INSTREAM FLOW STUDY GUIDELINES:

Technical and Habitat Suitability Issues including fish preference curves

UPDATED, April 1, 2013

Washington Department of FISH and WILDLIFE

WASHINGTON STATE DEPARTMENT OF ECOLOGY

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By Dr. Hal Beecher
Habitat Program
Department of Fish and Wildlife
PO Box 43155
Olympia, WA 98501-1091

and Brad Caldwell
Water Resources
Department of Ecology
PO Box 47600
Olympia, WA 98504-7600

Editing and Appendix Tables and Graphs by
Jim Pacheco
Water Resources
Department of Ecology
PO Box 47600
Olympia, WA 98504-7600

Errata:
May 14 2013. Fixed small stream steelhead rearing curve to remove preference at zero depth and adjusted cutthroat juvenile velocity curve.

INTRODUCTION

The Washington Department of Ecology (Ecology) is charged both with administering state water rights laws and the federal Clean Water Act. Under Washington state law Chapters 90.54 and 90.22 RCW require Ecology to maintain instream flows sufficient to protect and preserve fish and other instream values and beneficial uses. The Department of Ecology (Ecology) is mandated by the Water Resources Act of 1971 (Chapter 90.54 RCW) to maintain base flows[1] "necessary to provide for preservation of wildlife, fish, scenic, aesthetic and other environmental values, and navigational values." The word "preserve" means to keep from harm, damage, or danger.

Ecology must also meet the antidegradation requirements of Washington's water quality standards (Chapter 173-201A WAC). This law says existing beneficial uses shall be maintained and protected and no further degradation shall be allowed. The minimum instream flow may not cause any further degradation of beneficial uses such as: fish; fish spawning, rearing and migration; wildlife; recreation; boating; sport fishing; and aesthetics.

Additionally, the minimum instream flow must protect fish, game, birds, and other wildlife, recreational and aesthetic values and water quality (Chapter 90.22 RCW).

The Department of Fish and Wildlife (WDFW) is mandated to "preserve, protect, perpetuate, and manage the wildlife and food fish, game fish …" (Chapter 77.04.012 RCW); part of this mandate is to protect habitat, including streamflows.

For projects requiring a federal license or permit involving a discharge into navigable waters, a section 401 Water Quality Certification is required under the Clean Water Act. Ecology is required to condition certifications to ensure compliance with state water quality standards and other applicable state law such as Chapters 90.54 and 90.22. This authority under the Clean Water Act allows Ecology to mandate minimum instream flows on hydroelectric projects.

The Washington Department of Fish and Wildlife (WDFW) recommends instream flows as conditions on water rights and Clean Water Act Section 401 certifications on hydroelectric power project licenses or exemptions (issued by the Federal Energy Regulatory Commission - FERC). When a major water project is planned, WDFW and Ecology request that the project proponent conduct an instream flow study in consultation with the agencies to provide adequate information on which to base an instream flow recommendation or requirement. WDFW defines a major water project is a project as:

a) diverting at least 1.0 cubic feet per second (cfs), and
b) changing flow by at least 10% of the monthly 90% exceedence flow at any point along the stream channel.

[1] In statute, the term "base flow" is used synonymously with the terms "instream flow" and "minimum instream flow." "Streamflow" refers to the amount of water flowing in a stream.

The purposes of WDFW's instream flow recommendation are:

1. to avoid reduction of habitat for fish and wildlife;
2. to ensure fish passage upstream and downstream; and
3. to maintain macrohabitat features of the stream channel.

To address fish habitat, WDFW and Ecology request use of an instream flow method which estimates the amount of habitat available at different flows that might occur with and without the proposed project. In most cases, this request is met by using the Physical Habitat Simulation (PHABSIM) program, part of the Instream Flow Incremental Methodology (IFIM), following quality control and model limitations consistent with the Instream Flow Study Guidelines.

A consultation documentation form is provided on the following page. Consultation with appropriate WDFW and Ecology personnel and adherence to the attached IFIM study guidelines during all phases of the instream study is crucial to completion of the study. We request documentation of each step of consultation by signature of a WDFW Habitat Program employee on the form on the following page.

Primary contacts:

WDFW:

Hal Beecher, Instream Flow Biologist	360-902-2421
Bob Vadas, Jr, Instream Flow Biologist	360-902-2594
Jonathan Kohr, Instream Flow Biologist	509-457-9306

Ecology:

Brad Caldwell, Instream Flow Biologist	360-407-6639
Jim Pacheco, Instream Flow Biologist	360-407-7458

Chris Maynard, Water Resources Program
Clean Water Act Section 401 certification
and hydroelectric power project licenses 360-407-6641

PROJECT:_____
STREAM:_____
FERC#:_____

Documentation of consultation with WDFW on instream flow studies - all blanks must be signed by WDFW personnel for completion of consultation.

SCOPING

Study site(s) approved_____date__/__/__
Transects approved_____date__/__/__
Target measurement flows approved_____date__/__/__

HYDRAULIC MODEL

Measured flows approved_____date__/__/__
Hydraulic model approved for the following ranges: date__/__/__

HABITAT PREFERENCE CURVES

Preference curve study design approved (including species, lifestages) _____date__/__/__
Preference curve study completed _____date__/__/__
Preference curves approved (copy to be attached) _____date__/__/__

INSTREAM FLOWS - LIST BY TIME PERIOD:

MONTH/DATE to MONTH/DATE	MINIMUM FLOW (cfs)
_____/____ to _____/____	_____
_____/____ to _____/____	_____
_____/____ to _____/____	_____
_____/____ to _____/____	_____
_____/____ to _____/____	_____
_____/____ to _____/____	_____
_____/____ to _____/____	_____

FLUSHING FLOW REQUIREMENT - >48 HRS/3 YRS _____ cfs

Approved by Department of Fish and Wildlife

_____date__/__/__
Instream Flow Biologist

_____date__/__/__
Regional Habitat Biologist

INSTREAM FLOW STUDY GUIDELINES:
Technical and Habitat Suitability Issues
including Fish Preference Curves
Updated as of April 1, 2013

PURPOSE OF AN INSTREAM FLOW STUDY

Existing or proposed projects often affect flow in a river or stream (i.e., hydropower, irrigation, or municipal/industrial diversions). Washington state resource agencies, including the Washington Department of Ecology (Ecology) and Washington Department of Fish and Wildlife (WDFW) may request studies to evaluate the impacts of altered flow on instream resources, including fish habitat and production, for the purpose of making decisions or recommendations on water use. This report offers guidelines on how to develop, conduct and analyze instream flow studies for determining impacts to fish and fish habitat.

Altered stream flows can impact fish by changing the magnitude, frequency, and/or timing of streamflow. Flow alterations change the availability and type of instream habitat and, in turn, change fish production and fish species composition. A widely used method called the Instream Flow Incremental Methodology (IFIM) (Bovee and Milhous 1978, Bovee 1982, Milhous, et al. 1984, Bovee, et al. 1998) is useful for estimating the streamflows needed to maintain the fish production potential of a stream.

This study provides information about the relationship between streamflow and fish habitat, which can be used in developing instream flow requirements for fish. Four key variables of fish habitat are examined:

- depth
- velocity
- substrate
- cover

IFIM uses several computer models, notably Physical HABitat SIMulation (PHABSIM) to determine how the quantity of fish habitat changes with streamflow.

Stream sites are chosen to represent a specific reach of each river. Field data are collected and entered into the computer model (PHABSIM) to simulate the distribution of water depths and velocities with respect to bottom substrate and overhead cover under a variety of flows. The simulated habitat parameters are then used to generate the quantity of available habitat at each modeled flow; this index is referred to as "weighted usable area" (WUA).

The habitat indexes (Weighted Usable Area or WUA) at each flow correspond to the biological requirements of the fish species and life history stage of interest. Results of an IFIM/PHABSIM

study predict how WUA for each species and lifestage change over a broad range of streamflows. With this fish habitat information and other information such as the hydrology, the resource agencies can recommend instream flows needed to maintain the fish and fish habitat in the stream.

An IFIM study cannot by itself determine the instream flow required by fish populations. The WUA graphs only show whether an increase or decrease in streamflow will increase or decrease the quantity of fish habitat. The study's fish habitat versus streamflow results have to be interpreted by knowledgeable biologists and others to arrive at an instream flow regime that satisfies applicable laws.

Sometimes the IFIM model will predict (for a certain fish species and lifestage) that the maximum amount of available habitat occurs at a flow that is higher than what typically is found during the late summer low flow period. This does not mean the model is incorrect. The model determines whether more or less flow makes more or less fish habitat based on the channel shape (its width and depth) – not on the hydrology (the quantity of flow which changes daily).

Whether an increase in fish habitat truly results in an increase in the fish population depends upon many different factors that affect fish survival. These include fish harvest, ocean survival, water quality, food supply, adult and juvenile fish passage survival, and predation.

A word of caution. IFIM is not a fixed sequence of procedures, but involves a number of important subjective decisions (e.g., transect selection, selection of computer models, and transect weighting). For this reason, the Washington state resource agencies require ongoing consultation during a study, including several meetings and field trips. Studies performed without adequate consultation may be partially or completely rejected, resulting in significant delays in project development.

Ramping Rates and Ramping Rate Studies

Interim ramping rates will be established according to Hunter (1992):

Season	Daylight Rates*	Night Rates
February 16 to June 15 (salmon fry)	No Ramping	2 inches/hour
June 16 to October 31 (steelhead and trout fry)	1 inch/hour	1 inch/hour
November 1 to February 15	2 inches/hour	2 inches/hour
*Daylight is defined as one hour before sunrise to one hour after sunset		

The rate of change of streamflow when diversion is started, stopped, or changed is referred to as the ramping rate. Ramping rates are a concern for fish protection because rapid decrease in flow can strand fish on gravel bars, as well as dewatering fish eggs.

The impacts of flow fluctuation are mitigated by specifying a rate of flow reduction, the ramping rate, and specifying times during the day and year at which ramping can occur. For most projects, a standard interim ramping rate and ramping schedule are provided early in consultation by the agencies. But if the standard ramping rates cannot be met or are determined by the developer to be difficult to meet, then site-specific ramping rate studies can be done. The agencies can assist with identifying transect locations and which critical flows should be measured.

KEY ELEMENTS OF INSTREAM FLOW STUDY

Consultation with the appropriate personnel in state agencies (Washington state Departments of Ecology (Ecology) and Fish and Wildlife (WDFW)) and other resource management agencies (including U.S. Fish and Wildlife Service and National Marine Fisheries Service) and affected Tribal Governments the responsibility of the project proponent at all stages of the study.
Stages of the study include:

1) planning or scoping - develop study plan and obtain approval from all parties;
2) fish habitat preference curve verification or use of default curves
3) field data collection;
4) hydraulic model calibration;
5) and habitat model runs.

Having approval of the study plan, model calibration, and preference curves and computer options selected by all interested agencies will prevent surprise delays at the end of the process.

PLANNING

Early in the planning phase, when the project is still flexible, the project proponent should schedule a meeting when representatives of all agencies and tribes can attend. At least 2 weeks notice is usually necessary. The purpose of the meeting is to discuss possible project designs and develop a study plan to assess the potential impacts on instream resources.

In preparation for the meeting, the project proponent should conduct a thorough reconnaissance of the stream reach to be affected by the project including downstream from the project to the next major confluence.

Documentation that would expedite agency review and planning include:

1) topographical maps with contour intervals no greater than 20 feet;
2) identification of areas along the stream that exhibit major morphological changes in the stream bed and/or stream banks;
3) graph of elevation plotted against the stream's longitudinal distance;
4) low altitude photo mosaic (preferred) or video tape of entire reach (low flow in winter is best if canopy closure is an issue);
5) on-the-ground photos or video tape of all habitat types and potential barriers to fish migration (with reference object for scale in pictures of potential barriers);

6) list of fish species known or expected in stream reach;
7) available hydrological data such as 10%, 50%, and 90% exceedence discharges by month; and information on the source of this data.

The proponent should conduct an instream flow study using PHABSIM or RHABSIM using the 3-flow (velocity regression) IFG4 program and the Dual SDR (Stage Discharge Rating) for the hydraulic model unless otherwise approved in advance by all agencies.

In preparation for the planning meeting or a follow-up site visit, the proponent should select and mark tentative transects to represent all habitats in the affected reach, including ramping rate transects both in the bypass reach and downstream of the powerhouse. A consultant or agency personnel with IFIM experience should select these tentative transects. A site visit should be done under suitable viewing conditions to allow agency representatives to view, modify as needed, and approve placement of transects.

The final product of the planning meeting is a study plan signed by all parties if possible agreeing to the plan. It should be as specific as possible and ensure that all parties understand what is expected from the study. This will allow scheduling and budgeting of the study. It should be amendable only by unanimous agreement of Ecology and WDFW and should seek the agreement of all other parties. The following elements should appear in the study plan:

1) hydraulic model(s) to be used (e.g., IFG4, WSP/ IFG2, MANSQ);
2) range of flows to be addressed and targeted flows to be measured as calibration flows;
3) available hydrographs to be used and any new hydrology to be collected;
4) locations of transects and study sites with maps and photos or videos as documentation;
5) habitat preference curve verification study plan (see below);
6) habitat models to be used (HABSIM or similar model, plunge pool, etc.);
7) any limiting factor analysis or time series analysis;
8) ramping rate study plan and sites.

FISH HABITAT PREFERENCE CURVE VERIFICATION

An instream flow study is incomplete if the project proponent has not made a reasonable effort to determine fish habitat preference at the study site or an approved substitute site. The study outlined here is a reasonable effort. If, after making a reasonable effort, the project proponent has not compiled enough data to verify or modify agencies' default generalized habitat preference curves, then default curves may be used with agency approval (see below and Appendix for discussion of default preference curves). Preference curve verification will be aimed at selected species and lifestages.

The preference curve verification study consists of three parts:

1) determine proportional habitat availability;
2) determine fish habitat utilization; and

3) analysis of fish preference by determining ratio of habitat utilization to habitat availability.

Useful references for habitat preference curve verification are Orth, Jones, and Maughan (1981), Bovee (1986, Instream Flow Information Paper No. 21), Slauson (1988), and Beecher, Johnson, and Carleton (1993).

Determining habitat availability. In PHABSIM the habitat variables are depth, velocity, substrate, and cover. The simplest way to determine the frequency of different ranges of habitat dimensions is to generate a table of depth and velocities frequencies from PHABSIM based on the streamflow occurring during field measurements. An alternative is to collect enough measurements of depth and velocity to map their distribution.

The frequency of a depth (or velocity or cover or substrate) range will be weighted by the weighting factor(s) for the transect(s) in which it is measured or simulated. If the preference curve verification study reach is smaller than the IFIM study reach, then different weighting factors may be required for determining mesohabitat availability than are used for the IFIM study.

Determining fish habitat utilization. These measurements should not be made during or immediately after habitat availability measurements in order to minimize fish disturbance.

Fish observations should be conducted by one or more snorkelers swimming slowly and cautiously upstream. Snorkelers should avoid disturbing fish. If more than one snorkeler is participating, they should coordinate positions to avoid disturbing fish or double-counting them. Before recording habitat data (depth, velocity, substrate, and cover) where a fish is observed, the snorkeler should determine that the fish is not disturbed. The observation is a good one if fish behavior includes (a) feeding, (b) territorial defense, or (c) returning to the observation point after measurement. (The snorkeler may determine that an observation is a good one even if these behaviors are not observed.) Snorkelers may either measure habitat data as they encounter fish, or they may mark fish positions with weighted flags and return to measure when all fish in the study site have been marked.

Analysis of fish habitat preference. The first stage in data analysis is to determine the final ranges (or bin size, Slauson, 1988) of each habitat dimension to be used. In many studies, small sample size of fish observations will limit how narrow those ranges will be.

Begin by using uniform initial ranges that are a reasonable size for the measurement equipment precision (e.g., 0.1 ft ranges for depth measurement with English unit wading rods). For each initial range, tabulate the proportion of preference curve verification study area that falls within that range. For example, we might find the following distribution of area in X Creek, listed with the observed number of fish (O) in each range:

Depth Interval	Frequency	Observations	Expected	Expected >5
0.00-0.09 ft	1.3%	O= 0	E= 1.13	
0.10-0.19 ft	1.4%	O= 0	E= 1.22	
0.20-0.29 ft	4.3%	O= 0	E= 3.74	E= 6.09
0.30-0.39 ft	4.8%	O= 0	E= 4.18	
0.40-0.49 ft	5.1%	O= 0	E= 4.44	E= 8.62
0.50-0.59 ft	7.8%	O= 1	E= 6.79	E= 6.79
0.60-0.69 ft	9.7%	O= 3	E= 8.44	E= 8.44
0.70-0.79 ft	14.7%	O=23	E=12.79	E=12.79
0.80-0.89 ft	18.2%	O=26	E=15.83	E=15.83
0.90-0.99 ft	15.0%	O=21	E=13.05	E=13.05
1.00-1.09 ft	11.5%	O= 7	E=10.01	E=10.01
1.10-1.19 ft	4.6%	O= 3	E= 4.00	
> 1.19 ft	1.6%	O= 3.	E= 1.39.	E= 5.39.

If the snorkeler had measured depth at 87 fish positions (N=87), the null hypothesis would be that fish were distributed independently of depth and should therefore be distributed at depths proportionally to the frequency with which those depths occur. The null expectation (E) of the number of fish in each depth range would be the product of N and the percent of total area in that depth range (D): E=ND. Depth ranges and corresponding values of E for X Creek are listed in the Expected column above.

Ranges will be combined using the criterion that E should be at least 5 in most if not all ranges (a standard derived from Chi-square tests, which may be used in preference curve development). Combining ranges are listed in the Expected >5 column above.

The ratio Observed/Expected (O/E) is calculated, then normalized (see Bovee, 1986) to create the preference factor so that the maximum value of P is 1.00:

Depth Interval with E>5	O/E Ratio	Preference
0.00-0.29 ft	0/6.09= 0.00	P=0.00
0.30-0.49 ft	0/8.62= 0.00	P=0.00
0.50-0.59 ft	1/6.79= 0.15	P=0.08
0.60-0.69 ft	3/8.44= 0.36	P=0.20
0.70-0.79 ft	23/12.79= 1.80	P=1.00
0.80-0.89 ft	26/15.83= 1.64	P=0.91
0.90-0.99 ft	21/13.05= 1.61	P=0.89
1.00-1.09 ft	7/10.01= 0.70	P=0.39
> 1.09 ft	6/5.39= 1.11	P=0.62.

These values of P could then be compared to agency fallback values and a mutually acceptable preference curve could be adopted for the “X” Creek IFIM study.

When sample sizes are small (e.g., N<20) a graph of use may appear jagged, but we expect a smooth relationship between depth or velocity and suitability. To better describe the suitability

we sample the distribution repeatedly and average the resulting values, then adjust the average to have a maximum value of 1.00.

Using the fish and depth distribution above as an example, but reducing the number of fish observed (N=19) as follows, we calculate Observed/Expected for each adjacent cluster of depth (or velocity) intervals until the Expected number of fish is at least 5 in the first column, 4 in the second column, 3 in the third column, 2 in the fourth column, and 1 in the fifth column.

