channel: LB overhung by red osier dogwood - 2 juvenile steelhead, 2 juvenile chinook

T3 RB (main) channel: deep pool next to log jam on RB - many juvenile coho
shallow bar, transition from pool to run (about 1/4 across) - school of juvenile coho & 1 young-of-yr steelhead
R edge of run - juvenile chinook
middle of current to 3/4 across - several juvenile steelhead, about 7 whitefish
LB side channel - 2 juvenile (0) steelhead (steelhead juveniles are I unless otherwise noted)

T4 RB (main) channel -several juvenile coho about 1/4 out
edge of current - juvenile steelhead
mid-current - no fish
1 juvenile steelhead & 2 juvenile chinook on edge of current
LB side channel - no fish

upstream of T6 - juvenile chinook in current near RB, adult suckers in deep, fast water

T5 run with sandy bottom on RB, cobbles in remainder - sculpins, sucker fry
1/4 across - juvenile chinook and juvenile steelhead, adult squawfish
1/3 across - juvenile chinook, juvenile coho, juvenile chinook
2/3 across - juvenile chinook
3/4 across - juvenile steelhead
LB in shadow - no fish

upstream in riffle and tail of chute - higher density of same fishes plus whitefish
many juvenile chinook along brush pile on RB, more juvenile steelhead

Appendix C. Calibration Information for the IFIM Computer Model.