Depth interval	Area	Fish	Expected	Observed/Group Expected				
				E>5	E>4	E>3	E>2	E>1
0.00-0.09 ft	1.3%	O=0	0.247	0.153	0	0	0	0
0.10-0.19 ft	1.4%	O=0	0.266	0.153	0	0	0	0
0.20-0.29 ft	4.3%	O=0	0.817	0.153	0	0	0	0
0.30-0.39 ft	4.8%	O=0	0.912	0.153	0	0	0	0
0.40-0.49 ft	5.1%	O=0	0.969	0.153	0	0	0	0
0.50-0.59 ft	7.8%	O=0	1.482	0.153	0	0.301	0	0
0.60-0.69 ft	9.7%	O=1	1.843	0.153	1.294	0.301	1.294	0.543
0.70-0.79 ft	14.7%	O=5	2.793	1.760	1.294	1.760	1.294	1.790
0.80-0.89 ft	18.2%	O=6	3.458	1.760	1.585	1.760	1.735	1.735
0.90-0.99 ft	15.0%	O=4	2.85	1.192	1.585	1.192	1.404	1.404
1.00-1.09 ft	11.5%	O=2	2.185	1.192	0.862	1.192	0.915	0.915
1.10-1.19 ft	4.6%	O= 0	0.874	0.562	0.892	0.849	0.849	0.849
> 1.19 ft	1.6%	O= 1	0.304	0.562	0.892	0.849	0.849	0.849

When we convert the Observed/Expected values to values that peak at 1.00 by dividing each value above by the maximum value in that column, we derive the following:

Depth interval	Area	Fish	Expected	Suitability ((Obs/Exp)/Exp_{max})						
				E>5	E>4	E>3	E>2	E>1	Ave.	Final
0.00-0.09 ft	1.3%	O= 0	0.247	0.087	0	0	0	0	0.017	0.017
0.10-0.19 ft	1.4%	O= 0	0.266	0.087	0	0	0	0	0.017	0.017
0.20-0.29 ft	4.3%	O= 0	0.817	0.087	0	0	0	0	0.017	0.017
0.30-0.39 ft	4.8%	O= 0	0.912	0.087	0	0	0	0	0.017	0.017
0.40-0.49 ft	5.1%	O= 0	0.969	0.087	0	0	0	0	0.017	0.017
0.50-0.59 ft	7.8%	O= 0	1.482	0.087	0	0.171	0	0	0.052	0.052
0.60-0.69 ft	9.7%	O= 1	1.843	0.087	0.816	0.171	0.746	0.303	0.425	0.427
0.70-0.79 ft	14.7%	O=5	2.793	1.000	0.816	1.000	0.746	1.000	0.912	0.918
0.80-0.89 ft	18.2%	O=6	3.458	1.000	1.000	1.000	1.000	0.969	0.994	1.000
0.90-0.99 ft	15.0%	O=4	2.85	0.677	1.000	0.677	0.809	0.784	0.789	0.794
1.00-1.09 ft	11.5%	O= 2	2.185	0.677	0.563	0.677	0.528	0.511	0.591	0.595
1.10-1.19 ft	4.6%	O= 0	0.874	0.319	0.563	0.482	0.489	0.474	0.466	0.468
> 1.19 ft	1.6%	O= 1	0.304	0.319	0.563	0.482	0.489	0.474	0.466	0.468

Fallback preference curves, including those for plunge pools, are listed in the Appendix or are available from the agencies.

Life-stage timing. Timing of spawning and emergence are often important determinants of what flows are required at different times. Temperature can be a critical factor in life-stage timing. Consequently, temperature should be monitored in affected reaches throughout the year. Surveys to determine timing of fry emergence should bracket the times when emergence is expected.

STREAM SIZE DEPENDENT PREFERENCE CURVE ANALYSIS

Recently we determined that habitat suitability or preference varies with stream size. Thus we present fallback habitat suitability criteria (HSCs) stratified by stream size, where stream size is measured as toe-of-bank width near hydraulic controls (see Swift 1976, 1979). Small streams are narrower than 35 ft. Future work on habitat suitability may further discriminate among medium and one or more larger stream size categories.

HYDRAULIC MODEL CALIBRATION

The agencies' first choice of hydraulic models is IFG4 using 3 sets of velocity measurements to establish regressions of velocity with flow and the Dual SDR option. Agencies expect to review a hydraulic model based on measured data (unmodified input). We will consider additional models with minor modifications to the input on a case by case basis. Recently, 2D and 3D hydraulic models have been developed (Leclerc et al. 1995, Hardy 1998) which involve different calibration approaches that have considerable promise over a wide range of flows.

If modifications improve extrapolation (i.e., more realistic velocities and better velocity adjustment factors at higher flows) of IFG4 without deterioration of interpolation, then minor or slight modifications will be accepted.

The agencies request the following material for each hydraulic model calibration run (always include a run with unmodified input):

(1) field notes;

(2) input file (bed and water surface elevations, velocities, substrate/cover, and calibration discharges for velocity regression models; bed and water surface elevations, roughness coefficients, substrate/cover, and calibration discharge for step-backwater models. Include both an unmodified and modified version of the input file along with a table of any data modifications.

(3) tables for each transect of "calibration details" with simulated velocities paired with corresponding measured velocities for each calibration flow (thus, model needs to be run for calibration flow). If several 1-velocity models are being run, please provide tables of measured velocities with predicted velocities (e.g., measured high flow velocities with extrapolated high

flow velocities from medium and low flow models, and similar treatments of medium flow and low flow velocities);

(4) tables of pre and post calibration velocity adjustment factors (VAF) for each transect and each simulated flow over the proposed range of the model;

(5) tables of "computational details" for each simulated flow, including calibration flows;

(6) list of options used in the hydraulic model;

(7) map of site showing placement of numbered transects in relation to pools, riffles, chutes, large boulders, large woody debris, and other channel features; and

(8) table of stage differences between flows and between transects (for example:

	T1	diff	T2	diff	T3
400cfs:	91.20	0.10	91.30	0.15	91.45
diff:	.10		.09		.10
200cfs	91.10	0.11	91.21	0.14	91.35
diff:	.05		.07		.05
100cfs	91.05	0.09	91.14	0.16	91.30

We recommend limiting extrapolation to flows at which all VAFs are between 0.80 and 1.20, and at which no simulated velocities exceed 10.00 feet per second. If it is necessary to model higher or lower flows, additional field work to allow calibration of an additional or extended model will be required.

Where possible, have each transect in the study tied to a common benchmark. We review stages of zero flow in different transects and expect them to make a normal upstream progression. If transects are modeled separately, this test cannot be done and our model review is prolonged.

Other hydraulic models can be considered as needed if conditions preclude a 3-flow IFG4, but these should only be used with prior approval of the agencies.

HABITAT MODEL

A major product of an instream flow study is a set of tables and graphs showing the habitat to stream flow relationship. In PHABSIM and RHABSIM, this is produced by HABITAT or HABSIM program and uses weighted usable area (WUA) as a measure of fish habitat.

PHABSIM accepts 1 Substrate/Cover code in the input file. Separate runs of HABTAT should be run for spawning and rearing lifestages. For biological realism, use cover for rearing and substrate for spawning in those cells where both are recorded.

In contrast, RHABSIM accepts codes for two different attributes. This allows the HABSIM to use substrate for spawning lifestages and cover for rearing lifestages in a single run.

In studies with multiple sites, the tables discussed above should be provided for each site individually and for all sites combined. The combined or composite tables should have results at each site weighted according to the total stream area (including unsampled areas) that it represents.

The final report, in which these tables are presented, should also include:
(1) the preference curves used with documentation of agency approval; and
(2) a list of options used in the habitat model.

Plunge pool analysis. In some high-gradient, boulder- or bedrock-channel streams, the only fish habitat is in pools. This approach is based on the following assumptions about habitat quality in pools:
(1) surface turbulence/bubble plume should cover about half the pool surface, and, as plume coverage increases beyond or decreases below half of pool area, habitat quality will decline rapidly;
(2) pool area not covered by surface turbulence/bubble plume is valuable as habitat when depth equals or exceeds 0.5 ft or 10% of pool width, whichever is greater, but any depth over 3.0 ft should be considered usable, subject to preference verification;
(3) spawning habitat response to changes in flow in pools is best assessed by using standard IFIM transects with depth, velocity, and substrate measurements near the tail of pools.

Pool habitat for juvenile and adult trout should be calculated as follows:

Habitat = area of calm, deep water X preference for ratio
of plume area to calm, deep area (see Table 13).

The field method for plunge pool analysis requires establishment of permanent transects and vertical depth measurement points ("verticals") along the transects. We recommend at least 3 transects. Record distances between transects. These transects should be visited at several different flows of interest. At each flow, depth should be measured at verticals up to 3.0 ft deep. Depths should be recorded with corresponding distances along the transect. The person conducting the field work should (a) identify the boundaries between plume and calm water and (b) record the distances along each transect where they occur. If velocity is substantially greater than 1 fps, that point might be considered to be in the plume if the boundary is not otherwise obvious.

Photographs from the same high vantage point should be taken at each measurement. Colored flags at reference points along each transect will facilitate interpretation of photographs.

Feeding Station Analysis. - The state agencies no longer consider this method to be a suitable alternative to calculation of WUA (see also Annear et al., 2004). Use of this method is no longer recommended because it has had less validation of assumptions than PHABSIM.

INTERPRETATION OF HABITAT MODELS AND DEVELOPMENT OF INSTREAM FLOW RECOMMENDATIONS

The agencies will recommend instream flows which will not reduce habitat for the most flow-sensitive species and relevant life stage in a given month. Flow recommendations based on model results (PHABSIM, RHABSIM, plunge pool, etc.) are subject to field verification or "ground-truthing".

This approach has been oversimplified to "recommending the peak of the WUA vs. flow curve." However, our recommendations are tempered by:

1) our knowledge of site hydrology and effects of hydrology on fish (e.g., scouring of redds and incubation flows),
2) agency management objectives and risk to species (e.g., greater emphasis on rainbow trout than on the more numerous mountain whitefish that typically occupy deeper, faster water), and
3) on modeled responses of coexisting species to flow.

For a more detailed discussion of agency considerations in interpretation of studies and development of recommendations, see Annear, et al. (2004).

Hydrology affects fish in several ways. High flows interact with geology and vegetation to form and maintain the channel, including depth, cover, and substrate quality. High flows also stimulate migrations upstream and downstream in migratory salmonids. The significance of high flows is discussed in more detail by Wald (2009). The Departments of Fish and Wildlife and Ecology recognize the following principles and standards based on Wald's recommendations.

Fish migration and spawning flows – High flow pulses to facilitate salmon spawning and migration should provide adequate water temperature, sufficient flow depth, appropriate seasonality and diurnal conditions, and sufficient flow duration for adult fish to migrate upstream to suitable spawning or holding areas and for juvenile fish to migrate downstream when necessary. Needed magnitude, frequency, and duration depend on fish stock and stream. Review of hydrological record and any fish count data available may be required to develop site-specific recommendations. Vadas (2000) has found that flows suitable for spawning are often conducive to upstream migration.

Flushing flows – Flushing flows to improve gravel quality for spawning and incubation habitat provide the greatest benefit when they occur at the beginning of spawning seasons. Flushing flows in the fall remove organic matter and fines that accumulate during the summer. Flushing flows in the spring provide migration flows while they reduce the amount of fines in spawning gravels. The departments of Fish and Wildlife and Ecology recommend preserving or providing

the mean annual discharge as a flushing flow for 6 to 12 hours duration during specified seasons and at intervals of at least 2 per year if not provided naturally. Release rates should be controlled according to specified ramping rates (Hunter 1992).

Channel maintenance flows **-** Channel maintenance flows for activating geomorphic processes are greater in magnitude and duration than flows necessary for initiation of bedload movement. The departments of Fish and Wildlife and Ecology recommend preserving or providing the 2-year frequency peak flow or 200% of mean annual discharge for at least 24 hours duration at specified seasons as a channel maintenance flow at intervals of 2 years if not provided naturally. The 2-year frequency peak flow should be based on natural hydrology, not hydrology modified by extensive increases in impervious surface nor other hydrologic modifications. Release rates should be controlled according to specified ramping rates (Hunter 1992).

Channel forming flows –The departments of Fish and Wildlife and Ecology recommend preserving or providing the 10-year frequency peak flow for at least 24 hours duration at specified seasons as a channel forming flow at intervals of 10 years if not provided naturally. The 10-year frequency peak flow should be based on natural hydrology, not hydrology modified by extensive increases in impervious surface nor other hydrologic modifications. Release rates should be controlled according to specified ramping rates (Hunter 1992).

Time-series analysis. Project proponents may wish to do time-series analysis (Milhous 1986). Evaluation of changes in habitat over time as well as changing habitat needs over time is an important consideration for rearing fish. The agencies neither request nor endorse the use of time-series models. However, if requested to consider results of such analysis, agencies will accept them only over the range of flows for which the hydraulic model is accepted by the agencies. In addition, any time-series of alternative flow regimes must incorporate a temperature-based metabolic factors, i.e., the habitat-temperature index (HTI), into the analysis, as follows:

> If two different flow regimes, A and B, lead to two different amounts of WUA, WUA(A) and WUA(B), at a given time, we can compare WUA(A) and WUA(B) as they are affected by temperature. HTI = 2^(T/10), where T is water temperature in degrees C at that season. The comparison of interest is WUA(A)/HTI vs WUA(B)/HTI. HTI need not be used for spawning or incubation.

RAMPING RATE STUDIES

Information needed for ramping rate determination includes: (1) identification of critical stranding sites, (2) determination of stage-discharge relationship at critical sites, (3) determination of travel time for a block of water traveling through a reach of interest, and (4) determination of attenuation of stage change over distance at different flows. Much of this information can be gathered conveniently and concurrently with PHABSIM studies.
Critical sites are sites where juvenile fish are most likely to be stranded if stage is reduced rapidly. This can happen where the stream is wide and the cross section has a relatively flat slope, typically at a gravel bar or sand bar.

The applicant should identify potential critical sites both within the bypass reach and downstream from the powerhouse site. Following tentative critical site selection, agency personnel should be shown sites so that they can make a final decision on sites and transects.

The applicant should conduct a series of stage-discharge measurements at each critical site transect. A 3-flow stage discharge model that covers the range of flows over which the ramping events are expected to occur would be adequate. A detailed cross-sectional profile should be determined by surveying elevations along each critical site transect. Stage-discharge measurements should identify critical flows, such as flows that coincide with inflection points on the cross-sectional profile. Stage-discharge relationships will provide a basis for ramping rates by showing what change in depth is produced by what change in flow.

Dye studies should be used to give a preliminary estimate of travel time for a block of water from a release point, either at the diversion structure or powerhouse, to each critical site. Dye studies should be conducted over a range of flows to evaluate the influence of discharge on travel time. These will provide a preliminary estimate of necessary duration of flow continuation at the powerhouse to prevent reaches from drying up in the event of an emergency shut-down.

Data developed in these studies will be the basis for interim ramping rate recommendations. Additional studies, including test ramps with measurements of depth change at critical site transects, will be required once the facility is constructed. They will be the basis for operational ramping rates.

MONITORING

Monitoring the effects of flow regime (e.g., fish population response, attainment of flows, and channel conditions including passage) will be required. The agencies may recommend changes in flow regime based on the monitoring results.

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INSTREAM FLOW STUDY GUIDELINES

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Appendix Notes

Tables and figures in this appendix list the WDFW and Ecology recommended preference codes and values for instream flow modeling using PHABSIM or RHABSIM models. These values are based on habitat suitability studies, in which WDFW and/or Ecology staff (or individuals following WDFW-Ecology study guidelines) recorded the depth, velocity, and substrate used by fish in a study reach and compared these observed results to the measured percent availability of different depths, velocities, or substrates in that study reach.

Recommended Preferences do not always accurately reflect local conditions. Therefore these preference values should only be used after consultation with and written agreement of WDFW and/or Ecology instream flow biologists.

Cover/Substrate preference tables and coding

Table 1 lists codes 0.1 through 0.9, which are cover codes, and 1 through 9, which are components of the substrate code. Adjacent to each code are the recommended preference factors used to determine preference value.

Substrate codes use the format "ab.c" where "a" is the component code for dominant particle size (i.e. the type of substrate that covers greatest area of bottom surface in a particular cell, not necessarily the largest diameter particle; e.g., sand may be dominant over cobble), "b" is the component code for the subdominant particle size, and "c" is tenths of cell area covered by dominant (50% or greater) substrate type. For example, the code 46.8 indicates 80% medium gravel and 20% small cobble.

Cover codes use the format 0.c, where "c" defines the type of cover. For example, 0.1 is an undercut bank, 0.2 is overhanging vegetation, etc.

Since PHABSIM can only accept 1 Cover/Substrate code, separate data decks should be developed for spawning and rearing lifestages. For biological realism, use cover for rearing and substrate for spawning in those cells where both are recorded.

RHABSIM can accept codes for two different attributes. This allows the user to choose one attribute (e.g. substrate) for the spawning lifestages and the other attribute (e.g cover) for the rearing lifestages in a single data deck. But care must be taken to properly set up and assign the attributes in the HYDSIM program.

Recommended Preference (RP) in substrate tables 2 through 6 are calculated from generic preferences in **Table 1** according to the following equation:

$$\mathbf{RP = c * Pa + (1-c) * Pb}$$

where RP is the preference factor, Pa is the preference factor for substrate component "a" in Table 1, and Pb is the preference factor for substrate component "b" in Table 1. Exceptions are noted by an asterisk.

Exceptions: There are many exceptions to the RP equation based on biological considerations. For example, if the dominant substrate was silt, clay, or organic (component code 1), or sand (component code 2), the substrate was assigned a RP of 0.00, regardless of the suitability of the subdominant component. Moreover, if the subdominant substrate was silt, clay, or organic, or sand made up 30% or more of the substrate, the RP was assigned a value of 0.00, regardless of the quality of the dominant substrate, due to the smothering effect of fine substrates.

For salmonid spawning, the presence of bedrock (code 9) always resulted in a RP of 0.00, and in most cases, the presence of boulders (code 8) and for rainbow trout, large cobble (code 7) also resulted in an RP of 0.00 due to the inability of the fish to dig through, or move the substrate.

For salmonid juvenile rearing, boulders (component code 8) were found to be extremely valuable. Any presence of boulder, whether dominant or subdominant, results in a RP of 1.00.

Every code combination is neither listed nor necessary. When there is a gap, PHABSIM and RHABSIM assume a straight line between entered codes. For example, Table 2 lists the codes 47.5 (RP 0.75) and 47.9 (RP 0.95). If a value for 47.7 were needed, PHABSIM or RHABSIM would derive a RP of 0.85.

Another case is with redundant codes. A redundant code occurs when 100% of the substrate is of one type. If the substrate is 100% small gravel, any code between 33.5 - 33.9 could be used. By convention, redundant codes use the format aa.9.

Depth and velocity preference curves

Figures 1a-21b show the various recommended preference curves along with the coordinates used to make the curves. When available, the calculated preference curve and coordinates are provided to show the observed/expected calculations (see pages 10-12 under the heading Analysis of fish habitat preference) along with sample size and study locations. In these cases, recommended preference curves represent smoothed versions of the calculated preference curves. Smoothing of preference coordinates is based on professional judgment and observations from studies of wild fish. Such smoothing removed stair-stepped patterns at the upper and lower ends of the hydraulic distributions, by setting zero depth to zero suitability and spreading the sum of raw suitabilities out over the more-proximal categories.

Some of the “Calculated depth preference curves” show habitat value in a depth interval that includes 0.00 ft. This is a consequence of grouped observations and weighted calculations. Recommended Preferences begin with calculated suitabilities that are then adjusted based on actual observations and professional judgment.

Depth and velocity preference curves are being revised continually as new data are obtained and analyzed. Please contact the Department of Ecology or WDFW for the most recent preference curves for salmon, trout, and other game fishes.

TABLE 1. Generic Cover/Substrate Codes and Preference Values[1]

Code	type of cover Note: Cover Codes are not used for spawning	Rearing	
		fry	juvenile
00.1	undercut bank	1.00	1.00
00.2	overhanging vegetation near or touching water[2]	1.00	1.00
00.3	rootwad (including partly undercut)	1.00	1.00
00.4	log jam/submerged brush pile	1.00	1.00
00.5	log(s) parallel to bank	0.30	0.80
00.6	aquatic vegetation	1.00	0.80
00.7	short (<1') terrestrial grass	0.40	0.10
00.8	tall (>3') dense grass[3]	0.70	0.70
00.9	vegetation > 3 vertical ft above SZF	0.20	0.20

Code	type of substrate	Spawning				Rearing	
		salmon	steelhead[4]	resident trout	native char[5]	fry	juvenile
1	silt, clay, or organic	0.00	0.00	0.00	0.00	0.10	0.10
2	sand	0.00	0.00	0.00	0.00	0.10	0.10
3	sm gravel (.1-.5")	0.30	0.50	0.80	1.00	0.10	0.10
4	med gravel (.5-1.5")	1.00	1.00	1.00	1.00	1.00	0.30
5	lrg gravel (1.5-3")	1.00	1.00	0.80	1.00	1.00	0.30
6	sm cobble (3-6")	1.00	1.00	0.50	0.70	1.00	0.50
7	lrg cobble (6-12")	0.50	0.30	0.00	0.70	1.00	0.70
8	boulder (>12")	0.00	0.00	0.00	0.00	1.00	1.00
9	bedrock	0.00	0.00	0.00	0.00	0.10	0.30

[1] This table reflects average values for the listed species. Site specific preferences would supersede this table.
[2] This includes low tree branches (<3 vertical ft above water surface elevation at stage of zero flow (SZF)) and bushes overhanging the bank-full water's edge.
[3] This category refers to stout, almost bushy type grasses such as reed canary grass up to the bank-full water's edge.
[4] This category includes intermountain and coastal cutthroat (*Oncorhynchus clarki*).
.[5] This category includes Bull Trout (*Salvelinus confluentus*) and Dolly Varden (*S. malma*).

TABLE 2. Complete Salmon Spawning Substrate Preference[1] Table

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.0	Cover codes are not factors for spawning habitat		
00.1			
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
13.9	0.00	0.30	0.00*
17.9	0.00	0.30	0.00*
18.5	0.00	0.00	0.00
21.5	0.00	0.00	0.00
23.9	0.00	0.30	0.00*
27.9	0.00	0.50	0.00*
28.5	0.00	0.00	0.00
29.9	0.00	0.00	0.00
31.5	0.30	0.00	0.00*
31.7	0.30	0.00	0.00*
31.8	0.30	0.00	0.24
31.9	0.30	0.00	0.27
32.5	0.30	0.00	0.00*
32.7	0.30	0.00	0.00*
32.8	0.30	0.00	0.24
32.9	0.30	0.00	0.27
33.9	0.30	0.30	0.30
34.5	0.30	1.00	0.65
34.9	0.30	1.00	0.37
35.5	0.30	1.00	0.65
35.9	0.30	1.00	0.37
36.5	0.30	1.00	0.65
36.9	0.30	1.00	0.37
37.5	0.30	0.50	0.40
37.9	0.30	0.50	0.32
38.5	0.30	0.00	0.15
38.9	0.30	0.00	0.27
39.5	0.30	0.00	0.00*
39.9	0.30	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	0.30	0.65
43.9	1.00	0.30	0.93
44.9	1.00	1.00	1.00
46.9	1.00	1.00	1.00
47.5	1.00	0.50	0.75
47.9	1.00	0.50	0.95
48.5	1.00	0.00	0.5
48.9	1.00	0.00	0.9
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	0.30	0.65
53.9	1.00	0.30	0.93
54.5	1.00	1.00	1.00
56.9	1.00	1.00	1.00
57.5	1.00	0.50	0.75
57.9	1.00	0.50	0.95
58.5	1.00	0.00	0.5
58.9	1.00	0.00	0.9
59.5	1.00	0.00	0.00*
59.9	1.00	0.00	0.00*

[1] Assume straight line between codes. Values are derived from RP equation (see pg. 19).
[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 20).
* Asterisk indicated deviation from the RP formula.

Table 2 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
61.5	1.00	0.00	0.00*
61.7	1.00	0.00	0.00*
61.8	1.00	0.00	0.80
61.9	1.00	0.00	0.90
62.5	1.00	0.00	0.00*
62.7	1.00	0.00	0.00*
62.8	1.00	0.00	0.80
62.9	1.00	0.00	0.90
63.5	1.00	0.30	0.65
63.9	1.00	0.30	0.93
64.5	1.00	1.00	1.00
66.9	1.00	1.00	1.00
67.5	1.00	0.50	0.75
67.9	1.00	0.50	0.95
68.5	1.00	0.00	0.50
68.9	1.00	0.00	0.90
71.7	0.50	0.00	0.00*
71.8	0.50	0.00	0.40
71.9	0.50	0.00	0.45
72.5	0.50	0.00	0.00*
72.7	0.50	0.00	0.00*
72.8	0.50	0.00	0.40
72.9	0.50	0.00	0.45
73.5	0.50	0.30	0.40
73.9	0.50	0.30	0.48
74.5	0.50	1.00	0.75
74.9	0.50	1.00	0.55
75.5	0.50	1.00	0.75
75.9	0.50	1.00	0.55
76.5	0.50	1.00	0.75
76.9	0.50	1.00	0.55
77.9	0.50	0.50	0.50
78.5	0.50	0.00	0.25
78.9	0.50	0.00	0.45
79.5	0.50	0.00	0.00*
79.9	0.50	0.00	0.00*
81.5	0.00	0.00	0.00
82.9	0.00	0.00	0.00
83.5	0.00	0.30	0.00*
87.9	0.00	0.50	0.00*
88.9	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	0.30	0.00*
97.9	0.00	0.50	0.00*
98.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 3. Complete Juvenile Salmon and Trout Cover/Substrate Preference[1] Table

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.1	a & b values are not used to determine cover preference		1.00
00.2			1.00
00.3			1.00
00.4			1.00
00.5			0.80
00.6			0.80
00.7			0.10
00.8			0.70
00.9			0.20
11.9[2]	0.10	0.10	0.10
13.9	0.10	0.10	0.10
14.5	0.10	0.30	0.20
14.9	0.10	0.30	0.12
15.5	0.10	0.30	0.20
15.9	0.10	0.30	0.12
16.5	0.10	0.50	0.30
16.9	0.10	0.50	0.14
17.5	0.10	0.70	0.40
17.9	0.10	0.70	0.16
18.5	0.10	1.00	1.00*
18.9	0.10	1.00	1.00*
19.5	0.10	0.30	0.20
19.9	0.10	0.30	0.12
21.5	0.10	0.10	0.10
23.9	0.10	0.10	0.10
24.5	0.10	0.30	0.20
24.9	0.10	0.30	0.12
25.5	0.10	0.30	0.20
25.9	0.10	0.30	0.12
26.5	0.10	0.50	0.30
26.9	0.10	0.50	0.14
27.5	0.10	0.70	0.40
27.9	0.10	0.70	0.16
28.5	0.10	1.00	1.00*
28.9	0.10	1.00	1.00*
29.5	0.10	0.30	0.20
29.9	0.10	0.30	0.12
31.5	0.10	0.10	0.10
33.9	0.10	0.10	0.10
34.5	0.10	0.30	0.20
34.9	0.10	0.30	0.12
35.5	0.10	0.30	0.20
35.9	0.10	0.30	0.12
36.5	0.10	0.50	0.30
36.9	0.10	0.50	0.14
37.5	0.10	0.70	0.40
37.9	0.10	0.70	0.16
38.5	0.10	1.00	1.00*
38.9	0.10	1.00	1.00*
39.5	0.10	0.30	0.20
39.9	0.10	0.30	0.12
41.5	0.30	0.10	0.20
41.9	0.30	0.10	0.28
42.5	0.30	0.10	0.20
42.9	0.30	0.10	0.28
43.5	0.30	0.10	0.20
43.9	0.30	0.10	0.28
44.9	0.30	0.30	0.30
45.9	0.30	0.30	0.30
46.5	0.30	0.50	0.40
46.9	0.30	0.50	0.32
47.5	0.30	0.70	0.50
47.9	0.30	0.70	0.34
48.5	0.30	1.00	1.00*
48.9	0.30	1.00	1.00*
49.5	0.30	0.30	0.30
49.9	0.30	0.30	0.30
51.5	0.30	0.10	0.20
51.9	0.30	0.10	0.28
52.5	0.30	0.10	0.20
52.9	0.30	0.10	0.28
53.5	0.30	0.10	0.20
53.9	0.30	0.10	0.28
54.5	0.30	0.30	0.30
55.9	0.30	0.30	0.30
56.5	0.30	0.50	0.40
56.9	0.30	0.50	0.32
57.5	0.30	0.70	0.50
57.9	0.30	0.70	0.34

[1] Assume straight line between codes. Values are derived from RP equation (see pg 19).
[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 20).
* Asterisk indicated deviation from the RP formula.

Table 3 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
58.5	0.30	1.00	1.00*
58.9	0.30	1.00	1.00*
59.5	0.30	0.30	0.30
59.9	0.30	0.30	0.30
61.5	0.50	0.10	0.30
61.9	0.50	0.10	0.46
62.5	0.50	0.10	0.30
62.9	0.50	0.10	0.46
63.5	0.50	0.10	0.30
63.9	0.50	0.10	0.46
64.5	0.50	0.30	0.40
64.9	0.50	0.30	0.48
65.5	0.50	0.30	0.40
65.9	0.50	0.30	0.48
66.9	0.50	0.50	0.50
67.5	0.50	0.70	0.60
67.9	0.50	0.70	0.52
68.5	0.50	1.00	1.00*
68.9	0.50	1.00	1.00*
69.5	0.50	0.30	0.40
69.9	0.50	0.30	0.48
71.5	0.70	0.10	0.40
71.9	0.70	0.10	0.64
72.5	0.70	0.10	0.40
72.9	0.70	0.10	0.64
73.5	0.70	0.10	0.40
73.9	0.70	0.10	0.64
74.5	0.70	0.30	0.50
74.9	0.70	0.30	0.66
75.5	0.70	0.30	0.50
75.9	0.70	0.30	0.66
76.5	0.70	0.50	0.60
76.9	0.70	0.50	0.68
77.9	0.70	0.70	0.70
78.5	0.70	1.00	1.00*
78.9	0.70	1.00	1.00*
79.5	0.70	0.30	0.50
79.9	0.70	0.30	0.66
81.5	1.00	0.10	1.00*
87.9	1.00	0.70	1.00*
88.9	1.00	1.00	1.00
89.5	1.00	0.30	1.00*
89.9	1.00	0.30	1.00*
91.5	0.30	0.10	0.20
91.9	0.30	0.10	0.28
92.5	0.30	0.10	0.20
92.9	0.30	0.10	0.28
93.5	0.30	0.10	0.20
93.9	0.30	0.10	0.28
94.5	0.30	0.30	0.30
95.9	0.30	0.30	0.30
96.5	0.30	0.50	0.40
96.9	0.30	0.50	0.32
97.5	0.30	0.70	0.50
97.9	0.30	0.70	0.34
98.5	0.30	1.00	1.00*
98.9	0.30	1.00	1.00*
99.9	0.30	0.30	0.30

TABLE 4. Complete Steelhead (Oncorhynchus mykiss) Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.0	Cover codes are not factors for spawning habitat		
00.1			
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
13.9	0.00	0.50	0.00*
14.5	0.00	1.00	0.00*
16.9	0.00	1.00	0.00*
17.5	0.00	0.30	0.00*
17.9	0.00	0.30	0.00*
18.5	0.00	0.00	0.00
21.5	0.00	0.00	0.00
23.9	0.00	0.50	0.00*
27.9	0.00	0.30	0.00*
28.5	0.00	0.00	0.00
29.9	0.00	0.00	0.00
31.5	0.50	0.00	0.00*
31.7	0.50	0.00	0.00*
31.8	0.50	0.00	0.40
31.9	0.50	0.00	0.45
32.5	0.50	0.00	0.00*
32.7	0.50	0.00	0.00*
32.8	0.50	0.00	0.40
32.9	0.50	0.00	0.45
33.9	0.50	0.50	0.50
34.5	0.50	1.00	0.75
34.9	0.50	1.00	0.55
35.5	0.50	1.00	0.75
35.9	0.50	1.00	0.55
36.5	0.50	1.00	0.75
36.9	0.50	1.00	0.55
37.5	0.50	0.30	0.40
37.9	0.50	0.30	0.48
38.5	0.50	0.00	0.00*
38.9	0.50	0.00	0.00*
39.5	0.50	0.00	0.00*
39.9	0.50	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	0.50	0.75
43.9	1.00	0.50	0.95
44.5	1.00	1.00	1.00
44.9	1.00	1.00	1.00
46.9	1.00	1.00	1.00
47.5	1.00	0.30	0.65
47.9	1.00	0.30	0.93
48.5	1.00	0.00	0.00*
48.9	1.00	0.00	0.00*
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	0.50	0.75
53.9	1.00	0.50	0.95
54.5	1.00	1.00	1.00
56.9	1.00	1.00	1.00
57.5	1.00	0.30	0.65
57.9	1.00	0.30	0.93

[1] Assume straight line between codes. Values are derived from RP equation (see pg 19).
[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 20).
* Asterisk indicated deviation from the RP formula.

Table 4 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
58.5	1.00	0.00	0.00*
58.9	1.00	0.00	0.00*
59.5	1.00	0.00	0.00*
59.9	1.00	0.00	0.00*
61.5	1.00	0.00	0.00*
61.7	1.00	0.00	0.00*
61.8	1.00	0.00	0.80
61.9	1.00	0.00	0.90
62.5	1.00	0.00	0.00*
62.7	1.00	0.00	0.00*
62.8	1.00	0.00	0.80
62.9	1.00	0.00	0.90
63.5	1.00	0.50	0.75
63.9	1.00	0.50	0.95
64.5	1.00	1.00	1.00
66.9	1.00	1.00	1.00
67.5	1.00	0.30	0.65
67.9	1.00	0.30	0.93
68.5	1.00	0.00	0.00*
68.9	1.00	0.00	0.00*
69.5	1.00	0.00	0.00*
69.9	1.00	0.00	0.00*
71.5	0.30	0.00	0.00*
71.7	0.30	0.00	0.00*
71.8	0.30	0.00	0.24
71.9	0.30	0.00	0.27
72.5	0.30	0.00	0.00*
72.7	0.30	0.00	0.00*
72.8	0.30	0.00	0.24
72.9	0.30	0.00	0.27
73.5	0.30	0.50	0.40
73.9	0.30	0.50	0.32
74.5	0.30	1.00	0.65
74.9	0.30	1.00	0.37
75.5	0.30	1.00	0.65
75.9	0.30	1.00	0.37
76.5	0.30	1.00	0.65
76.9	0.30	1.00	0.37
77.5	0.30	0.30	0.30
77.9	0.30	0.30	0.30
78.5	0.30	0.00	0.00*
78.9	0.30	0.00	0.00*
79.5	0.30	0.00	0.00*
79.9	0.30	0.00	0.00*
81.5	0.00	0.00	0.00*
82.9	0.00	0.00	0.00*
83.5	0.00	0.50	0.00*
83.9	0.00	0.50	0.00*
84.5	0.00	1.00	0.00*
86.9	0.00	1.00	0.00*
87.5	0.00	0.30	0.00*
87.9	0.00	0.30	0.00*
88.5	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	0.50	0.00*
93.9	0.00	0.50	0.00*
94.5	0.00	1.00	0.00*
96.9	0.00	1.00	0.00*
97.5	0.00	0.30	0.00*
97.9	0.00	0.30	0.00*
98.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 5. Complete Generic Trout Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.1	Cover codes are not factors for spawning habitat		
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
13.9	0.00	0.80	0.00*
14.5	0.00	1.00	0.00*
14.9	0.00	1.00	0.00*
15.5	0.00	0.80	0.00*
15.9	0.00	0.80	0.00*
16.5	0.00	0.50	0.00*
16.9	0.00	0.50	0.00*
17.5	0.00	0.00	0.00
21.5	0.00	0.00	0.00
23.9	0.00	0.80	0.00*
24.5	0.00	1.00	0.00*
24.9	0.00	1.00	0.00*
25.5	0.00	0.80	0.00*
25.9	0.00	0.80	0.00*
26.5	0.00	0.50	0.00*
26.9	0.00	0.50	0.00*
27.5	0.00	0.00	0.00
29.9	0.00	0.00	0.00
31.5	0.80	0.00	0.00*
31.7	0.80	0.00	0.00*
31.8	0.80	0.00	0.64
31.9	0.80	0.00	0.72
32.5	0.80	0.00	0.00*
32.7	0.80	0.00	0.00*
32.8	0.80	0.00	0.64
32.9	0.80	0.00	0.72
33.9	0.80	0.80	0.80
34.5	0.80	1.00	0.90
34.9	0.80	1.00	0.82
35.5	0.80	0.80	0.80
35.9	0.80	0.80	0.80
36.5	0.80	0.50	0.65
36.9	0.80	0.50	0.77
37.5	0.80	0.00	0.00*
37.9	0.80	0.00	0.00*
38.5	0.80	0.00	0.00*
38.9	0.80	0.00	0.00*
39.5	0.80	0.00	0.00*
39.9	0.80	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	0.80	0.90
43.9	1.00	0.80	0.98
44.9	1.00	1.00	1.00
45.5	1.00	0.80	0.90
45.9	1.00	0.80	0.98
46.5	1.00	0.50	0.75
46.9	1.00	0.50	0.95
47.5	1.00	0.00	0.00*
47.9	1.00	0.00	0.00*
48.5	1.00	0.00	0.00*
48.9	1.00	0.00	0.00*
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	0.80	0.00	0.00*
51.7	0.80	0.00	0.00*
51.8	0.80	0.00	0.64
51.9	0.80	0.00	0.72
52.5	0.80	0.00	0.00*
52.7	0.80	0.00	0.00*
52.8	0.80	0.00	0.64
52.9	0.80	0.00	0.72
53.5	0.80	0.80	0.80
53.9	0.80	0.80	0.80

[1] Assume straight line between codes. Values are derived from RP equation (see pg 19).
[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 20).
* Asterisk indicated deviation from the RP formula.

TABLE 5 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
54.5	0.80	1.00	0.90
54.9	0.80	1.00	0.82
55.9	0.80	0.80	0.80
56.5	0.80	0.50	0.65
56.9	0.80	0.50	0.77
57.5	0.80	0.00	0.00*
57.9	0.80	0.00	0.00*
58.5	0.80	0.00	0.00*
58.9	0.80	0.00	0.00*
59.5	0.80	0.00	0.00*
59.9	0.80	0.00	0.00*
61.5	0.50	0.00	0.00*
61.7	0.50	0.00	0.00*
61.8	0.50	0.00	0.40
61.9	0.50	0.00	0.45
62.5	0.50	0.00	0.00*
62.7	0.50	0.00	0.00*
62.8	0.50	0.00	0.40
62.9	0.50	0.00	0.45
63.5	0.50	0.80	0.65
63.9	0.50	0.80	0.53
64.5	0.50	1.00	0.75
64.9	0.50	1.00	0.55
65.5	0.50	0.80	0.65
65.9	0.50	0.80	0.53
66.9	0.50	0.50	0.50
67.5	0.50	0.00	0.00*
67.9	0.50	0.00	0.00*
68.5	0.50	0.00	0.00*
68.9	0.50	0.00	0.00*
69.5	0.50	0.00	0.00*
69.9	0.50	0.00	0.00*
71.5	0.00	0.00	0.00
72.9	0.00	0.00	0.00
73.5	0.00	0.80	0.00*
73.9	0.00	0.80	0.00*
74.5	0.00	1.00	0.00*
74.9	0.00	1.00	0.00*
75.5	0.00	0.80	0.00*
75.9	0.00	0.80	0.00*
76.5	0.00	0.50	0.00*
76.9	0.00	0.50	0.00*
77.9	0.00	0.00	0.00
82.9	0.00	0.00	0.00
83.5	0.00	0.80	0.00*
83.9	0.00	0.80	0.00*
84.5	0.00	1.00	0.00*
84.9	0.00	1.00	0.00*
85.5	0.00	0.80	0.00*
85.9	0.00	0.80	0.00*
86.5	0.00	0.50	0.00*
86.9	0.00	0.50	0.00*
87.5	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	0.80	0.00*
93.9	0.00	0.80	0.00*
94.5	0.00	1.00	0.00*
94.9	0.00	1.00	0.00*
95.5	0.00	0.80	0.00*
95.9	0.00	0.80	0.00*
96.5	0.00	0.50	0.00*
96.9	0.00	0.50	0.00*
97.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 6. Complete Bull Trout (Salvelinus confluentus) and Dolly Varden (S. malma) Spawning Substrate Preference[1]

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
00.1	Cover codes are not factors for spawning habitat		
00.2			
00.3			
00.4			
00.5			
00.6			
00.7			
00.8			
00.9			
11.9[2]	0.00	0.00	0.00
31.7	1.00	0.00	0.00*
31.8	1.00	0.00	0.80
31.9	1.00	0.00	0.90
32.5	1.00	0.00	0.00*
32.7	1.00	0.00	0.00*
32.8	1.00	0.00	0.80
32.9	1.00	0.00	0.90
33.9	1.00	1.00	1.00
35.9	1.00	1.00	1.00
36.5	1.00	0.70	0.85
36.9	1.00	0.70	0.97
37.5	1.00	0.70	0.85
37.9	1.00	0.70	0.97
38.5	1.00	0.00	0.50
38.9	1.00	0.00	0.90
39.5	1.00	0.00	0.00*
39.9	1.00	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	1.00	1.00
45.9	1.00	1.00	1.00
46.5	1.00	0.70	0.85
46.9	1.00	0.70	0.97
47.5	1.00	0.70	0.85
47.9	1.00	0.70	0.97
48.5	1.00	0.00	0.50
48.9	1.00	0.00	0.90
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	1.00	1.00
55.9	1.00	1.00	1.00
56.5	1.00	0.70	0.85
56.9	1.00	0.70	0.97
57.5	1.00	0.70	0.85
57.9	1.00	0.70	0.97
58.5	1.00	0.70	0.85
58.9	1.00	0.70	0.97
59.5	1.00	0.00	0.00*
59.9	1.00	0.00	0.00*
61.5	0.70	0.00	0.00*
61.7	0.70	0.00	0.00*
61.8	0.70	0.00	0.56
61.9	0.70	0.00	0.63
62.5	0.70	0.00	0.00*
62.7	0.70	0.00	0.00*
62.8	0.70	0.00	0.56
62.9	0.70	0.00	0.63
63.5	0.70	1.00	0.85
63.9	0.70	1.00	0.73
64.5	0.70	1.00	0.85
64.9	0.70	1.00	0.73
65.5	0.70	1.00	0.85
65.9	0.70	1.00	0.73
66.9	0.70	0.70	0.70

[1] Assume straight line between codes. Values are derived from RP equation (see pg 19).
[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 20).
* Asterisk indicated deviation from the RP formula.