Appendix C1. IFG4 Input File

Kalama River at Mahaffey's and lower salmon hatchery measured 828 cfs on 5-14-98, 690 cfs on 6-10-98, 262 cfs on 8-3-98, and 190 cfs on 9-17-98.

```
IOC      11000002000010000 10 1
QARD2050.0
QARD1900.0
QARD1700.0
QARD1500.0
QARD1400.0
QARD1300.0
QARD1200.0
QARD1100.0
QARD1075.0
QARD1050.0
QARD1025.0
QARD1000.0
QARD 975.0
QARD 950.0
QARD 925.0
QARD 900.0
QARD 875.0
QARD 850.0
QARD 825.0
QARD 800.0
QARD 750.0
QARD 700.0
QARD 650.0
QARD 625.0
QARD 600.0
QARD 575.0
QARD 550.0
QARD 500.0
QARD 300.0
QARD 100.0
XSEC   1.0       0.0 .50     95.00    .00250
      1.0-12.0100.6 -6.597.65  0.096.52  5.095.45  7.5 92.8 10.090.42
      1.0 12.589.72 15.088.75 17.586.72 20.083.67 25.084.12 30.085.12
      1.0 35.085.52 40.086.07 45.0 86.7 50.0 87.8 55.089.27 60.090.35
      1.0 65.089.82 70.089.82 75.090.37 80.092.57 85.0 95.0 90.095.71
      1.0 95.0 96.5100.097.41105.097.59110.097.83115.097.96120.097.88
      1.0125.097.86130.598.31135.098.92140.0100.1150.0101.8170.0105.0
NS    1.0    99.90    99.90    99.90    99.90    99.90    99.90
NS    1.0    22.90    22.90    22.90    22.90    22.90    22.90
NS    1.0    22.90    22.90    22.90    22.90    22.90    22.90
NS    1.0    22.90    22.90    29.50    29.50    18.50    18.70
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NS     1.0     18.50     12.50     12.50     12.50     12.50     12.50
NS     1.0     12.50     12.50     22.90     22.90     14.80     15.50
CAL1   1.0     98.38    828.00
VEL1   1.0            .26 3.54 2.97 2.42 2.25 2.25 1.56 1.83 2.12 1.90
VEL1   1.0 1.56 1.34 1.08  .59  .11 -.08 -.06 -.36 -.59 -.94-1.18 -.61
VEL1   1.0 -.96 -.81 -.58 -.42 -.49 -.51 -.68 0.00
CAL2   1.0     98.24    690.00
VEL2   1.0            .24 3.03 2.96 2.03 1.39 1.91 1.84 1.68 1.67 1.67
VEL2   1.0 1.52 1.47  .80  .53  .16 -.19 -.27 -.54 -.87 -.81 -.70 -.61
VEL2   1.0 -.73 -.71 -.48 -.45 -.44 -.53 -.64 0.00
CAL3   1.0     97.65    262.00
VEL3   1.0           0.00 1.54 1.45 1.39 1.11 1.17  .93  .81  .58  .76
VEL3   1.0  .78  .43  .22 -.05 -.10 -.25 -.03 -.36 -.26 -.41 -.61 -.29
VEL3   1.0      -.11
CAL4   1.0     97.44    190.00
VEL4   1.0            .02  .81 1.32 1.20 1.04  .94  .92  .71  .65  .64
VEL4   1.0  .66  .31  .21  .01  .04 -.06 -.21 -.30 -.29 -.16 -.43 -.22
VEL4   1.0 -.18 0.00
XSEC   2.0     230.0 .50     95.94    .00250
       2.0-13.2103.4-10.2100.4 -7.099.09 -5.098.66 -2.598.63  0.098.36
       2.0  2.598.04  5.097.75  7.597.68 10.0 97.6 12.597.32 15.097.53
       2.0 17.597.49 20.097.35 22.597.28 25.097.37 27.5 97.6 30.0 98.1
       2.0 32.598.43 35.098.39 37.5 98.3 40.098.18 45.0 98.1 50.097.92
       2.0 55.097.83 60.0 97.7 65.097.59 70.097.02 75.096.51 80.096.29
       2.0 85.095.94 90.096.27 95.096.48100.096.59105.096.95110.097.43
       2.0115.098.27120.098.22125.098.07130.097.92135.098.17140.097.83
       2.0145.0 97.4150.097.39155.097.94160.098.19161.898.24162.098.56
       2.0166.0100.0171.0100.7181.0102.4
NS     2.0       .80       .80     43.50     43.50     43.50     43.50
NS     2.0     65.50     65.50     65.70     68.80     67.70     65.60
NS     2.0     65.50     56.60     64.60     56.80     56.80     56.50
NS     2.0     56.50     54.50     54.50     54.50     56.80     56.50
NS     2.0     56.50     67.90     67.90     67.60     76.50     76.50
NS     2.0     57.50     67.70     65.80     76.80     64.90     76.70
NS     2.0     67.70     75.80     75.50     57.50     64.60     67.50
NS     2.0     68.80     75.70     75.70     67.70     57.80     57.80
NS     2.0     56.70     56.70     26.90
CAL1   2.0     99.09    828.00
VEL1   2.0           0.00  .52  .87 1.27 1.79 2.13 2.68  .51 4.19 5.38
VEL1   2.0 5.20 3.54 2.62 2.32 2.12  .76  .20  .66 1.39 1.19 2.27 3.65
VEL1   2.0 3.99 3.89 5.29 5.25 6.20 6.20 6.30 4.68 5.33 4.93 3.54 1.28
VEL1   2.0 1.09 2.16 1.74  .03 2.04 1.36 1.24  .89  .30 0.00      0.00
VEL1   2.0
CAL2   2.0     98.87    690.00
VEL2   2.0                0.00  .97 1.45 1.50 1.48 2.13  .45 3.73 5.15
VEL2   2.0 4.32 3.18 2.33 2.10 1.85  .93 0.00 0.00 1.19 1.12 2.04 3.55
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VEL2   2.0 4.00 4.17 4.52 5.22 5.56 5.67 6.17 5.60 5.53 5.38 3.50 2.05
VEL2   2.0 1.49 2.95 1.55  .15 1.76 1.14 1.08  .72  .30 0.00 0.00
VEL2   2.0
CAL3   2.0     98.02    262.00
VEL3   2.0                     0.00 0.00  .52  .97 0.00 1.73 2.53
VEL3   2.0 3.11 2.91 2.51 1.54 1.46  .16
VEL3   2.0 1.00 1.35 3.19 2.55 4.08 4.87 4.71 4.25 4.08 3.09 1.78  .29
VEL3   2.0                .08 0.00 0.00 0.00 0.00 0.00 0.00
VEL3   2.0
CAL4   2.0     97.83    190.00
VEL4   2.0                              .81 1.04 0.00 1.77 1.71
VEL4   2.0 1.43 2.02 1.39 1.55 1.42  .36                     0.00
VEL4   2.0  .50 0.00 2.11 2.35 3.54 3.83 3.65 4.66 3.04 3.84 1.69  .24
VEL4   2.0                     0.00 0.00 0.00 0.00 0.00
VEL4   2.0
XSEC   3.0     118.0 .50     95.94    .00250
       3.0 19.0103.7 24.098.47 25.097.74 27.597.46 30.097.69 32.598.01
       3.0 35.098.21 37.598.03 40.098.11 42.598.06 45.098.07 50.098.38
       3.0 55.098.61 60.098.42 65.098.43 70.098.46 75.098.36 80.099.11
       3.0 90.0100.8100.0100.2110.0100.0130.099.28135.099.06137.598.86
       3.0140.098.71142.598.43145.098.12147.598.06150.097.92152.597.84
       3.0155.097.77157.597.63160.097.27165.096.76170.096.42175.096.23
       3.0180.095.94185.095.81190.096.21195.096.63200.096.92205.096.84
       3.0210.096.78215.096.52220.095.83225.094.91230.093.71235.094.13
       3.0240.097.36241.098.86243.0105.0
NS     3.0    88.50    88.50    88.50    25.60    62.80    65.90
NS     3.0    67.70    65.80    76.50    76.50    76.50    76.70
NS     3.0    76.70    67.70    65.60    65.60    56.80    54.50
NS     3.0    52.50    52.50    52.50    54.50    56.60    65.50
NS     3.0    65.50    65.80    65.80    65.50    65.50    64.60
NS     3.0    54.80    64.70    64.70    56.70    64.80    64.80