Table 6 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
67.9	0.70	0.70	0.70
68.5	0.70	0.00	0.35
68.9	0.70	0.00	0.63
69.5	0.70	0.00	0.00*
71.5	0.70	0.70	0.00*
71.7	0.70	0.00	0.00*
71.8	0.70	0.00	0.56
71.9	0.70	0.00	0.63
72.5	0.70	0.00	0.00*
72.7	0.70	0.00	0.00*
72.8	0.70	0.00	0.56
72.9	0.70	0.00	0.63
73.5	0.70	1.00	0.85
73.9	0.70	1.00	0.73
74.5	0.70	1.00	0.85
74.9	0.70	1.00	0.73
75.5	0.70	1.00	0.85
75.9	0.70	1.00	0.73
76.5	0.70	0.70	0.70
76.9	0.70	0.70	0.70
77.9	0.70	0.70	0.70
78.5	0.70	0.00	0.35
78.9	0.70	0.00	0.63
79.5	0.70	0.00	0.00*
79.9	0.70	0.00	0.00*
81.5	0.00	0.00	0.00*
82.9	0.00	0.00	0.00*
83.5	0.00	1.00	0.50
83.9	0.00	1.00	0.10
84.5	0.00	1.00	0.50
84.9	0.00	1.00	0.10
85.5	0.00	1.00	0.50
85.9	0.00	1.00	0.10
86.5	0.00	0.70	0.35
86.9	0.00	0.70	0.07
87.5	0.00	0.70	0.35
87.9	0.00	0.70	0.07
88.9	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	1.00	0.00*
99.9	0.00	0.00	0.00

TABLE 7. Chum Salmon (O. keta) Spawning Substrate Preference Data
Kennedy Creek, Duckabush and Dosewallips rivers (8 studies, 138 redds). For the full table of 3 digit codes, use Table 2.

Dominant substrate	Calculated preference	Recommended Preference
1 silt	0.08-0.18	0.00
2 sand	0.08-0.49	0.00
3 small gravel	0.49-0.76	0.30
4 medium gravel	0.76-1.00	1.00
5 large gravel	0.72-1.00	1.00
6 small cobble	0.62-0.90	1.00
7 large cobble	0.24-0.62	0.50
8 boulder	0.00-0.35	0.00
9 bedrock	no data	0.00

TABLE 8. Coho Salmon (O. kisutch) Spawning Substrate Preference Data
Dewatto River and Fletcher Canyon Creek (2 studies, 30 redds). For the full table of 3 digit codes, use Table 2.

Dominant substrate	Calculated preference	Recommended Preference
1 silt	0.00	0.00
2 sand	0.06	0.00
3 small gravel	0.06-1.00	0.30
4 medium gravel	0.25-0.61	1.00
5 large gravel	0.61-0.93	1.00
6 small cobble	0.93	1.00
7 large cobble	0.18-0.93	0.50
8 boulder	0.18	0.00
9 bedrock	0.18	0.00

TABLE 9. Pink Salmon (O. gorbuscha) Spawning Substrate Preference Data
Squire Creek, N. Fork Stillaguamish, Dosewallips, and Duckabush rivers (3 studies, 46 redds). For the full table of 3 digit codes, use Table 2.

Dominant substrate	Calculated preference	Recommended Preference
1 silt	0.00	0.00
2 sand	0.00-0.60	0.00
3 small gravel	0.60-0.74	0.30
4 medium gravel	0.74-1.00	1.00
5 large gravel	0.77-1.00	1.00
6 small cobble	0.28-0.93	1.00
7 large cobble	0.00-0.28	0.50
8 boulder	0.00	0.00
9 bedrock	no data	0.00

TABLE 10. Sockeye Salmon (O. nerka) Spawning Substrate Preference Data.
Cedar River & Big Creek (Quinault Basin) (4 studies, 1053 redds). For the full table of 3 digit codes, use Table 2.

Dominant substrate	Calculated preference	Recommended Preference
1-silt	0.00	0.00
2-sand	0.00	0.00
3-small gravel	0..20-0.30	0.30
4-medium gravel	0.60-1.00	1.00
5-large gravel	1.00	1.00
6-small cobble	0.20-1.00	1.00
7-large cobble	0.00-0.20	0.50
8-boulder	no data	0.00
9-bedrock	no data	0.00

TABLE 11. Bull Trout (S. confluentus) and Dolly Varden (S. malma) Spawning Substrate Preference Data.
Based on 4 streams, 34 redds. For the full table of 3 digit codes, use Table 7.

Dominant substrate	Calculated preference	Recommended Preference
1-silt	NA	0.00
2-sand	0.00-1.00	0.00
3-small gravel	0.20-1.00	1.00
4-medium gravel	0.60-1.00	1.00
5-large gravel	1.00	1.00
6-small cobble	1.00	0.70
7-large cobble	0.45	0.70
8-boulder	0.00	0.00
9-bedrock	0.00	0.00

TABLE 12. Cutthroat Trout (O. clarki) Spawning Substrate Preference. Not yet finalized

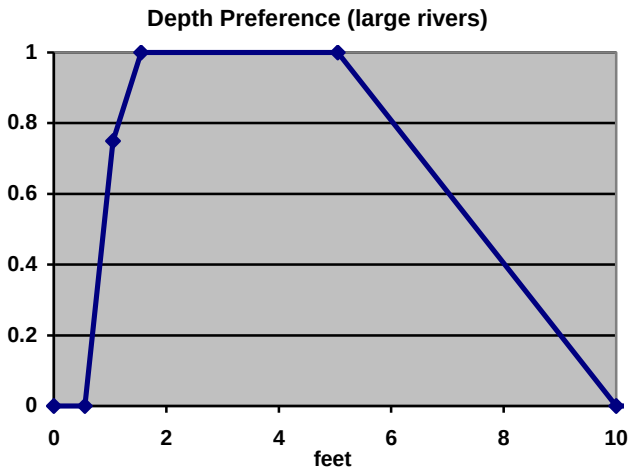
TABLE 13. Preference Factors for Ratios of Turbulence
Plume to Calm, Deep Area in Plunge Pool Method (from page 15)

Ratio (plume to calm, deep)	**Preference Factor**
0.0	**0.10**
0.25	**0.40**
0.5	**0.80**
1.0	**1.00**
2.0	**0.50**
4.0	**0.25**
8.0	**0.125**
16.0	**0.06**
32.0	**0.03**

FIGURE 1a. Chinook Salmon (Oncorhynchus tshawytscha) Large River Spawning Depth Preference

For all stocks: Use Large rivers when mean annual flow (MAF) >3,000 cfs (Analysis based on Caldwell et al 1987. Use Columbia – Snake when MAF > 100,000 cfs (Hanrahan et al. 2004). **Preference has changed from the 2004 edition.**

Plotted depth (feet)	Recommended depth preference	
	large rivers	Columbia – Snake
0.00	0.0	0.0
0.55	0.0	-
1.05	0.75	-
1.55	1.0	0.0
5.05	1.0	0.4
8.15		1.0
10	0.0	-
30	0.0	1.0
35	0.0	0.0



For Chinook Salmon Spawning Substrate Preference, use Table 2.

HSC notes: Large river examples include the Skagit and Snohomish rivers. If your stream is close to the 3000 cfs break point, please contact Ecology or WDFW biologists for help in selecting the proper curve.

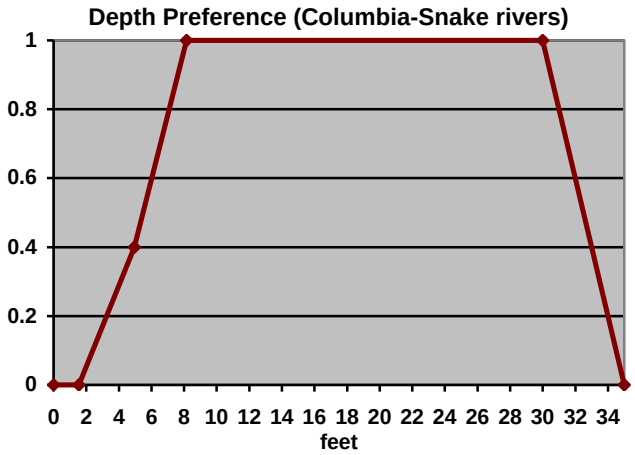
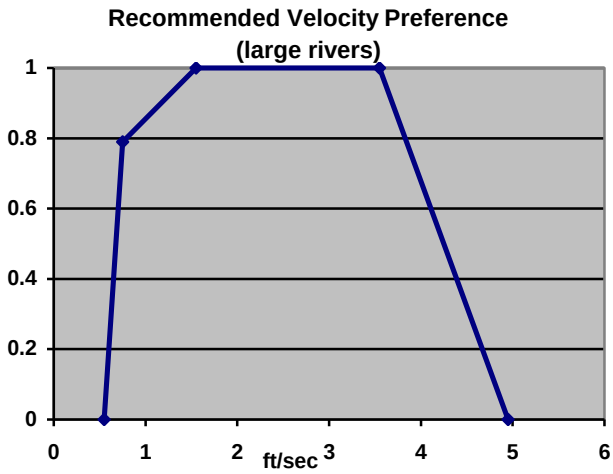
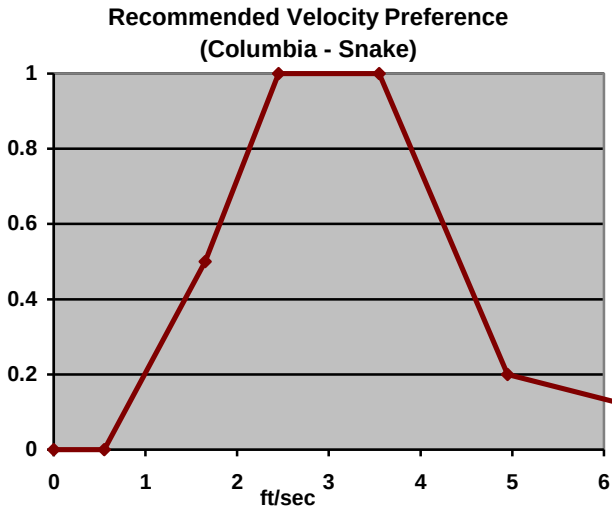


FIGURE 1b. Chinook Salmon Large River Spawning Velocity Preference
For all stocks: Use large rivers when MAF >3,000 cfs (Analysis based on Caldwell et al 1987).
Use Columbia – Snake when MAF > 100,000 cfs (Hanrahan, Dauble and Geist 2004).
Preference has changed from 2004.

Plotted velocity (ft/sec)	Recommended velocity suitability	
	large rivers	Columbia – Snake
0.00	0.0	0.0
0.35	-	0.0
0.55	0.0	-
0.75	0.79	-
1.55	1.0	
1.65		0.50
2.45	-	1.0
3.55	1.0	1.0
4.95	0.0	0.2
6.55	0.0	0.1
7.0+	0.0	0



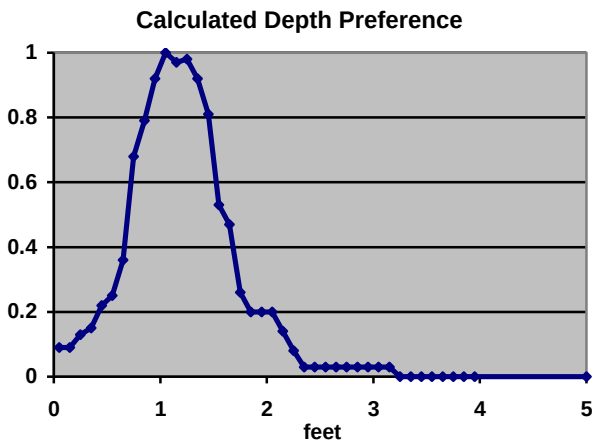


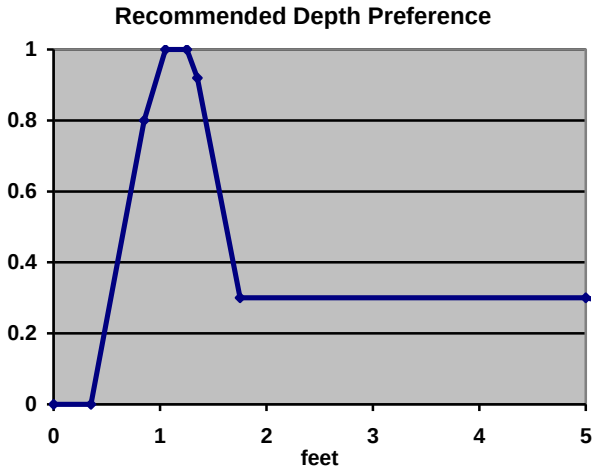
HSC notes: Large river examples include the Skagit and Snohomish rivers. If your stream is close to the 3000 cfs break point, please contact Ecology or WDFW biologists for help in selecting the proper curve.

For Chinook Salmon Spawning Substrate Preference, use Table 2.

FIGURE 2a. Chinook Salmon Stream and River Spawning Depth Preference
For all stocks: Streams and rivers have a MAF <3,000 cfs. Analysis based on 5 studies and 165 redds (West Fork Humptulips, American, Yakima, Little Naches and upper Chehalis rivers).
Preference has changed from the 2004 edition.

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.09	0.00	0.00
0.20-0.29	0.13	0.35	0.00
0.30-0.39	0.15	0.85	0.80
0.40-0.49	0.22	1.05	1.0
0.50-0.59	0.25	1.25	1.0
0.60-0.69	0.36	1.35	0.92
0.70-0.79	0.68	1.75	0.3
0.80-0.89	0.79	5.0	0.3
0.90-0.99	0.92	10+	0
1.00-1.09	1.0		
1.10-1.19	0.97		
1.20-1.29	0.98		
1.30-1.39	0.92		
1.40-1.49	0.81		
1.50-1.59	0.53		
1.60-1.69	0.47		
1.70-1.79	0.26		
1.80-2.09	0.20		
2.10-2.19	0.14		
2.20-2.29	0.08		
2.30-3.19	0.03		
3.35-5.0+	0.0		



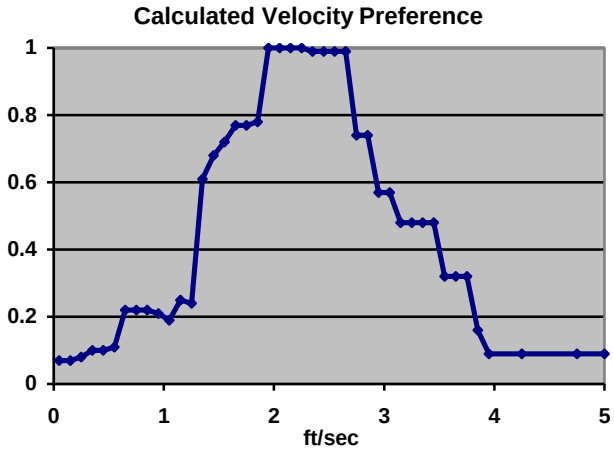


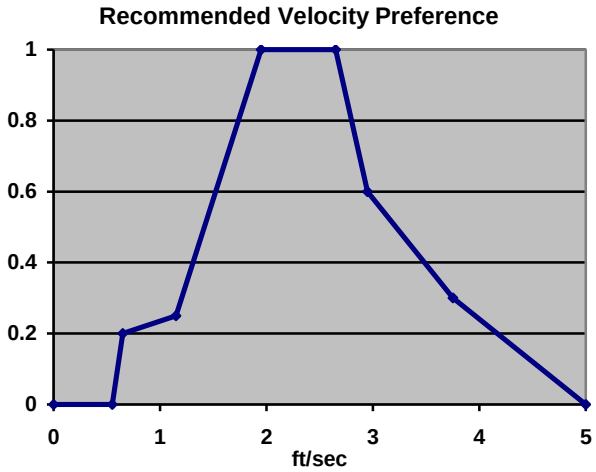
HSC notes: The calculated preference from 0.0 to 0.39 ft was based on averages from the binning process, not observations. We decided use a 0.0 preference from 0.0 to 0.35 ft. to reflect a physical minimum depth needed for spawning fish. The calculated preference decrease reduction after 1.7 ft comes from studies with high preference dropping to 0.0 due to a lack of habitat availability. We chose to maintain a 0.30 preference out to 5' then reduced it to 0.0 at 10'.

For Chinook Salmon Spawning Substrate Preference, use Table 2.

FIGURE 2b. Chinook Salmon Stream and River Spawning Velocity Preference
For all stocks: Streams and rivers have a MAF <3,000 cfs. Analysis based on 5 studies and 164 redds (West Fork Humptulips, American, Yakima, Little Naches and upper Chehalis rivers).
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.19	0.07	0.00	0.00
0.20-0.29	0.08	0.55	0.00
0.30-0.49	0.10	0.65	0.2
0.50-0.59	0.11	1.15	0.25
0.60-0.89	0.22	1.95	1.0
0.90-0.99	0.21	2.65	1.0
1.00-1.09	0.19	2.95	0.60
1.10-1.19	0.25	3.75	0.30
1.20-1.29	0.24	5.0	0
1.30-1.39	0.61		
1.40-1.49	0.68		
1.50-1.59	0.72		
1.60-1.79	0.77		
1.80-1.89	0.78		
1.90-2.29	1.0		
2.30-2.69	0.99		
2.70-2.89	0.74		
2.90-3.09	0.57		
3.10-3.49	0.48		
3.50-3.79	0.32		
3.80-3.89	0.16		
3.90-5.0	0.09		



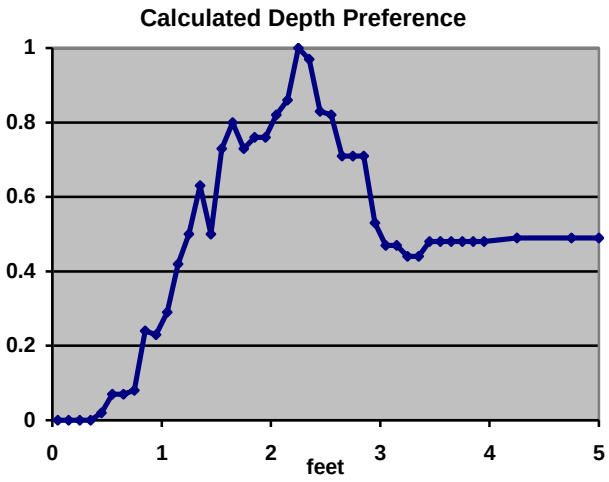


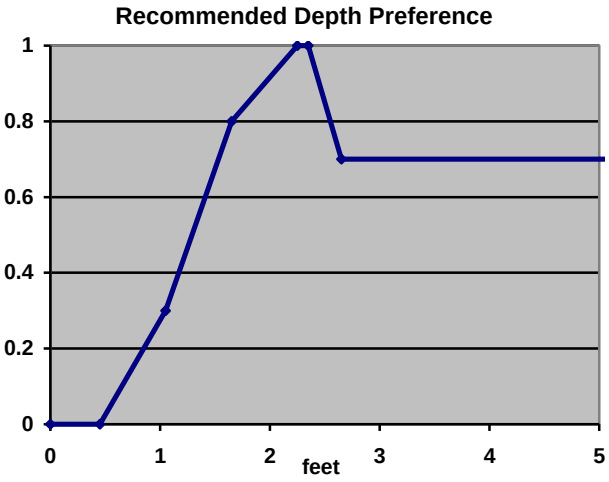
HSC notes: The calculated preference from 0.0 to 0.59 ft was based on statistics, not observations. We decided use a 0.0 preference from 0.0 to 0.55 ft.

For Chinook Salmon Spawning Substrate Preference, use Table 2.

FIGURE 3a. Chinook Salmon Juvenile Rearing Depth Preference
Analysis based on 8 studies (Dungeness, Chiwawa, Mad & Similkameen, and Tucannon Rivers and Kendall Creek) and 5585 fish. Kendal Creek was a utilization study with 5055 observations. **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.39	0.00	0.00	0.00
0.40-0.49	0.02	0.45	0.00
0.50-0.69	0.07	1.05	0.30
0.70-0.79	0.08	1.65	0.80
0.80-0.89	0.24	2.25	1.00
0.90-0.99	0.23	2.35	1.00
1.00-1.09	0.29	2.65	0.70
1.10-1.19	0.42	10.0	0.70
1.20-1.29	0.50	30+	0.0
1.30-1.39	0.63		
1.40-1.49	0.50		
1.50-1.59	0.73		
1.60-1.69	0.80		
1.70-1.79	0.73		
1.80-1.99	0.76		
2.00-2.09	0.82		
2.10-2.19	0.86		
2.20-2.29	1.0		
2.30-2.39	0.97		
2.40-2.49	0.83		
2.50-2.59	0.82		
2.60-2.89	0.71		
2.90-2.99	0.53		
3.00-3.19	0.47		
3.20-3.39	0.44		
3.40-3.99	0.48		
4.00-5.0	0..49		



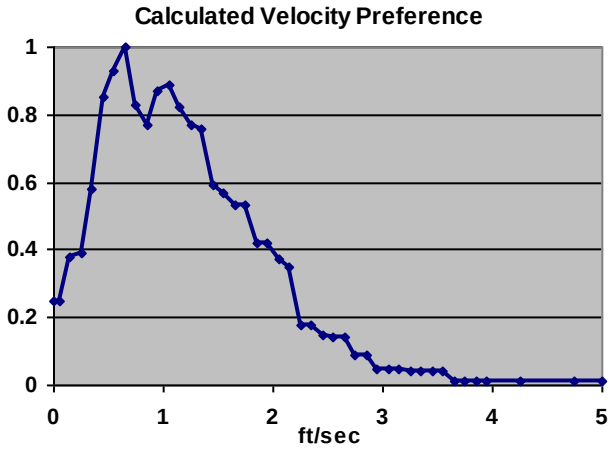


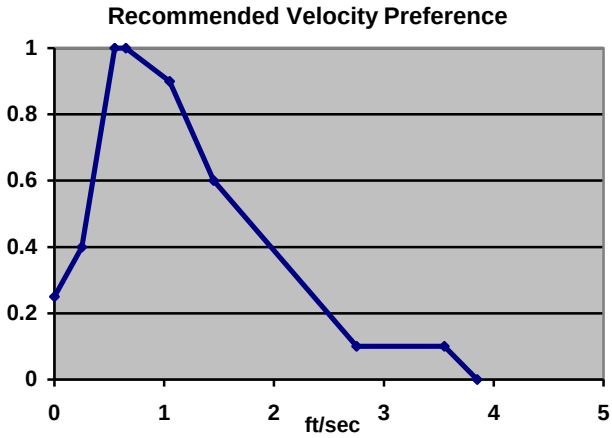
For Chinook Salmon Juvenile Rearing Cover/Substrate Preference, use Table 3.

HSC Notes: The calculated preference decrease reduction after 2.8 ft comes from studies with high preference dropping out due to a lack of habitat availability. We chose to maintain a preference of 0.70 out to 10.0' then reduced it to 0.0 at 30'.

FIGURE 3b. Chinook Salmon Juvenile Rearing Velocity Preference
Analysis based on 8 studies (Dungeness, Chiwawa, Mad & Similkameen, & Tucannon Rivers and Kendal Creek) and 5556 fish. Kendal Creek was a utilization study with 5025 observations.
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.25	0.00	0.25
0.10-0.19	0.38	0.25	0.40
0.20-0.29	0.39	0.55	1.0
0.30-0.39	0.58	0.65	1.0
0.40-0.49	0.85	1.05	0.90
0.50-0.59	0.93	1.45	0.60
0.60-0.69	1.0	2.75	0.10
0.70-0.79	0.83	3.55	0.10
0.80-0.89	0.77	3.85	0.0
0.90-0.99	0.87		
1.00-1.09	0.89		
1.10-1.19	0.82		
1.20-1.29	0.77		
1.30-1.59	0.76		
1.60-1.79	0.83		
1.80-1.99	0.42		
2.00-2.09	0.37		
2.10-2.19	0.35		
2.25-2.39	0.18		
2.40-2.49	0.15		
2.50-2.69	0.14		
2.70-2.89	0.09		
2.90-3.19	0.05		
3.20-3.59	0.04		
3.60-5.0	0.01		

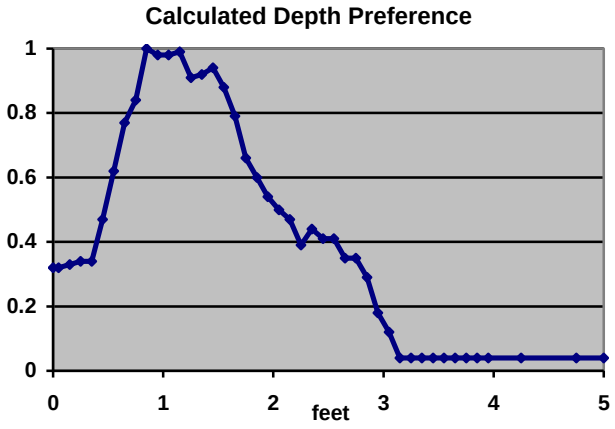


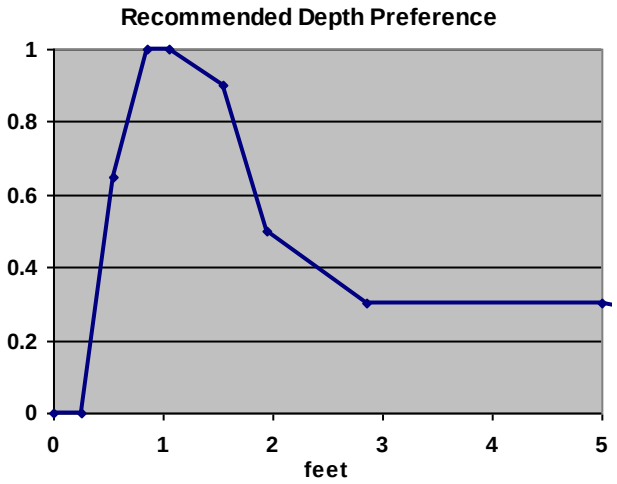


For Chinook Salmon Juvenile Rearing Cover/Substrate Preference, use Table 3.

FIGURE 4a. Coho Salmon (*O. kisutch*) Spawning Depth Preference
Analysis based on 5 studies and 66 redds (Fletcher Canyon and Irely creeks, and Humptulips and Dewatto rivers). **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth Preference
0.00-0.09	0.32	0.00	0.0
0.10-0.19	0.35	0.25	0.0
0.20-0.39	0.34	0.55	0.65
0.40-0.49	0.47	0.85	1.0
0.50-0.59	0.62	1.05	1.0
0.60-0.69	0.77	1.55	0.90
0.70-0.79	0.84	1.95	0.50
0.80-0.89	1.0	2.85	0.30
0.90-1.09	0.98	5	0.30
1.10-1.19	0.99	10	0
1.20-1.29	0.91		
1.30-1.39	0.92		
1.40-1.49	0.94		
1.50-1.59	0.88		
1.60-1.69	0.79		
1.70-1.79	0.66		
1.80-1.89	0.60		
1.90-1.99	0.54		
2.00-2.09	0.50		
2.10-2.19	0.47		
2.20-2.29	0.39		
2.30-2.39	0.44		
2.40-2.59	0.41		
2.60-2.79	0.35		
2.80-2.89	0.29		
2.90-2.99	0.18		
3.00-3.09	0.12		
3.10-5.0	0.04		



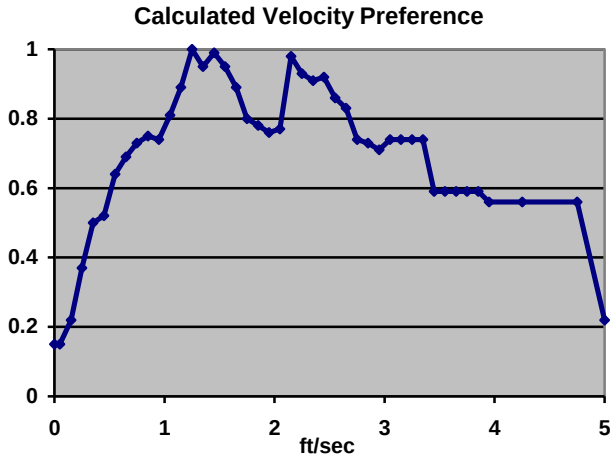


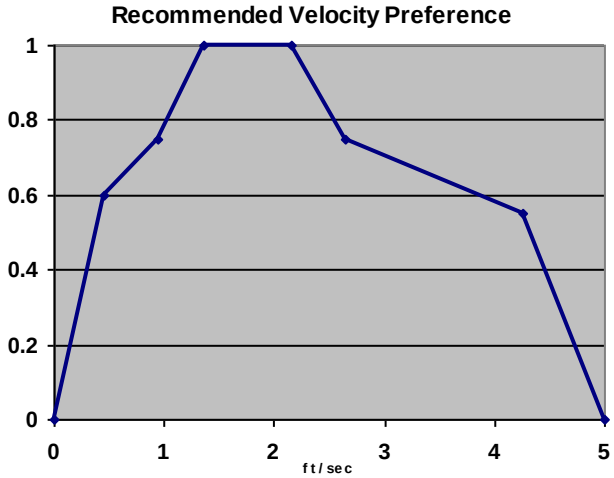
For Coho Salmon Spawning Substrate Preference, use Table 2. See Table 8 for calculated preference information

HSC Notes: The calculated preference decrease reduction after 2.85 ft comes from a study with 1.0 preference dropping to 0.0 due to a lack of habitat availability. We chose to maintain 0.30 preference out to 5' and then reduced it to 0.0 at 10'.

FIGURE 4b. Coho Salmon Spawning Velocity Preference
Analysis based on 5 studies and 66 redds (Fletcher Canyon and Irely creeks, and Humptulips and Dewatto rivers). **Preference has changed from the 2004 edition.**

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Velocity interval (ft/sec)	Velocity preference
0.00 0.09	0.15	0.00	0.0
0.10-0.19	0.22	0.45	0.60
0.20-0.29	0.37	0.95	0.75
0.30-0.39	0.50	1.25	1.0
0.40-0.49	0.52	2.15	1.0
0.50-0.59	0.64	2.65	0.75
0.60-0.69	0.69	4.25	0.55
0.70-0.79	0.73	5.0	0.0
0.80-0.89	0.75	7.0	0.0
0.90-0.99	0.74		
1.00-1.09	0.81		
1.10-1.19	0.89		
1.20-1.29	1.0		
1.30-1.39	0.95		
1.40-1.49	0.99		
1.50-1.59	0.95		
1.60-1.69	0.89		
1.70-1.79	0.80		
1.80-1.89	0.78		
1.90-1.99	0.76		
2.00-2.09	0.77		
2.10-2.19	0.98		
2.20-2.29	0.93		
2.30-2.39	0.91		
2.40-2.49	0.82		
2.50-2.59	0.86		
2.60-2.69	0.83		
2.70-2.79	0.74		
2.80-2.89	0.73		
2.90-2.99	0.71		
3.00-3.39	0.74		
3.40-3.89	0.59		
3.90-4.95	0.56		
5.0	0.22		





For Coho Salmon Spawning Substrate Preference, use Table 2. See Table 8 for calculated preference information

HSC notes: The bimodal peaks come in part from small vs. large stream differences. Unfortunately there were not enough studies to test for statistical significance.

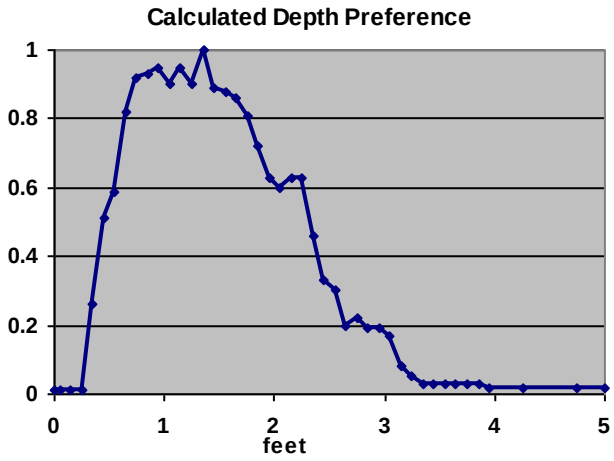
Coho Salmon Juvenile Depth Preference (No Longer Recommended)
Coho Salmon Juvenile Velocity Preference (No Longer Recommended)
Analysis based on 4 studies and 451 fish (Dungeness, Satsop Rivers and Kenedy Creek) and (Beecher, et al. 2010).

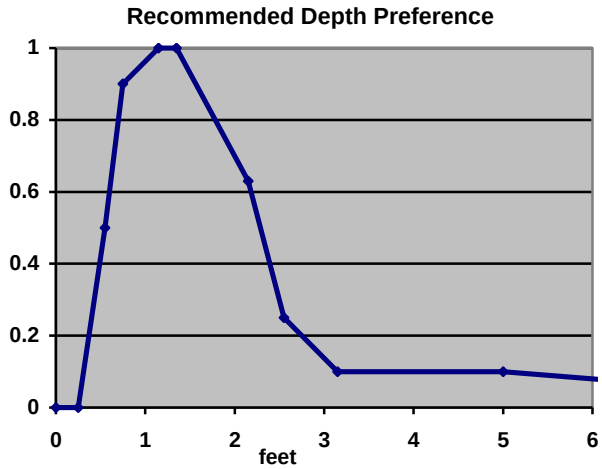
Previous versions of the Instream Flow Study Guidelines provided default coho juvenile depth and velocity curves based on Beecher et al 2002. Subsequent research has shown that despite validation of the habitat suitability criteria and hydraulic model, the stream flow relating to peak coho rearing habitat did not resemble the stream flow relating to increased coho salmon production (Beecher et al 2010).

Based on this new research we have removed the coho rearing curves and do not recommend using coho rearing HSC curves when analyzing an instream flow study.

FIGURE 5a. Fall Chum salmon (*O. keta*) Spawning Depth Preference
Analysis based on 8 studies and 109 redds (Hill & Kennedy creeks and Duckabush River).
Preference has changed from the 2004 edition.

Fall chum: spawning from Nov-Jan			
Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted Depth (feet)	Depth preference
0.00-0.29	0.01	0.00	0.00
0.30-0.39	0.26	0.25	0.00
0.40-0.49	0.51	0.55	0.50
0.50-0.59	0.59	0.75	0.90
0.60-0.69	0.82	1.15	1.00
0.70-0.79	0.92	1.35	1.00
0.80-0.89	0.93	2.15	0.63
0.90-0.99	0.95	2.55	0.25
1.00-1.09	0.90	3.15	0.10
1.10-1.19	0.95	4.95	0.10
1.20-1.29	0.90	10.0	0.0
1.30-1.39	1.0		
1.40-1.49	0.89		
1.50-1.59	0.88		
1.60-1.69	0.86		
1.70-1.79	0.81		
1.80-1.89	0.72		
1.90-1.99	0.63		
2.00-2.09	0.60		
2.10-2.29	0.63		
2.30-2.39	0.46		
2.40-2.49	0.33		
2.50-2.59	0.30		
2.60-2.69	0.20		
2.70-2.79	0.22		
2.80-2.99	0.19		
3.00-3.09	0.17		
3.10-3.19	0.08		
3.20-3.29	0.05		
3.30-3.89	0.03		
3.90-5.0	0.02		



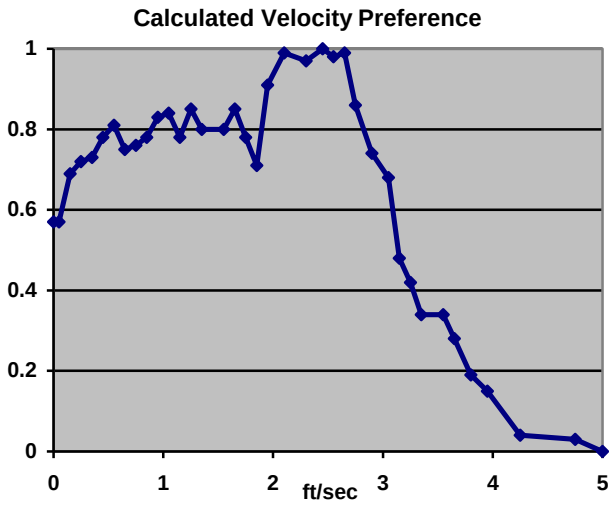


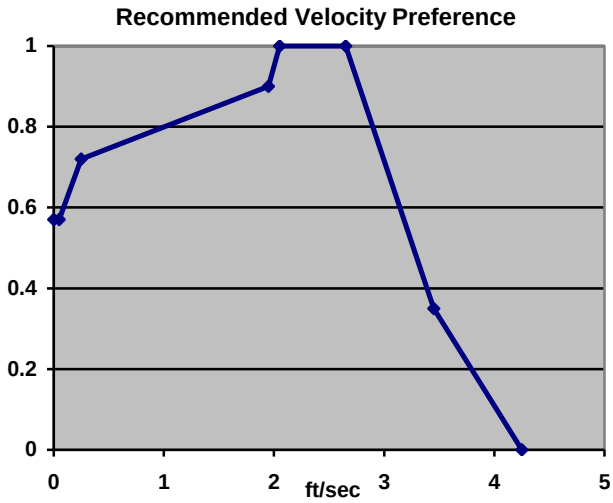
HSC Notes: We found some differences between small and large streams, but there were not enough small stream (<35' LBTW) studies to test for statistical significance. For depth preference after 3.15 ft we chose to maintain a 0.10 preference out to 5' then reduce it to 0.0 at 10'.

For Fall Chum Salmon Spawning Substrate Preference, use Table 2. See Table 7 for calculated preference information.

FIGURE 5b. Fall Chum Salmon Spawning Velocity Preference
Analysis based on 8 studies and 109 redds (Hill & Kennedy creeks and Duckabush River).
Preference has changed from the 2004 edition.

Fall chum: spawns from Nov to Jan			
Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted Velocity (ft/sec)	Velocity preference
0.00-0.09	0.57	0.00	0.57
0.10-0.19	0.69	0.05	0.57
0.20-0.29	0.72	0.25	0.72
0.30-0.39	0.73	1.95	0.90
0.4-0.49	0.78	2.05	1.0
0.5-0.59	0.81	2.65	1.0
0.6-0.69	0.75	3.45	0.35
0.7-0.79	0.76	4.25	0.00
0.8-0.89	0.78	10+	0.00
0.9-0.99	0.83		
1.0-1.09	0.84		
1.1-1.19	0.78		
1.2-1.29	0.85		
1.3-1.59	0.80		
1.6-1.69	0.85		
1.7-1.79	0.78		
1.8-1.89	0.71		
1.9-1.99	0.91		
2.0-2.19	0.99		
2.2-2.39	0.97		
2.4-2.49	1.00		
2.5-2.59	0.98		
2.6-2.69	0.99		
2.7-2.79	0.86		
2.8-2.99	0.74		
3.0-3.09	0.68		
3.1-3.19	0.48		
3.2-3.29	0.42		
3.3-3.59	0.34		
3.6-3.69	0.28		
3.7-3.89	0.19		
3.9-3.99	0.15		
4.0-4.49	0.04		
4.5-4.99	0.03		
5.0	0		

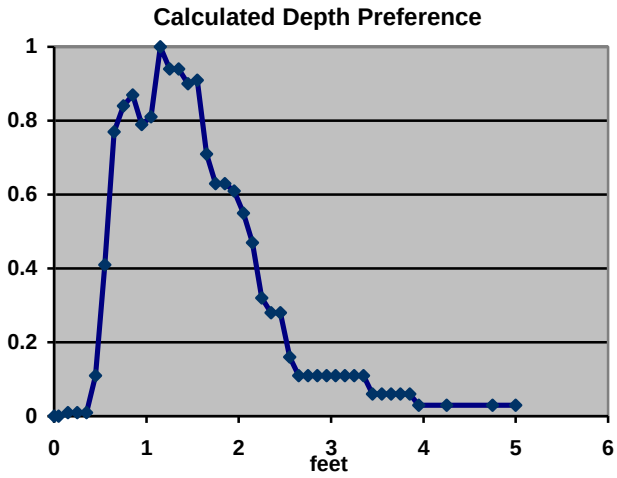


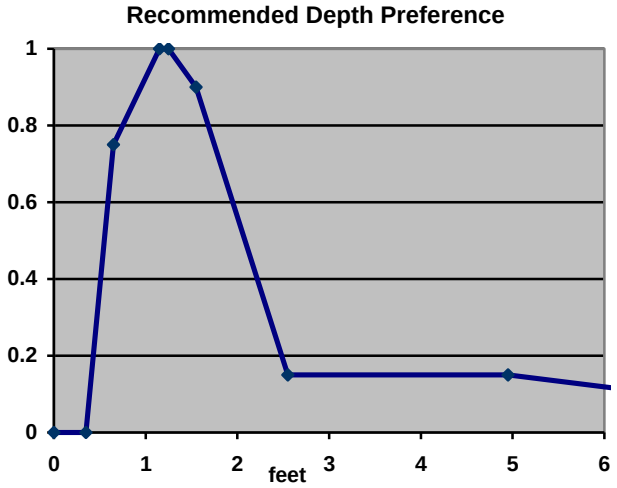


For Fall Chum Salmon Spawning Substrate Preference, use Table 2. See Table 7 for calculated preference information.