NS     3.0    56.50    62.80    76.50    74.60    76.50    72.80
NS     3.0    62.80    67.60    64.80    61.90    62.80      .80
NS     3.0      .80      .80      .80
CAL1   3.0     99.37    828.00
VEL1   3.0          1.58 2.15 2.44 2.61 2.51 3.33 3.42 2.94 2.67 2.51
VEL1   3.0 1.58 1.82 2.04 2.25 2.49 1.06                0.00 0.00  .81
VEL1   3.0 1.95 2.24 2.30 2.90 2.18 2.86 3.20 3.08 3.29 4.92 5.24 5.58
VEL1   3.0 5.28 4.95 3.40 3.52 2.46 2.02 1.65 1.36  .36  .08  .09  .02
VEL1   3.0 0.00
CAL2   3.0     99.25    690.00
VEL2   3.0           .92 2.07 2.04 2.60 2.37 2.68 3.19 2.37 2.32 1.07
VEL2   3.0 3.08 2.65 1.80 2.03 2.30  .74                0.00 0.00 0.00
VEL2   3.0  .92 1.05 1.70 2.08 2.71 2.73 2.85 3.24 3.63 3.62 4.09 4.76
VEL2   3.0 4.76 4.67 3.44 2.55 2.36 1.37  .94  .93  .23  .08  .07 0.00
VEL2   3.0      0.00
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CAL3   3.0     98.47    262.00
VEL3   3.0      0.00  .72 1.73 1.74 2.01 1.43 1.88 2.19 1.53 1.47  .83
VEL3   3.0 0.00  .91 0.00 0.00  .50
VEL3   3.0  .20  .20 0.00  .37  .31  .74 1.22 1.11 1.44 2.15 2.37 2.84
VEL3   3.0 3.05 2.70 2.38 1.87 1.70 1.18  .48 0.00 -.01 0.00 0.00 0.00
VEL3   3.0      0.00
CAL4   3.0     98.24    190.00
VEL4   3.0           0.00  .85 1.42 1.20 2.02 1.69 1.87 1.36 1.01 1.78
VEL4   3.0       .29 0.00 0.00  .69
VEL4   3.0           0.00 0.00 0.00  .30  .38  .28  .66 1.89 2.36 2.53
VEL4   3.0 2.58 2.71 2.36 1.67 1.69 1.03  .53 0.00 0.00 0.00 0.00 0.00
VEL4   3.0
XSEC   4.0      50.0 .50     95.94     .00250
       4.0-10.0104.3 -3.599.45  0.098.02  2.597.48  5.0 97.5  7.597.33
       4.0 10.097.25 12.5 97.2 15.097.23 17.597.56 20.097.62 25.0 98.0
       4.0 30.098.43 35.099.27 38.199.39 38.2 99.5 50.0101.5 75.0101.2
       4.0100.0100.2112.0 99.5115.099.12120.098.95125.098.69130.098.05
       4.0135.097.75140.097.57145.097.26150.096.86155.096.42160.095.78
       4.0162.595.51165.095.31167.595.02170.095.18172.595.43175.095.86
       4.0180.096.43185.097.22190.098.06192.598.32195.098.45197.598.42
       4.0200.098.44202.5 98.4205.098.35207.598.37210.098.54212.598.65
       4.0215.098.92217.599.17220.0 99.2223.099.45232.599.22239.5102.2
NS     4.0       .80       .80     51.50     62.50     65.70     65.70
NS     4.0     65.70     65.70     75.70     75.70     75.70     75.70
NS     4.0     65.70     65.70     65.70     65.70     42.50     22.90
NS     4.0     24.80     62.50     62.50     62.50     61.50     61.50
NS     4.0     62.80     65.50     65.50     65.50     65.50     65.80
NS     4.0     65.50     64.80     57.70     62.90     72.50     72.90
NS     4.0     76.70     67.80     76.70     67.80     67.80     78.50
NS     4.0     67.80     67.80     67.60     67.60     67.60     67.60
NS     4.0     76.60     76.60     68.50     68.50     76.50     71.80
CAL1   4.0     99.50    828.00
VEL1   4.0      0.00  .47  .87 1.63 1.90 2.24 2.49 1.89 2.41 1.98 1.29
VEL1   4.0 1.02 0.00      0.00                0.00  .36  .90 1.42 1.52
VEL1   4.0 2.16 2.74 2.51 2.85 3.33 4.59 4.70 4.78 4.60 4.99 4.44 3.99
VEL1   4.0 2.19  .35 2.00 1.79  .14 1.47 1.04 2.43 2.86 2.33 2.19 1.75
VEL1   4.0  .96 1.20  .91 0.00
CAL2   4.0     99.39    690.00
VEL2   4.0      0.00  .47 1.16 1.88 1.81 2.28 1.83 1.71 2.31 1.98 1.32
VEL2   4.0  .92 0.00 0.00                          .47  .85 1.27 1.50
VEL2   4.0 2.14 2.55 2.52 2.86 3.25 4.09 4.38 4.26 4.52 4.31 4.32 3.97
VEL2   4.0 1.88  .52 1.80 1.60  .12 1.55 1.10 2.21 2.73 2.19 2.00 1.53
VEL2   4.0 1.26  .18  .06 0.00
CAL3   4.0     98.52    262.00
VEL3   4.0           0.00  .77  .90  .93 1.18 1.05 1.08  .91  .81  .40
VEL3   4.0 0.00                                     0.00  .31
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VEL3   4.0  .76 1.57 1.82 2.03 2.66 3.01 2.69 3.07 2.86 2.93 2.24 1.76
VEL3   4.0  .74 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
VEL3   4.0
CAL4   4.0     98.32    190.00
VEL4   4.0            0.00  .20  .68 1.08  .60 1.10  .64 1.12  .58  .30
VEL4   4.0 0.00                                        0.00
VEL4   4.0  .24  .84 1.25 1.46 1.99 2.33 2.28 2.70 2.42 2.61 2.15 1.83
VEL4   4.0  .85  .09 0.00 0.00      0.00           0.00
VEL4   4.0
XSEC   5.0     132.0 .50     94.43    .00250
     5.0-10.7100.5 -6.099.55 -3.098.93 -2.398.46 -1.098.24  0.0 97.9
     5.0  2.397.41  5.0 97.1 10.096.35 15.096.27 20.096.29 25.096.08
     5.0 30.095.74 35.0 95.6 40.095.33 45.095.02 50.094.73 55.094.57
     5.0 60.094.53 65.094.53 70.094.65 75.094.65 80.094.49 85.094.68
     5.0 90.0 94.8 95.094.48100.094.43105.094.49110.094.48115.095.32
     5.0120.096.65122.597.53124.798.35127.5 99.1130.8100.5
NS     5.0    16.50     17.50     17.50     17.50     75.80     75.80
NS     5.0    75.80     75.80     67.50     67.80     65.70     56.70
NS     5.0    56.70     56.70     64.80     64.80     65.80     65.60
NS     5.0    62.90     62.80     62.70     62.70     62.70     62.70
NS     5.0    62.60     62.70     67.80     72.80     72.80     27.80
NS     5.0    12.50     12.50     12.50     12.50     18.50
CAL1   5.0     98.46    828.00
VEL1   5.0               0.00      0.00      .41 1.33 1.83 2.40 2.64
VEL1   5.0 2.57 2.72 3.05 2.85 3.06 2.46 2.27 2.42 2.65 2.08 2.17 2.71
VEL1   5.0 2.52 2.37 2.27 1.78 1.23  .06  .01 0.00
CAL2   5.0     98.24    690.00
VEL2   5.0                    0.00 0.00      .34 1.22 1.59 2.37 2.42
VEL2   5.0 2.39 2.32 2.57 2.62 2.12 2.22 1.82 1.92 2.05 1.60 1.54 1.86
VEL2   5.0 1.61 1.53 1.58 1.21  .61  .46 0.00  .09 0.00
CAL3   5.0     97.41    262.00
VEL3   5.0                          0.00 0.00 0.00 0.00  .72  .86
VEL3   5.0 1.23 1.53 1.71 1.53 1.54 1.44 1.23  .99  .93  .69  .67  .95
VEL3   5.0  .96 1.10 1.23  .86  .52  .14 0.00 0.00
CAL4   5.0     97.12    190.00
VEL4   5.0                                        0.00 0.00
VEL4   5.0  .66  .77 1.30 1.70 1.36 1.48 1.36  .87  .65  .55  .55  .79
VEL4   5.0  .87  .83  .75  .49  .52  .10  .01
ENDJ
```

Appendix C2. Summary of Calibration Details

Kalama River

Calibration Information for Calculated Discharges

Transect Number	**1**	**2**	**3**	**4**	**5**
Discharge	812.87 692.11 277.68 251.86	889.35 773.99 266.72 196.40	857.10 696.43 251.30 192.22	739.40 668.63 255.19 191.96	843.40 618.74 255.85 179.86
Stage	98.38 98.24 97.65 97.44	99.09 98.87 98.02 97.83	99.37 99.25 98.47 98.24	99.50 99.39 98.52 98.32	98.46 98.24 97.41 97.12
Plotting Stage	3.38 3.24 2.65 2.44	3.15 2.93 2.08 1.89	3.43 3.31 2.53 2.30	3.56 3.45 2.58 2.38	4.03 3.81 2.98 2.69
Ratio of Measured vs. Predicted Discharge					
	1.02 1.02 0.88 1.10	0.96 1.04 1.01 0.99	1.04 0.97 0.95 1.04	1.00 1.00 1.01 0.99	1.05 0.95 0.99 1.02
Mean Error of Stage/Discharge Relationship for Calculated Q					
	6.42	2.42	4.07	0.49	3.27
Mean Error of Stage/Discharge Relationship for Given Q					
	1.75	1.80	1.97	2.67	2.15
Stage/Discharge Relationship (S vs. Q) **S=A*Q**B+SZF**					
A=	0.5894	0.3253	0.5689	0.4920	0.6762
B=	0.2613	0.3326	0.2677	0.2995	0.2668
SZF=	95.00	95.94	95.94	95.94	94.43
Beta Coefficient Log/Log Discharge/Stage Relationship					
	4.59	2.87	3.65	3.54	3.72

Appendix C3. Summary of Data Changes

Data Changes for Calibration of Kalama River IFG4 Model.