FIGURE 6a. Summer Chum Salmon Spawning Depth Preference
Analysis based on 8 studies and 116 redds (Duckabush and Dosewallips rivers).
Preference has changed from the 2004 edition.

Summer chum: Spawns from Sept to early Oct			
Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.09	0.00	0.00	0.00
0.10-0.39	0.01	0.35	0.00
0.40-0.49	0.11	0.65	0.75
0.50-0.59	0.41	1.15	1.00
0.60-0.69	0.77	1.25	1.00
0.70-0.79	0.84	1.55	0.90
0.80-0.89	0.87	2.55	0.15
0.90-0.99	0.79	5.0	0.15
1.00-1.09	0.81	10.0+	0.00
1.10-1.19	1.0		
1.20-1.39	0.94		
1.40-1.49	0.90		
1.50-1.59	0.91		
1.60-1.69	0.71		
1.70-1.89	0.63		
1.90-1.99	0.61		
2.00-2.09	0.55		
2.10-2.19	0.47		
2.20-2.29	0.32		
2.30-2.49	0.28		
2.50-2.59	0.16		
2.60-3.39	0.11		
3.40-3.89	0.06		
3.90-5.0	0.03		



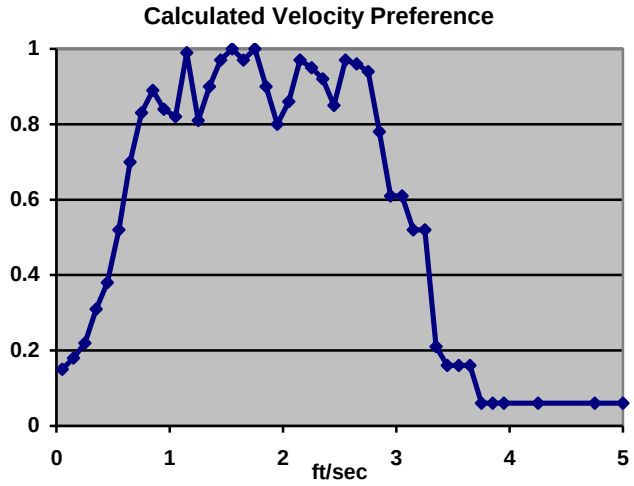


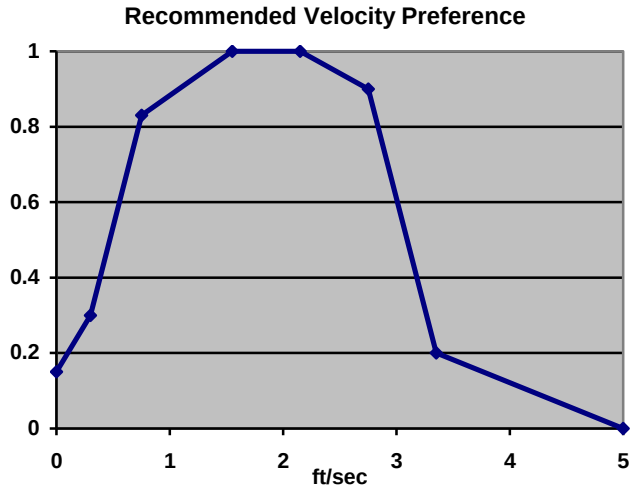
HSC Notes: There were no summer chum HSC studies conducted on small streams.
For depth preference above 2.50 ft we chose to maintain a 0.15 preference out to 5' then reduced it to 0.0 at 10'.

For Summer Chum Salmon Spawning Substrate Preference, use Table 2. See Table 7 for calculated preference information.

FIGURE 6b. Summer Chum Salmon Spawning Velocity Preference
Analysis based on 8 studies and 116 redds (Duckabush and Dosewallips rivers).
Preference has changed from the 2004 edition.

Summer chum: Spawning from Sept to early Oct			
Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted Velocity (ft/sec)	Velocity preference
0.00-0.09	0.15	0.00	0.15
0.10-0.19	0.18	0.35	0.30
0.20-0.29	0.22	0.75	0.83
0.30-0.39	0.31	1.55	1.0
0.40-0.49	0.38	2.15	1.0
0.50-0.59	0.52	2.75	0.90
0.60-0.69	0.70	3.35	0.20
0.70-0.79	0.83	5.0+	0.0
0.80-0.89	0.89		
0.90-0.99	0.84		
1.00-1.09	0.82		
1.10-1.19	0.99		
1.20-1.29	0.81		
1.30-1.39	0.90		
1.40-1.49	0.97		
1.50-1.59	1.0		
1.60-1.69	0.97		
1.70-1.79	1.0		
1.80-1.89	0.90		
1.90-1.99	0.80		
2.00-2.09	0.86		
2.10-2.19	0.97		
2.20-2.29	0.96		
2.30-2.39	0.92		
2.40-2.49	0.85		
2.50-2.59	0.97		
2.60-2.69	0.96		
2.70-2.79	0.94		
2.80-2.89	0.78		
2.90-3.09	0.61		
3.10-3.29	0.52		
3.30-3.39	0.21		
3.40-3.69	0.16		
3.70-5.0	0.06		





HSC Notes: All summer chum HSC studies conducted on large streams (>=35' LBTW). We were unable to make a small vs. large stream comparison and cannot say if this curve represents preference in smaller streams

For Summer Chum Salmon Spawning Substrate Preference, use Table 2. See Table 7 for calculated preference information.

FIGURE 7a. Pink Salmon (*O. gorbuscha*) Spawning Depth Preference
Analysis based on 3 studies and 46 redds (Squire Creek, and North Fork Stillaguamish, Dosewallips, and Duckabush rivers). **Preferences are unchanged from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.49	0.77	0.00	0.00
0.50-0.69	1.00	0.55	1.00
0.70-0.99	0.89	0.65	1.00
1.00-1.19	0.68	1.15	0.68
1.20-1.29	0.43	1.45	0.20
1.30-2.09	0.09	2.15	0.05
2.10 +	0.00	5.00+	0.00

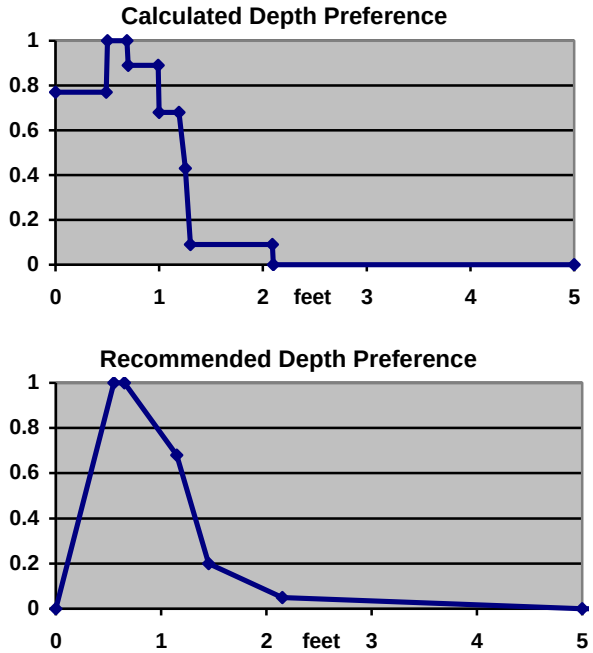
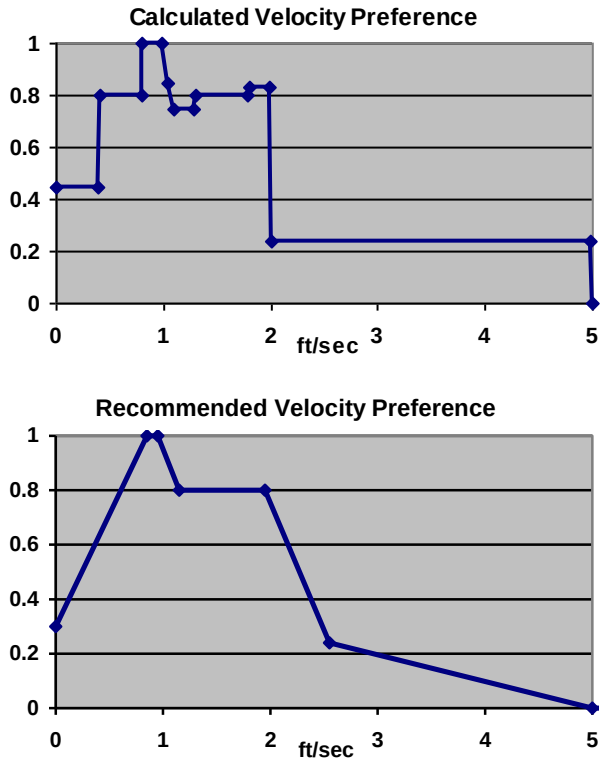


FIGURE 7b. Pink Salmon Spawning Velocity Preference

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.39	0.45	0.00	0.30
0.40-0.79	0.80	0.85	1.00
0.80-0.99	1.00	0.95	1.00
1.00-1.09	0.85	1.15	0.80
1.10-1.29	0.75	1.95	0.80
1.30-1.79	0.80	2.55	0.24
1.80-1.99	0.83	5.00	0.00
2.00-4.99	0.24	99	0.00
5.00 +	No data		

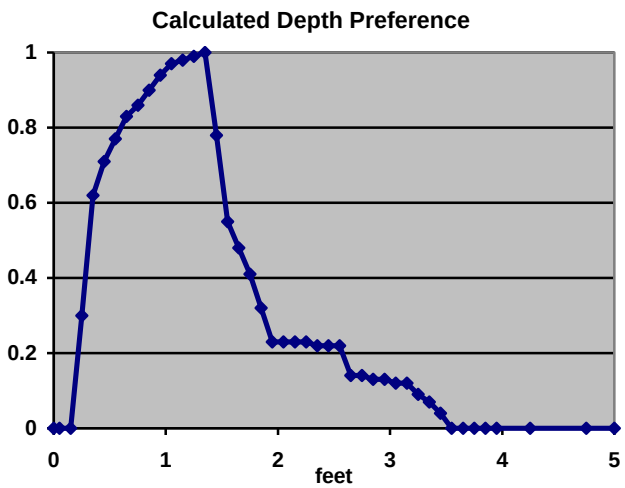


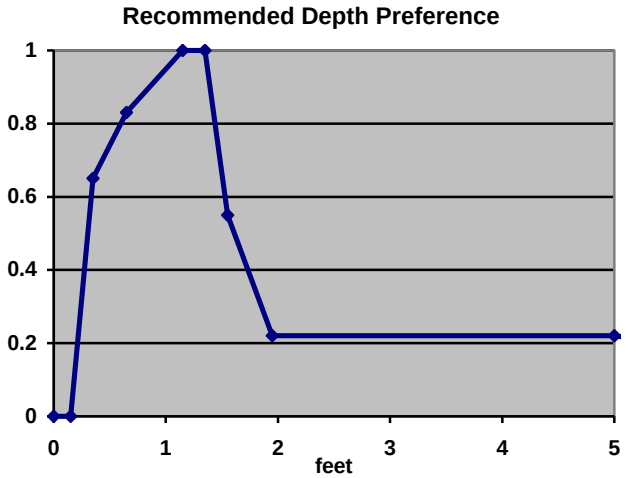
HSC Notes: All streams were large, i.e. were over 35' in LBTW.

For Pink Salmon Spawning Substrate Preference, use Table 2. See Table 9 for calculated preference information.

FIGURE 8a. Sockeye Salmon (*O. nerka*) Spawning Depth Preference
Analysis based on 4 studies and 1,053 redds (Cedar River and Big Creek (Quinault basin)).
Preference has changed from the 2004 edition.

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.0-0.19	0.00	0.00	0.00
0.20-0.29	0.30	0.15	0.00
0.30-0.39	0.62	0.35	0.60
0.40-0.49	0.71	0.65	0.83
0.50-0.59	0.77	1.15	1.0
0.60-0.69	0.83	1.35	1.0
0.70-0.79	0.86	1.55	0.55
0.80-0.89	0.90	1.95	0.22
0.90-0.99	0.94	5.0	0.22
1.00-1.09	0.97	10	0
1.10-1.19	0.98		
1.20-1.29	0.99		
1.30-1.39	1.00		
1.40-1.49	0.78		
1.50-1.59	0.55		
1.60-1.69	0.48		
1.70-1.79	0.41		
1.80-1.89	0.32		
1.90-2.29	0.23		
2.30-2.59	0.22		
2.60-2.79	0.14		
2.80-2.99	0.13		
3.00-3.19	0.12		
3.20-3.29	0.09		
3.30-3.39	0.07		
3.40-3.49	0.04		
3.5+	0.00		



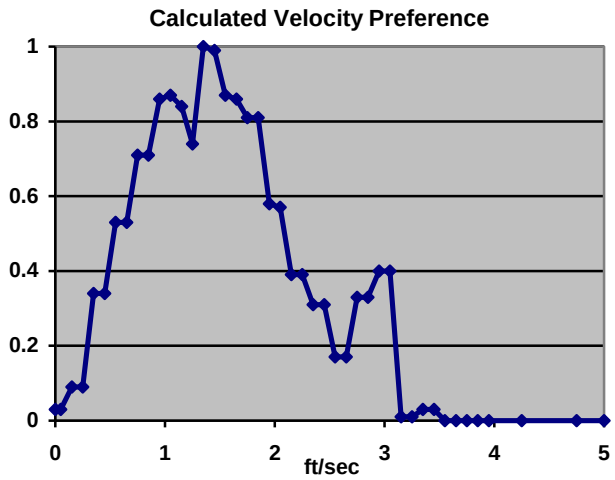


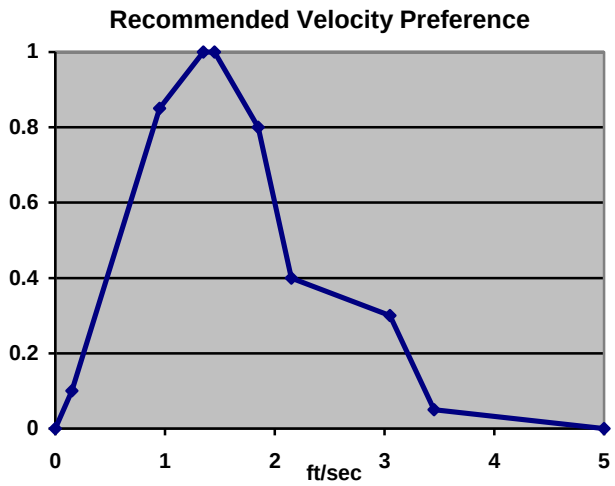
For Sockeye Salmon Spawning Substrate Preference, use Table 2. See Table 10 for calculated substrate preference information.

HSC Notes: For depth preference after 1.90 ft. we chose to maintain a 0.22 preference out to 5' then reduce it to 0.0 at 10'.

FIGURE 8b. Sockeye Salmon Spawning Velocity Preference
Analysis based on 4 studies and 1,053 redds (Cedar River & Big Creek (Quinault basin)).
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.0-0.09	0.03	0.00	0.00
0.10-0.29	0.09	0.15	0.10
0.30-0.49	0.34	0.95	0.85
0.50-0.69	0.53	1.35	1.0
0.70-0.89	0.71	1.45	1.0
0.90-0.99	0.86	1.85	0.80
1.00-1.09	0.87	2.15	0.40
1.10-1.19	0.84	3.05	0.30
1.20-1.29	0.74	3.45	0.05
1.30-1.39	1.0	5	0
1.40-1.49	0.99		
1.50-1.59	0.87		
1.60-1.69	0.86		
1.70-1.89	0.81		
1.90-1.99	0.58		
2.00-2.09	0.57		
2.10-2.29	0.39		
2.30-2.49	0.31		
2.50-2.69	0.17		
2.70-2.89	0.33		
2.90-3.09	0.40		
3.10-3.29	0.01		
3.30-3.49	0.03		
3.5+	0.0		

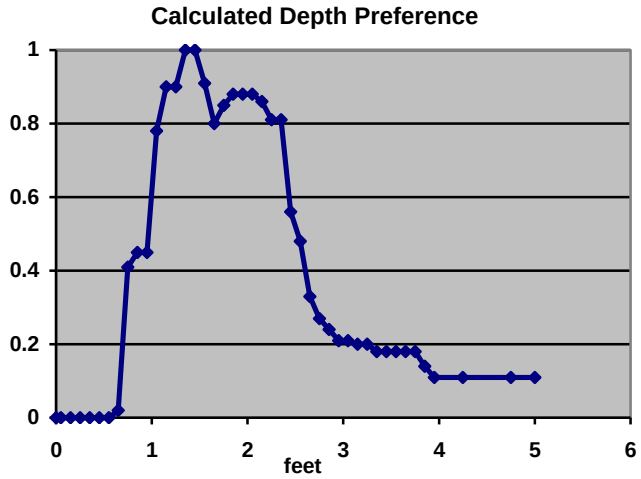


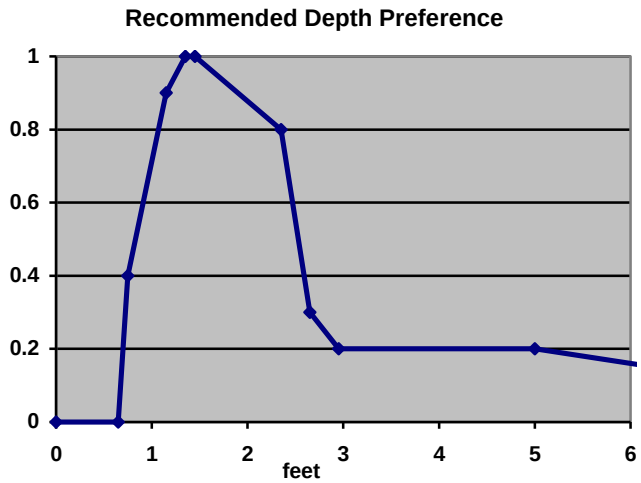


For Sockeye Salmon Spawning Substrate Preference, use Table 2. See Table 10 for calculated substrate preference information.

FIGURE 9a. Steelhead (*O. mykiss*) Spawning Depth Preference
Analysis based on 4 studies, 85 redds (Cedar and Sultan rivers and Chelan Fish Channel).
Preference has changed from the 2004 edition.