Transect	Vertical	Vel	Change
1	27	2	0.68 to 0.48
1	28	2	0.65 to 0.45
2	29	1	0.00 to 6.20
2	30	1	0.00 to 6.20
2	31	1	0.00 to 6.30
2	39	1	1.94 to 1.74
2	41	1	2.24 to 2.04
2	10	2	3.11 to 0.25
2	21	2	0.63 to 1.19
2	24	2	3.75 to 3.55
2	25	2	4.71 to 4.00
2	39	2	1.05 to 1.55
2	41	2	1.56 to 1.76
2	24	4	0.05 to 0.00
2	26	4	0.10 to 0.00
3	15	1	2.24 to 2.04
3	15	2	1.00 to 1.80
3	25	3	0.00 to 0.20
3	26	3	0.00 to 0.20
3	28	3	0.17 to 0.37
3	31	3	1.02 to 1.22
3	44	3	0.08 to 0.00
3	15	4	0.05 to 0.00
3	16	4	0.05 to 0.00
3	31	4	0.18 to 0.38
4	40	1	2.79 to 1.79
4	44	1	2.93 to 2.43
4	39	2	2.62 to 1.80
4	48	2	1.33 to 1.53
5	11	1	2.60 to 2.40
5	11	2	2.27 to 2.37
5	11	3	0.52 to 0.72
5	12	4	0.12 to 0.00
5	13	4	0.46 to 0.66
5	21	4	0.45 to 0.65

Appendix C4. Velocity Adjustment Factors

Kalama River at Mahaffey's and lower salmon hatchery measured 828 cfs on 5-14-98, 690 cfs on 6-10-98, 262 cfs on 8-3-98, and 190 cfs on 9-17-98.

1.00	2050.0	0.950
1.00	1900.0	0.956
1.00	1700.0	0.964
1.00	1500.0	0.972
1.00	1400.0	0.977
1.00	1300.0	0.981
1.00	1200.0	0.985
1.00	1100.0	0.989
1.00	1075.0	0.990
1.00	1050.0	0.991
1.00	1025.0	0.992
1.00	1000.0	0.993
1.00	975.0	0.994
1.00	950.0	0.995
1.00	925.0	0.996
1.00	900.0	0.996
1.00	875.0	0.997
1.00	850.0	0.998
1.00	825.0	0.999
1.00	800.0	1.000
1.00	750.0	1.001
1.00	700.0	1.003
1.00	650.0	1.004
1.00	625.0	1.005
1.00	600.0	1.005
1.00	575.0	1.006
1.00	550.0	1.006
1.00	500.0	1.007
1.00	300.0	1.008
1.00	100.0	1.025
2.00	2050.0	0.941
2.00	1900.0	0.950
2.00	1700.0	0.963
2.00	1500.0	0.975
2.00	1400.0	0.980
2.00	1300.0	0.986
2.00	1200.0	0.990
2.00	1100.0	0.994
2.00	1075.0	0.995
2.00	1050.0	0.996
2.00	1025.0	0.996
2.00	1000.0	0.997

2.00	975.0	0.997
2.00	950.0	0.998
2.00	925.0	0.998
2.00	900.0	0.998
2.00	875.0	0.999
2.00	850.0	0.999
2.00	825.0	0.998
2.00	800.0	0.998
2.00	750.0	0.997
2.00	700.0	0.995
2.00	650.0	0.993
2.00	625.0	0.991
2.00	600.0	0.989
2.00	575.0	0.987
2.00	550.0	0.985
2.00	500.0	0.981
2.00	300.0	1.016
2.00	100.0	0.910
3.00	2050.0	0.858
3.00	1900.0	0.877
3.00	1700.0	0.903
3.00	1500.0	0.928
3.00	1400.0	0.941
3.00	1300.0	0.952
3.00	1200.0	0.964
3.00	1100.0	0.974
3.00	1075.0	0.977
3.00	1050.0	0.979
3.00	1025.0	0.981
3.00	1000.0	0.984
3.00	975.0	0.986
3.00	950.0	0.988
3.00	925.0	0.990
3.00	900.0	0.991
3.00	875.0	0.993
3.00	850.0	0.994
3.00	825.0	0.996
3.00	800.0	0.997
3.00	750.0	0.998
3.00	700.0	0.998
3.00	650.0	0.997
3.00	625.0	0.995
3.00	600.0	0.994
3.00	575.0	0.992
3.00	550.0	0.989
3.00	500.0	0.981