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.59	0.00	0.00	0.00
0.60-0.69	0.02	0.65	0.00
0.70-0.79	0.41	0.75	0.40
0.80-0.99	0.45	1.15	0.90
1.00-1.29	0.95	1.35	1.00
1.30-1.49	1.00	1.45	1.00
1.50-1.59	0.91	2.35	0.80
1.60-1.69	0.80	2.65	0.30
1.70-1.79	0.85	2.95	0.20
1.80-2.09	0.88	5.0	0.20
2.10-2.19	0.86	10.0	0.0
2.20-2.39	0.81		
2.40-2.49	0.56		
2.50-2.59	0.48		
2.60-2.69	0.33		
2.50-2.59	0.48		
2.60-2.69	0.33		
2.70-2.79	0.27		
2.80-2.89	0.24		
2.90-3.09	0.21		
3.10-3.29	0.20		
3.30-3.79	0.18		
3.80-3.89	0.14		
3.90-5.0+	0.11		



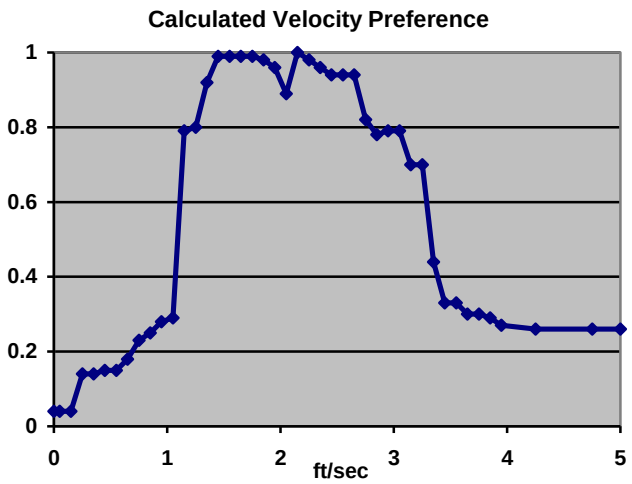


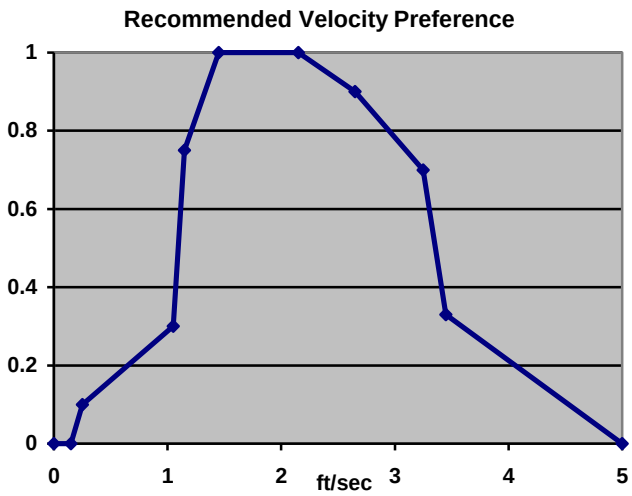
For Steelhead Spawning Substrate Preference, use Table 4.

HSC Notes: All study streams were over 50' LBTW. We were unable to make a small vs. large stream comparison.
For depth preference after 2.90 ft. we chose to maintain a 0.20 preference out to 5' then reduced it to 0.0 at 10'.

FIGURE 9b. Steelhead Spawning Velocity Preference
Analysis based on 4 studies, 85 redds (Cedar and Sultan rivers and Chelan Fish Channel).
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.19	0.04	0.00	0.0
0.20-0.39	0..14	0.15	0.0
0.40-0.59	0.15	0.25	0.10
0.60-0.69	0.18	1.05	0.30
0.70-0.79	0.23	1.15	0.75
0.80-0.89	0.25	1.45	1.0
0.90-0.99	0.28	2.15	1.0
1.00-1.09	0.29	2.65	0.90
1.10-1.19	0.79	3.25	0.70
1.20-1.29	0.8	3.45	0.33
1.30-1.39	0.92	5.0	0.0
1.40-1.79	0.99		
1.80-1.89	0.98		
1.90-1.99	0.96		
2.00-2.09	0.89		
2.10-2.19	1.0		
2.20-2.29	0.98		
2.30-2.39	0.96		
2.40-2.69	0.94		
2.70-2.79	0.82		
2.80-2.89	0.78		
2.90-3.09	0.79		
3.10-3.29	0.70		
3.30-3.39	0.44		
3.40-3.59	0.33		
3.60-3.79	0.30		
3.80-3.89	0.29		
3.90-3.99	0.27		
4.00-5.0	0.26		



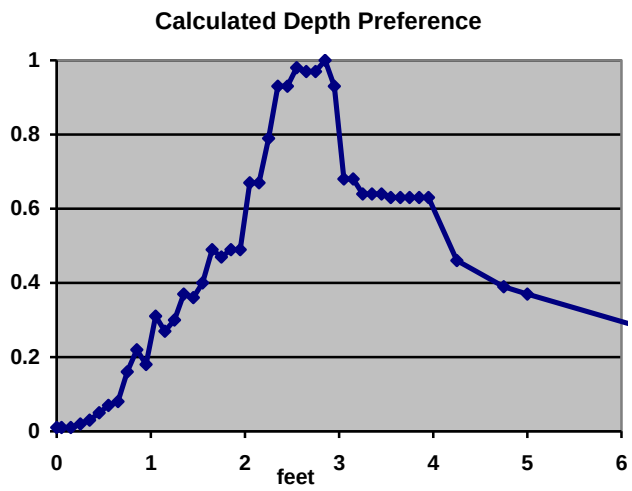


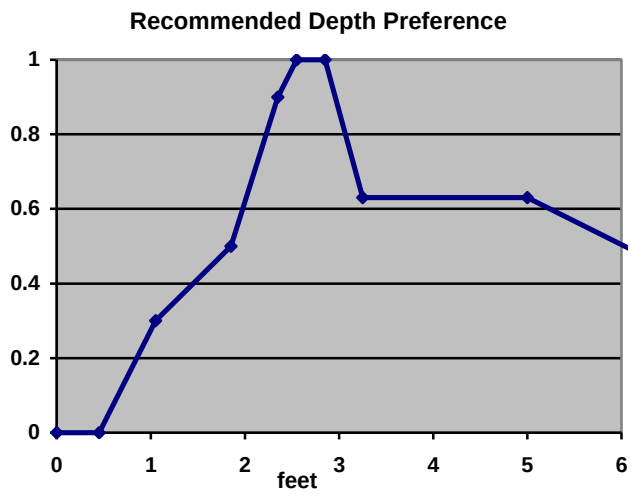
For Steelhead Spawning Substrate Preference, use Table 4.

HSC Notes: All study streams were over 50' in LBTW. We were unable to make a small vs. large stream comparison.

FIGURE 10a. O. mykiss Juvenile Depth Preference in Large Streams
Use on streams with >= 35' Low Bank Toe-Width (LBTW)[1]. Analysis based on 13 studies and 1003 fish (Mill, Martin, and Morse creeks, and Tucannon (2), Wishkah, Sultan, Dungeness (2), Cedar, Chewuch, Chiwawa, and Similkameen rivers). **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.01	0.00	0.00
0.20-0.29	0.02	0.45	0.00
0.30-0.39	0.03	1.05	0.30
0.40-0.49	0.05	1.85	0.50
0.50-0.59	0.07	2.35	0.90
0.60-0.69	0.08	2.55	1.0
0.70-0.79	0.16	2.85	1.0
0.80-0.89	0.22	3.25	0.63
0.90-0.99	0.18	5	0.63
1.00-1.09	0.31	10	0.0
1.10-1.19	0.27		
1.20-1.29	0.30		
1.30-1.19	0.37		
1.40-1.49	0.36		
1.50-1.59	0.40		
1.60-1.69	0.49		
1.70-1.79	0.47		
1.80-1.99	0.49		
2.00-2.19	0.67		
2.20-2.29	0.79		
2.30-2.49	0.93		
2.50-2.59	0.98		
2.60-2.79	0.97		
2.80-2.89	1.0		
2.90-2.99	0.93		
3.00-3.19	0.68		
3.20-3.49	0.64		
3.50-3.99	0.63		
4.00-4.49	0.46		
4.50-4.99	0.39		
5.0	0.37		





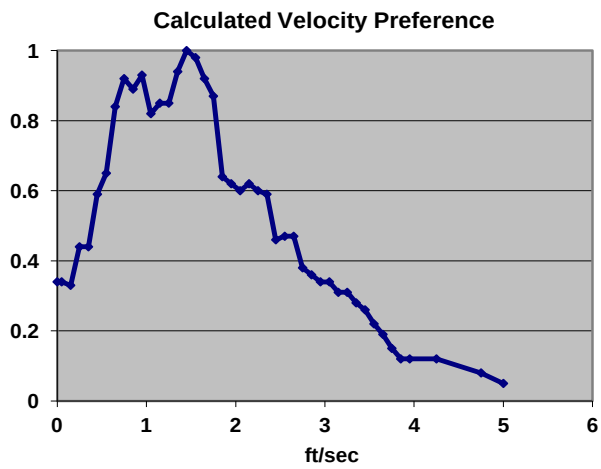
For Steelhead Juvenile Cover/Substrate Preference, use Table 3.

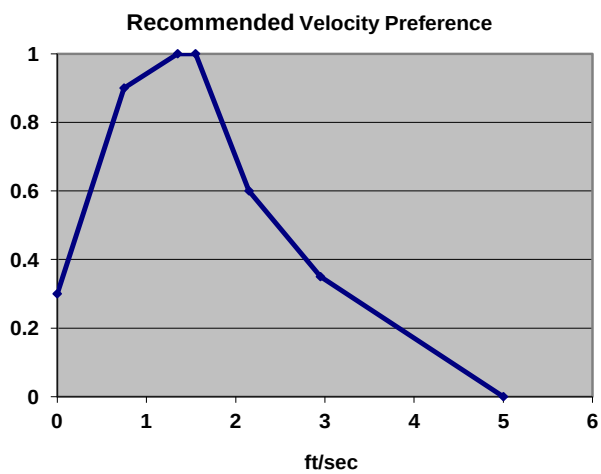
HSC Notes: The calculated preference reduction after 4.0 ft comes from studies with 1.0 preference dropping to 0.0 due to a lack of habitat availability. We chose to maintain a 0.63 preference out to 5' then reduced it to 0.0 at 10'.

[1] The median depth HSC peak in groups Small (<35') and Large (>=35') LBTW were 1.3 and 2.25 ft respectively. The distributions of the groups differed significantly (Wilcoxon rank sum test U_1=22, U_2=131, n_1=6, n_2=11, P<.005 two tailed).

FIGURE 10b. O. mykiss Juvenile Velocity Preference in Large Streams
Use on streams with >= 35' LBTW[1]. Analysis based on 13 studies and 1000 fish (Mill, Martin, and Morse creek, and Tucannon (2), Wishkah, Sultan, Dungeness (2), Cedar, Chewuch, Chiwawa, and Similkameen rivers). **Preference has changed from the 2004 edition.**

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.34	0.00	0.30
0.10-0.19	0.33	0.75	0.90
0.20-0.39	0.44	1.35	1.0
0.40-0.49	0.59	1.55	1.0
0.50-0.59	0.65	2.15	0.60
0.60-0.69	0.84	2.95	0.35
0.70-0.79	0.92	5	0.0
0.80-0.89	0.89		
0.90-0.99	0.93		
1.00-1.09	0.82		
1.10-1.29	0.85		
1.30-1.39	0.94		
1.40-1.49	1.0		
1.50-1.59	0.98		
1.60-1.69	0.92		
1.70-1.79	0.87		
1.80-1.99	0.64		
2.00-2.09	0.60		
2.10-2.19	0.62		
2.20-2.29	0.60		
2.30-2.39	0.59		
2.40-2.49	0.46		
2.50-2.69	0.47		
2.70-2.79	0.38		
2.80-2.89	0.36		
2.90-3.09	0.34		
3.10-3.29	0.31		
3.30-3.39	0.28		
3.40-3.49	0.26		
3.50-3.59	0.22		
3.60-3.69	0.19		
3.70-3.79	0.15		
3.80-4.49	0.12		
4.50-4.95	0.08		
5.0	0.05		



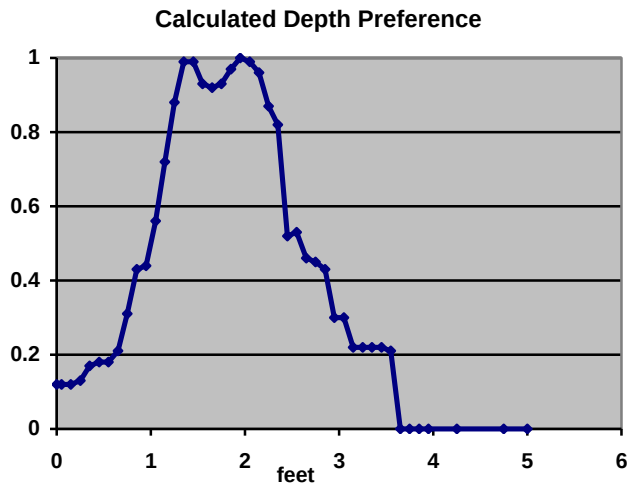


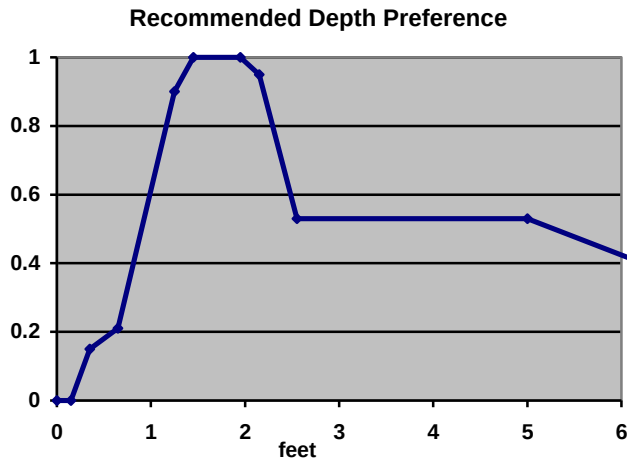
For Steelhead Juvenile Cover/Substrate Preference, use Table 3.

[1]The median velocity HSC peak in groups Small (<35') and Large (>=35') LBTW were 0.4 and 0.85 ft/sec respectively. The distributions of the groups differed significantly (Wilcoxon rank sum test U_1=33.5, U_2=119.5, n_1=6, n_2=11, P< 0.05 two tailed).

FIGURE 11a. O. mykiss Juvenile Depth Preference in Small Streams.
Use for Steelhead and Rainbow Trout juveniles on streams with < 35' LBTW[1]. Analysis based on 6 studies and 234 fish (Olson, Jordan, Harlan, Hancock, and Calligan creeks and Mad River). **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.12	0.00	0.0
0.20-0.29	0.13	0.15	0.0
0.30-0.39	0.17	0.35	0.15
0.40-0.59	0.18	0.65	0.21
0.60-0.69	0.21	1.25	0.90
0.70-0.79	0.31	1.45	1.0
0.80-0.89	0.43	1.95	1.0
0.90-0.99	0.44	2.15	0.95
1.00-1.09	0.56	2.55	0.53
1.10-1.19	072	5.0	0.53
1.20-1.29	0.88	10.0	0.0
1.30-1.49	0.99		
1.50-1.59	0.93		
1.60-1.69	0.92		
1.70-1.79	0.93		
1.80-1.89	0.97		
1.90-1.99	1.0		
2.00-2.09	0.99		
2.10-2.19	0.96		
2.20-2.29	0.87		
2.30-2.39	0.82		
2.40-2.49	0.52		
2.50-2.59	0.53		
2.60-2.69	0.46		
2.70-2.79	0.45		
2.80-2.89	0.43		
2.90-3.09	0.30		
3.10-3.49	0.22		
3.50-3.59	0.21		
3.60-5.0+	0		



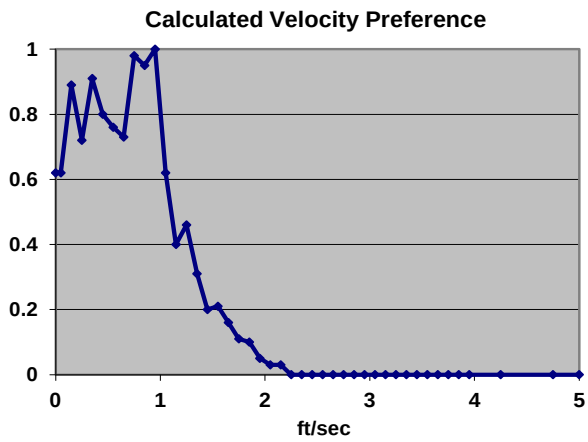


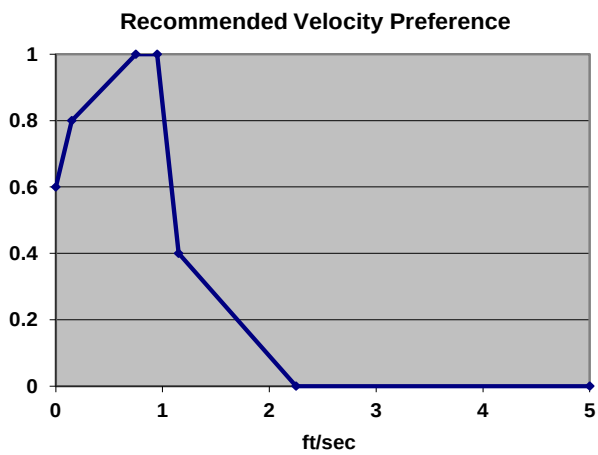
For Steelhead Juvenile Cover/Substrate Preference, use Table 3.

[1] The median depth HSC peak in groups Small (<35') and Large (>=35') LBTW were 1.3 and 2.25 ft. respectively. The distribution of the groups differed significantly (Wilcoxon rank sum test U_1=22, U_2=131, n_1=6, n_2=11, P<.005 two tailed).

FIGURE 11b. O. mykiss Juvenile Velocity Preference in Small Streams
Use for Steelhead and Rainbow Trout juveniles on streams with < 35' LBTW[1]. Analysis based on 6 studies and 234 fish (Olson, Jordan, Harlan, Hancock, and Calligan creeks and Mad River). **Preference has changed from the 2004 edition**.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0..62	0.00	0.60
0.10-0.19	0.89	0.15	0.80
0.20-0.29	0.72	0.75	1.0
0.30-0.39	0.91	0.95	1.0
0.40-0.49	0.80	1.15	0.40
0.50-0.59	0.76	2.25	0.00
0.60-0.69	0.73	5.0+	0.00
0.70-0.79	0.98		
0.80-0.89	0.95		
0.90-0.99	1.0		
1.00-1.09	0.62		
1.10-1.19	0.40		
1.20-1.29	0.46		
1.30-1.39	0.31		
1.40-1.49	0.20		
1.50-1.59	0.21		
1.60-1.69	0.16		
1.70-1.79	0.11		
1.80-1.89	0.10		
1.90-1.99	0.05		
2.00-2.19	0.03		
2.20+	0.0		



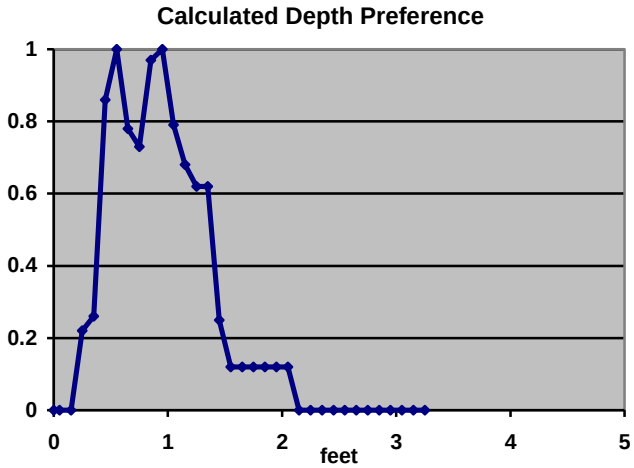


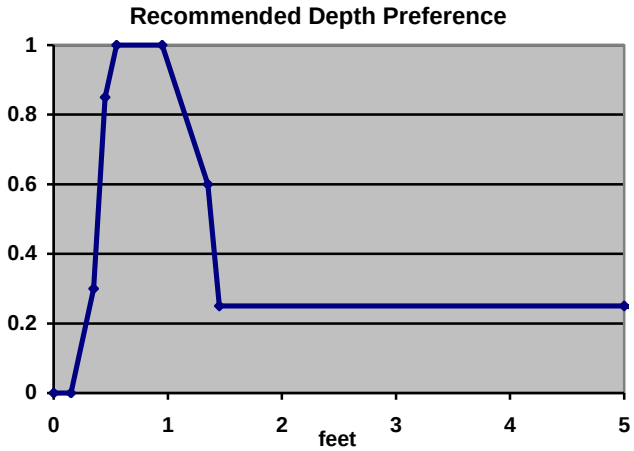
For Steelhead Juvenile Cover/Substrate Preference, use Table 3.

[1] The median velocity HSC peak in groups Small (<35') and Large (>=35') LBTW were 0.4 and 0.85 ft/sec respectively. The distributions of the groups differed significantly (Wilcoxon rank sum test U_1=33.5, U_2=119.5, n_1=6, n_2=11, P< 0.05 two tailed).

FIGURE 12a. Resident Rainbow Trout (*O. mykiss*) Spawning Depth Preference
Analysis based on 2 studies and 27 redds (upper Lake and Muller creeks).
Preference has changed from the 2004 edition.