3.00	300.0	1.009
3.00	100.0	0.912
4.00	2050.0	0.907
4.00	1900.0	0.918
4.00	1700.0	0.932
4.00	1500.0	0.948
4.00	1400.0	0.955
4.00	1300.0	0.962
4.00	1200.0	0.970
4.00	1100.0	0.977
4.00	1075.0	0.979
4.00	1050.0	0.980
4.00	1025.0	0.982
4.00	1000.0	0.984
4.00	975.0	0.985
4.00	950.0	0.987
4.00	925.0	0.989
4.00	900.0	0.990
4.00	875.0	0.992
4.00	850.0	0.993
4.00	825.0	0.995
4.00	800.0	0.996
4.00	750.0	0.999
4.00	700.0	1.001
4.00	650.0	1.003
4.00	625.0	1.004
4.00	600.0	1.005
4.00	575.0	1.006
4.00	550.0	1.006
4.00	500.0	1.008
4.00	300.0	1.005
4.00	100.0	0.911
5.00	2050.0	1.003
5.00	1900.0	1.005
5.00	1700.0	1.006
5.00	1500.0	1.007
5.00	1400.0	1.007
5.00	1300.0	1.007
5.00	1200.0	1.007
5.00	1100.0	1.006
5.00	1075.0	1.006
5.00	1050.0	1.006
5.00	1025.0	1.006
5.00	1000.0	1.006
5.00	975.0	1.005
5.00	950.0	1.005

5.00	925.0	1.005
5.00	900.0	1.004
5.00	875.0	1.004
5.00	850.0	1.003
5.00	825.0	1.003
5.00	800.0	1.002
5.00	750.0	1.001
5.00	700.0	1.000
5.00	650.0	0.998
5.00	625.0	0.997
5.00	600.0	0.996
5.00	575.0	0.995
5.00	550.0	0.993
5.00	500.0	0.990
5.00	300.0	0.970
5.00	100.0	0.911

Appendix D. Fish Habitat Preference Curves

```
Fishcrv for Kalama approved by Hal Beecher 12-3-98
H    101  9  7 75  0 Chinook                          Spawning
V    101  0.00  0.00  0.50  0.00  1.00  0.10  1.30  0.70  1.75  1.00  3.00  1.00
V    101  3.50  0.70  4.00  0.00 99.90  0.00
D    101  0.00  0.00  0.50  0.00  1.00  0.75  1.20  1.00  3.40  1.00  5.00  0.00
D    101 99.90  0.00
S   101  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.20 16.50  0.50
S   101 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.15 23.90  0.03
S   101 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
S   101 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.21 34.80  0.44
S   101 42.50  0.50 42.80  0.80 43.50  0.65 45.50  1.00 46.80  1.00 48.50  0.50
S   101 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S   101 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S   101 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S   101 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S   101 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S   101 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.06 84.80  0.20
S   101 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S   101 87.90  0.03 88.50  0.00 99.90  0.00
H    102 12  8 87  0 Chinook                          Juvenile
V    102  0.00  0.09  0.20  0.20  0.30  0.26  0.40  0.93  0.60  1.00  1.10  0.90
V    102  1.30  0.75  2.00  0.50  2.20  0.08  2.70  0.03  3.60  0.00 99.00  0.00
D    102  0.00  0.00  0.40  0.00  0.50  0.05  1.00  0.33  1.20  0.50  1.50  0.80
D    102  2.20  1.00 99.00  1.00
S   102  0.10  1.00  0.40  1.00  0.50  0.80  0.80  0.10 12.50  0.10 14.80  0.14
S   102 15.50  0.20 15.80  0.14 16.50  0.30 17.50  0.40 17.90  0.16 18.50  0.55
S   102 18.70  0.37 22.50  0.10 23.90  0.10 24.50  0.20 24.80  0.14 25.50  0.20
S   102 25.60  0.18 26.50  0.30 26.90  0.14 27.50  0.40 27.80  0.22 28.60  0.46
S   102 29.50  0.20 31.70  0.10 34.80  0.14 42.50  0.20 42.80  0.26 43.50  0.20
S   102 45.50  0.30 45.90  0.30 46.60  0.38 46.80  0.34 48.50  0.65 51.50  0.20
S   102 51.80  0.26 52.50  0.20 52.80  0.26 54.50  0.30 54.80  0.30 56.50  0.40
S   102 56.80  0.34 57.50  0.50 57.80  0.38 58.50  0.65 58.60  0.58 61.50  0.30
S   102 61.90  0.46 62.50  0.30 62.90  0.46 64.60  0.42 64.90  0.48 65.50  0.40
S   102 65.90  0.48 67.50  0.60 67.90  0.52 68.50  0.75 68.80  0.60 71.50  0.40
S   102 71.80  0.58 72.50  0.40 72.90  0.64 74.50  0.50 74.90  0.66 75.50  0.50
S   102 75.90  0.66 76.50  0.60 76.90  0.68 78.50  0.85 78.80  0.76 81.50  0.55
S   102 81.90  0.91 82.50  0.55 82.70  0.73 83.80  0.82 84.80  0.86 84.90  0.93
S   102 85.50  0.65 85.90  0.93 86.50  0.75 86.90  0.95 87.50  0.85 87.90  0.97
S   102 88.50  1.00 88.90  1.00 99.90  0.30
H    201 11  9 75  0 Steelhead                        Spawning
V    201  0.00  0.00  1.10  0.45  2.10  0.97  2.90  1.00  3.20  1.00  3.30  0.62
V    201  3.60  0.40  4.00  0.20  4.50  0.10  5.00  0.00 99.00  0.00
D    201  0.00  0.00  0.60  0.00  0.70  0.50  1.00  1.00  1.50  1.00  1.60  0.75
D    201  2.20  0.60  2.40  0.50 99.00  0.50
```

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S   201  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.80 16.50  0.50
S   201 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.25 23.90  0.05
S   201 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
S   201 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.35 34.80  0.60
S   201 42.50  0.50 42.80  0.80 43.50  0.75 45.50  1.00 46.80  1.00 48.50  0.50
S   201 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S   201 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S   201 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S   201 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S   201 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S   201 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.10 84.80  0.20
S   201 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S   201 87.90  0.03 88.50  0.00 99.90  0.00
H   202 13 14 87  0 Steelhead                    Juvenile
V   202  0.00  0.23  0.20  0.30  0.50  0.50  0.90  0.80  1.30  1.00  1.50  0.97
V   202  2.40  0.80  3.00  0.35  3.60  0.22  3.70  0.19  5.00  0.16  6.00  0.00
V   202 99.00  0.00
D   202  0.00  0.00  0.50  0.03  0.70  0.07  0.90  0.11  1.10  0.25  1.60  0.35
D   202  1.90  0.40  2.10  0.65  2.20  0.85  2.50  0.90  2.60  1.00  3.40  0.86
D   202  4.50  0.64 99.00  0.64
S   202  0.10  1.00  0.40  1.00  0.50  0.80  0.80  0.10 12.50  0.10 14.80  0.14
S   202 15.50  0.20 15.80  0.14 16.50  0.30 17.50  0.40 17.90  0.16 18.50  0.55
S   202 18.70  0.37 22.50  0.10 23.90  0.10 24.50  0.20 24.80  0.14 25.50  0.20
S   202 25.60  0.18 26.50  0.30 26.90  0.14 27.50  0.40 27.80  0.22 28.60  0.46
S   202 29.50  0.20 31.70  0.10 34.80  0.14 42.50  0.20 42.80  0.26 43.50  0.20
S   202 45.50  0.30 45.90  0.30 46.60  0.38 46.80  0.34 48.50  0.65 51.50  0.20
S   202 51.80  0.26 52.50  0.20 52.80  0.26 54.50  0.30 54.80  0.30 56.50  0.40
S   202 56.80  0.34 57.50  0.50 57.80  0.38 58.50  0.65 58.60  0.58 61.50  0.30
S   202 61.90  0.46 62.50  0.30 62.90  0.46 64.60  0.42 64.90  0.48 65.50  0.40
S   202 65.90  0.48 67.50  0.60 67.90  0.52 68.50  0.75 68.80  0.60 71.50  0.40
S   202 71.80  0.58 72.50  0.40 72.90  0.64 74.50  0.50 74.90  0.66 75.50  0.50
S   202 75.90  0.66 76.50  0.60 76.90  0.68 78.50  0.85 78.80  0.76 81.50  0.55
S   202 81.90  0.91 82.50  0.55 82.70  0.73 83.80  0.82 84.80  0.86 84.90  0.93
S   202 85.50  0.65 85.90  0.93 86.50  0.75 86.90  0.95 87.50  0.85 87.90  0.97
S   202 88.50  1.00 88.90  1.00 99.90  0.30
H   301 13 11 75  0 Coho                         Spawning
V   301  0.00  0.00  0.20  0.00  0.25  0.40  0.40  0.59  0.75  0.80  1.00  0.92
V   301  1.10  0.98  1.20  1.00  2.00  1.00  2.25  0.42  3.40  0.16  4.20  0.00
V   301 99.00  0.00
D   301  0.00  0.00  0.20  0.00  0.40  0.04  0.55  0.08  0.65  0.16  0.75  0.40
D   301  0.95  0.80  1.00  1.00  3.40  1.00  4.00  0.10 99.00  0.00
S   301  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.20 16.50  0.50
S   301 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.15 23.90  0.03
S   301 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
S   301 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.21 34.80  0.44
S   301 42.50  0.50 42.80  0.80 43.50  0.65 45.50  1.00 46.80  1.00 48.50  0.50
```

```
S    301 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S    301 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S    301 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S    301 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S    301 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S    301 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.06 84.80  0.20
S    301 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S    301 87.90  0.03 88.50  0.00 99.90  0.00
H     401 12  8 75  0 Chum                                   Spawning
V     401  0.00  0.09  0.20  0.10  0.40  0.20  0.80  0.40  1.90  1.00  2.20  1.00
V     401  2.70  0.80  3.20  0.70  3.50  0.35  3.70  0.10  5.00  0.00 99.00  0.00
D     401  0.00  0.00  0.40  0.17  0.70  1.00  1.50  1.00  1.80  0.44  2.50  0.23
D     401  5.00  0.00 99.00  0.00
S    401  0.10  0.00 12.50  0.00 14.80  0.20 15.50  0.50 15.80  0.20 16.50  0.50
S    401 17.50  0.15 17.90  0.03 18.50  0.00 22.90  0.00 23.50  0.15 23.90  0.03
S    401 24.50  0.50 24.80  0.20 25.50  0.50 25.60  0.40 26.50  0.50 26.90  0.10
S    401 27.50  0.15 27.80  0.06 28.60  0.00 29.50  0.00 31.70  0.21 34.80  0.44
S    401 42.50  0.50 42.80  0.80 43.50  0.65 45.50  1.00 46.80  1.00 48.50  0.50
S    401 51.50  0.50 51.80  0.80 52.50  0.50 52.80  0.80 54.50  1.00 56.80  1.00
S    401 57.50  0.65 57.80  0.86 58.50  0.50 58.60  0.60 61.50  0.50 61.90  0.90
S    401 62.50  0.50 62.90  0.90 64.60  1.00 65.90  1.00 67.50  0.65 67.90  0.93
S    401 68.50  0.50 68.80  0.80 71.50  0.15 71.80  0.24 72.50  0.15 72.90  0.27
S    401 74.50  0.65 74.90  0.37 75.50  0.65 75.90  0.37 76.50  0.65 76.90  0.37
S    401 78.50  0.15 78.80  0.24 81.50  0.00 82.70  0.00 83.80  0.06 84.80  0.20
S    401 84.90  0.10 85.50  0.50 85.90  0.10 86.50  0.50 86.90  0.10 87.50  0.15
S    401 87.90  0.03 88.50  0.00 99.90  0.00
```

Appendix E. Substrate and Cover Codes

Instream Flow Studies Substrate and Cover Code Application

November 23, 1987

The three-digit code used describes the dominant substrate (the first number, the subdominant substrate (the second number), and the percent of <u>only</u> the dominant substrate (the third number). The percent of the sulxiominant substrate can be determined by subtraction. Dominant substrate is determined by the largest quantity of a certain substrate not the size of the substrate. The sum of the percent dominant and the percent sulxiominant will total 100 percent. The coding will not allow the dominant percent to be less than 50 percent, or greater than 90 percent. All other preference values are determined by using weighted averages. The value of the dominant substrate is multiplied by the percent of the dominant substrate, and the product is added to the product of the subdominant substrate times the percent of subdominant substrate. The sum of all the codes observed times their preference value will be a value between 0.0 and 1.0. The coding should also give a preference value of zero for the entire substrate observation when the code is class zero, one, or two, and is 50 percent or more of the observation. Where there is a situation where addition of two values could equal more than 1.0, the value will default to 1.0. Overhanging vegetation should be counted as cover if it is within 3 to 4 feet of the water surface. Cover values should be incorporated with the substrate values for both salmon and steelhead juvenile life stages and for Chinook and steelhead adult holding.

Life Stage and Value of Substrate

		Salmon			Steelhead and Trout			
					Spawning		Rearing/Holding	
Code	**Substrate Size In Inches**	**Juvenile Rearing**	**Spawning**	**Adult Holding**	**Steelhead**	**Trout**	**Juvenile & Adult**	**Steelh Adult**
0	**Detritus**	**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
1	**Silt, Clay**	**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
2	**Sand**	**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
3	**Small Gravel .1-0.5**	**.1**	**.3**	**.1**	**.5**	**1**	**.1**	**.1**
4	**Medium Gravel .5-1.5**	**.3**	**1**	**.3**	**1.0**	**1**	**.3**	**.3**
5	**Large Gravel. 1.5-3.0**	**.3**	**1**	**.3**	**1.0**	**1**	**.3**	**.3**
6	**Small Cobble 3.0-6.0**	**.5**	**1**	**.3**	**1.0**	**.5**	**.5**	**.3**
7	**Large Cobble 6.0-12.0**	**.7**	**.3***	**.3**	**.3**	**.0**	**.7**	**.3**
8	**Boulder**	**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
9	**Bedrock**	**.3**	**0**	**.3**	**0**	**0**	**.3**	**.3**
0.1	**Undercut Bank**	**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.2	**Overhanging Vegetation**	**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.3	**Root Wad**	**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.4	**Log Jam**	**1.0**	**0**	**1.0**	**0**	**0**	**1.0**	**1.0**
0.5	**Log Instream**	**.8**	**0**	**.8**	**0**	**0**	**.8**	**.3**
0.6	**Submerged Vegetation**	**1.0**	**0**	**.8**	**0**	**0**	**1.0**	**.8**
0.8	**Grass/Bushes Up on Bank**	**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**
0.9	**Fine Organic Substrate**	**.1**	**0**	**.1**	**0**	**0**	**.1**	**.1**

(*0.6 for chinook spawning can be used, depending on river size)