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.0	0.00	0.00
0.20-0.29	0.22	0.15	0.00
0.30-0.39	0.26	0.35	0.30
0.40-0.49	0.86	0.45	0.85
0.50-0.59	1.0	0.55	1.0
0.60-0.69	0.78	0.95	1.0
0.70-0.79	0.73	1.35	0.60
0.80-0.89	0.97	1.45	0.25
0.90-0.99	1.0	5.0	0.25
1.00-1.09	0.79	10.0	0.0
1.10-1.19	0.68		
1.20-1.39	0.62		
1.40-1.49	0.25		
1.50-2.09	0.12		
2.1+	*No Data		



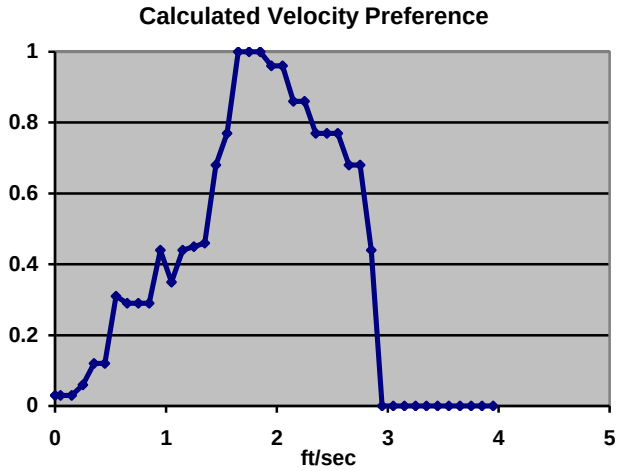


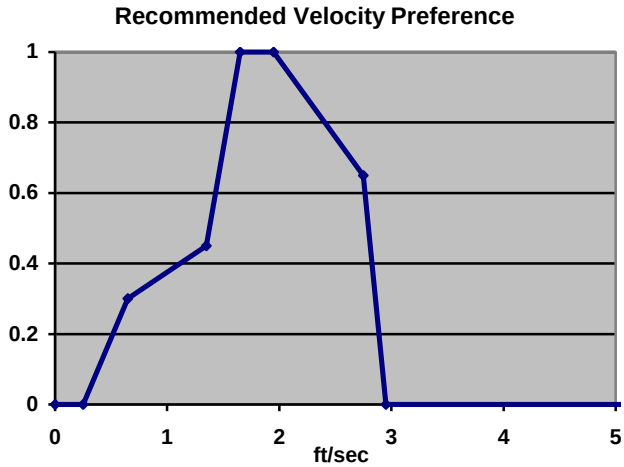
HSC Notes: Study sites were all small stream with shallow depths (< 2.5 ft.). We were unable to make a small vs. large stream comparison. We are unable to say if this curve represents preference in larger streams.
We chose to maintain a 0.25 preference out to 5' then reduced it to 0.0 at 10'.

For Resident Rainbow Trout Spawning Substrate Preference, use Table 5.

FIGURE 12b. Resident Rainbow Trout Spawning Velocity Preference
Analysis based on 2 studies and 27 redds (upper Lake and Muller creeks).
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.19	0.03	0.00	0.00
0.20-0.29	0.06	0.25	0.00
0.30-0.49	0.12	0.65	0.30
0.50-0.59	0.31	1.25	0.45
0.60-0.89	0.29	1.65	1.0
0.90-0.99	0.44	1.95	1.0
1.00-1.09	0.35	2.75	0.65
1.10-1.19	0.44	2.95+	0
1.20-1.29	0.45		
1.30-1.39	0.46		
1.40-1.49	0.68		
1.50-1.59	0.77		
1.60-1.89	1.0		
1.90-2.09	0.96		
2.10-2.29	0.86		
2.30-2.59	0.77		
1.60-1.79	0.68		
2.80-2.89	0.44		
2.95+	0.0		





For Resident Rainbow Trout Spawning Substrate Preference, use Table 5.

HSC Notes: Study sites were all small stream with shallow depths (< 2.5 ft.). We were unable to make a small vs. large stream comparison. We are unable to say if this curve represents preference in larger streams.

FIGURE 13a. Resident Rainbow Trout Winter Depth Preference
Campbell and Neuner (1985)[1]. **Preference is unchanged from 2004.**

Plotted depth (feet)	Recommended depth preference
0.00	0.00
0.20	0.00
0.30	0.20
0.50	1.00
1.50	1.00
3.00	0.25
3.50	0.10
6.00	0.10
99	0.10

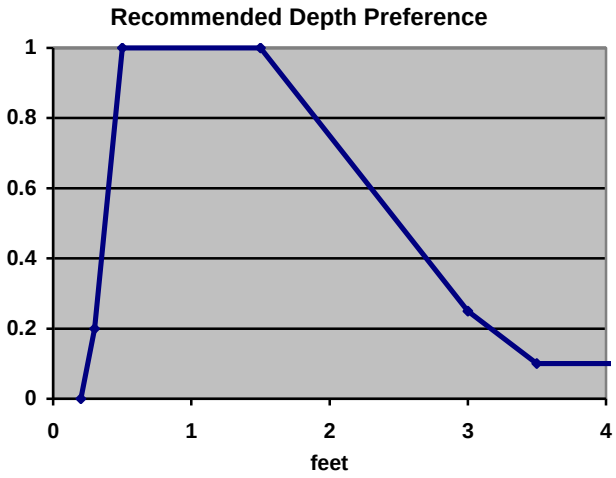
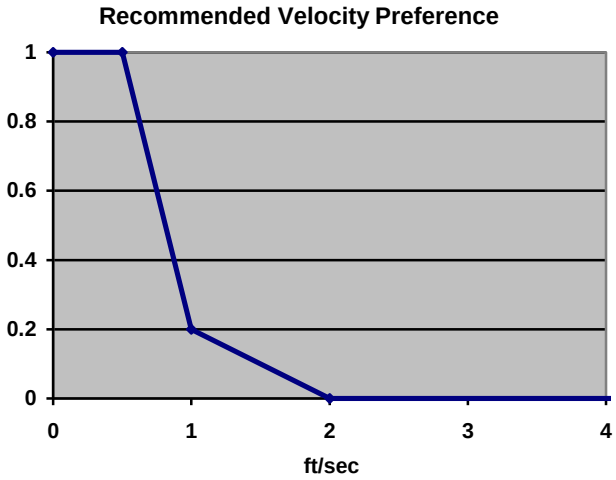


FIGURE 13b. Resident Rainbow Trout Winter Velocity Preference
Campbell and Neuner (1985). **Preference is unchanged from 2004.**

Plotted velocity (feet/sec)	Recommended velocity preference
0.00	1.00
0.50	1.00
1.00	0.20
2.00	0.00
99	0.00

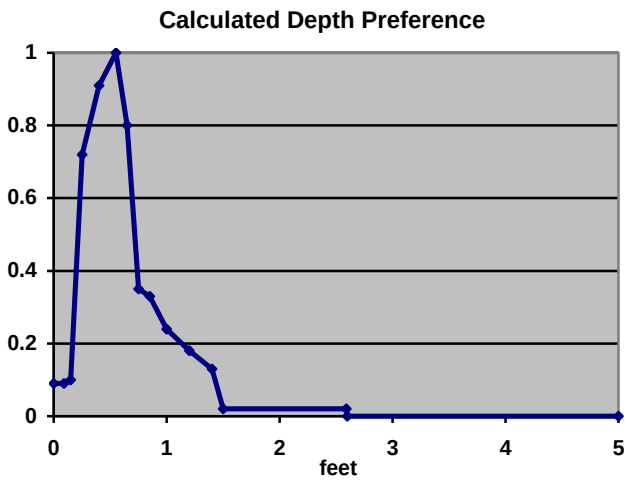


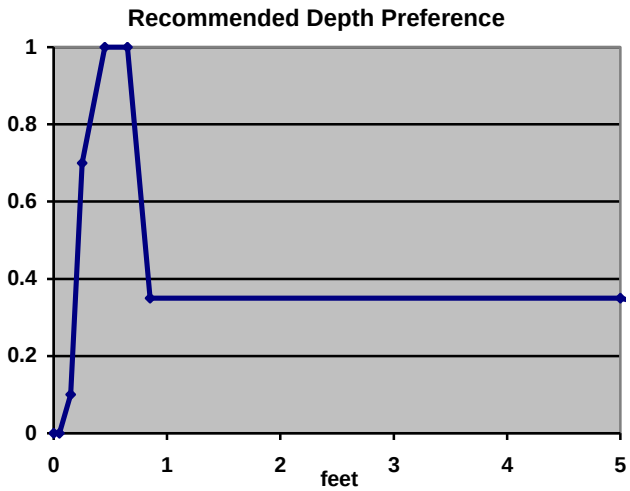
For Winter Cover/Substrate Preference, use Table 3

[1] Depth and velocity curves are estimates based on observations and professional judgment. Actual depth and velocities were not measured. Based on their observations during winter days, trout required deep pools or areas with a good level of interstitial spaces between the substrate (large gravel, cobbles, and boulders) for refuge. During the nighttime, the fish were always observed resting on the bottom in quiet areas with sandy to silty substrates (R. Campbell, R2 Resource Consultants, pers. comm., 2003).

FIGURE 14a. Cutthroat Trout (*O. clarki*) Spawning Depth Preference
Analysis based on 6 studies and 69 redds (Irely Creek).
Preference has changed from the 2004 edition.

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.09	0.09	0.00	0.00
0.10-0.19	0.10	0.05	0.00
0.20-0.29	0.72	0.15	0.10
0.30-0.49	0.91	0.25	0.70
0.40-0.49	0.94	0.45	1.0
0.50-0.59	1.0	0.65	1.0
0.60-0.69	0.88	0.85	0.35
0.70-0.79	0.35	5.00	0.35
0.80-0.89	0.33	10	0.0
0.90-1.09	0.24		
1.10-1.29	0.18		
1.30-1.49	0.13		
1.50-2.59	0.02		
2.60+	0.0		

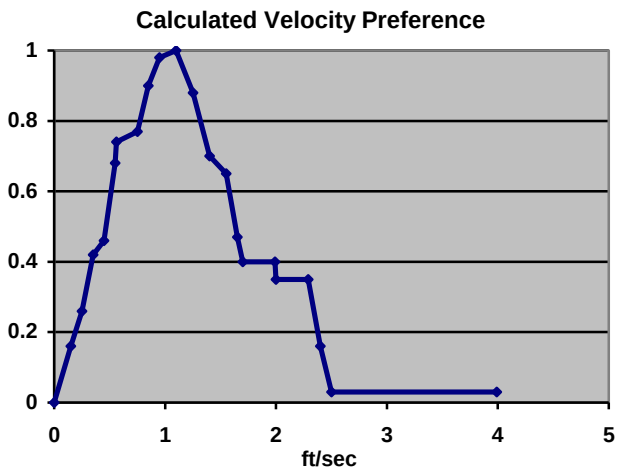


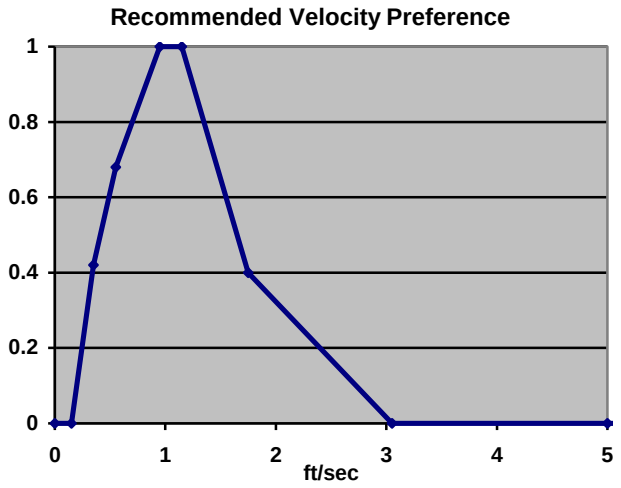


HSC Notes: The study stream was small (<35' LBTW). We were unable to make a small vs. large stream comparison and cannot say if this curve represents preference in larger streams.

FIGURE 14b. Cutthroat Spawning Velocity Preference
Analysis based on 6 studies and 69 redds (Irely Creek).
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00 0.09	0.05	0.00	0.00
0.10-0.19	0.16	0.15	0.00
0.20-0.29	0.26	0.35	0.42
0.30-0.39	0.42	0.55	0.68
0.40-0.49	0.46	0.95	1.00
0.50-0.59	0.68	1.15	1.00
0.60-0.69	0.74	1.75	0.40
0.70-0.79	0.77	3.05	0.0
0.80-0.89	0.90	5.00	0.0
0.90-0.99	0.98		
1.00-1.19	1.0		
1.20-1.29	0.88		
1.30-1.49	0.70		
1.50-1.59	0.65		
1.60-1.69	0.47		
1.70-1.99	0.40		
2.00-2.19	0.35		
2.30-2.49	0.16		
2.50-3.99	0.03		



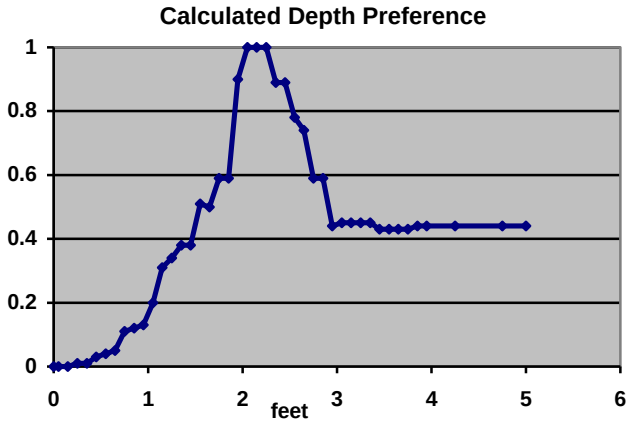


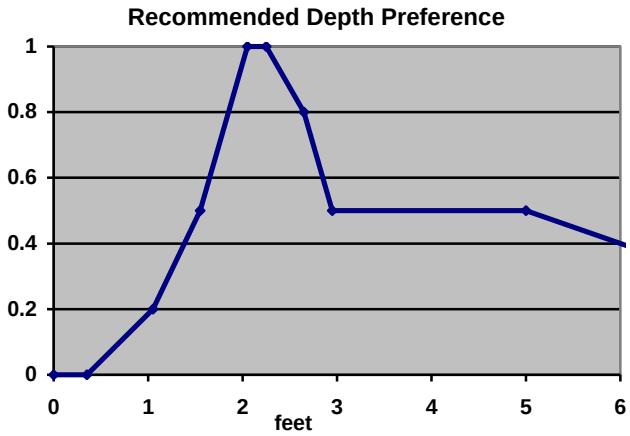
For Cutthroat Trout Spawning Substrate Preference, use Table 5

HSC Notes: The study stream was small (<35' LBTW). We were unable to make a small vs. large stream comparison and cannot say if this curve represents preference in larger streams.

FIGURE 15a. Cutthroat Trout Juvenile Depth Preference
Analysis based on 7 studies and 336 fish (Ohanapecosh River and Early Winters and Perry Creeks). **Preference has changed from 2004.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.00	0.00	0.00
0.20-0.39	0.01	0.35	0.00
0.40-0.49	0.03	1.05	0.20
0.50-0.59	0.04	1.55	0.50
0.60-0.69	0.05	2.05	1.00
0.70-0.79	0.11	2.25	1.00
0.80-0.89	0.12	2.65	0.80
0.90-0.99	0.13	2.95	0.50
1.00-1.09	0.20	5.0	0.50
1.10-1.19	0.31	10	0
1.20-1.29	0.34		
1.30-1.49	0.38		
1.50-1.59	0.51		
1.60-1.69	0.50		
1.70-1.89	0.59		
1.90-1.99	0.90		
2.00-2.29	1.00		
2.30-2.49	0.89		
2.50-2.59	0.78		
2.60-2.69	0.74		
2.70-2.89	0.59		
2.90-2.99	0.44		
3.00-3.39	0.45		
3.40-3.79	0.43		
3.80-4.99	0.44		
5.00+	0.44		





HSC Notes: There were not enough studies to conduct a small vs. large stream comparison.

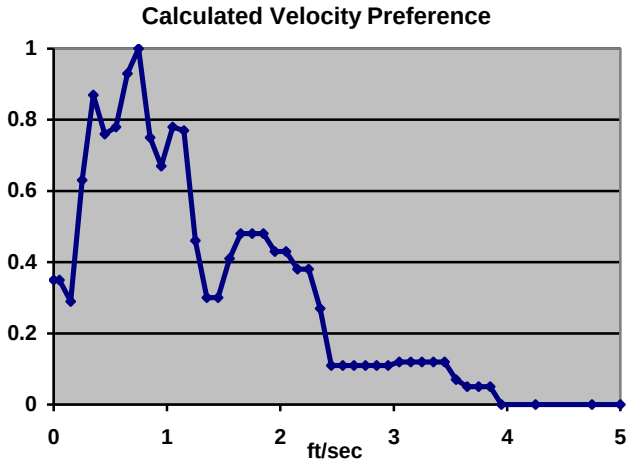
For Cutthroat Trout Winter Depth Preference, use Figure 13a

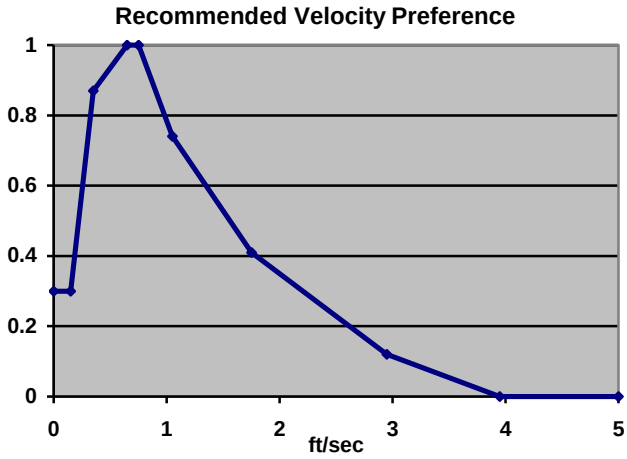
For Cutthroat Trout Winter Velocity Preference, use Figure 13b

For Cutthroat Trout Winter Substrate Preference, use Table 3

FIGURE 15b. Cutthroat Trout Juvenile Velocity Preference
Analysis based on 8 studies and 346 fish (Ohanapecosh River and Early Winters and Perry Creeks). **Preference has changed from the 2004 edition.**

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.35	0.00	0.30
0.10-0.19	0.29	0.15	0.30
0.20-0.29	0.63	0.35	0.87
0.30-0.39	0.87	0.65	1.00
0.40-0.49	0.76	0.75	1.00
0.50 0.59	0.78	1.05	0.74
0.60-0.69	0.93	1.75	0.41
0.70-0.79	1.00	2.95	0.12
0.80 0.89	0.75	3.95	0.00
0.90-0.99	0.67	5+	0.00
1.00-1.09	0.78		
1.10-1.19	0.77		
1.20-1.29	0.46		
1.30-1.49	0.30		
1.50-1.59	0.41		
1.60-1.89	0.48		
1.90-2.09	0.43		
2.10-2.29	0.38		
2.30 2.39	0.27		
2.40-2.99	0.11		
3.00-3.49	0.12		
3.50-3.59	0.06		
3.60-3.89	0.05		
3.90+	No data		





HSC Notes: There were not enough studies to conduct a small vs. large stream comparison.

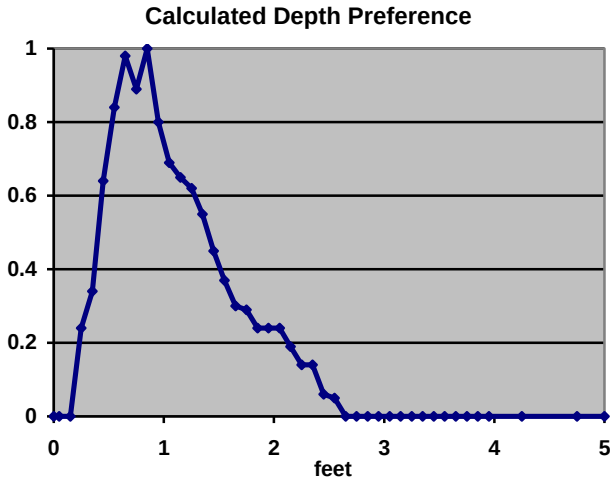
For Cutthroat Trout Winter Depth Preference, use Figure 13a

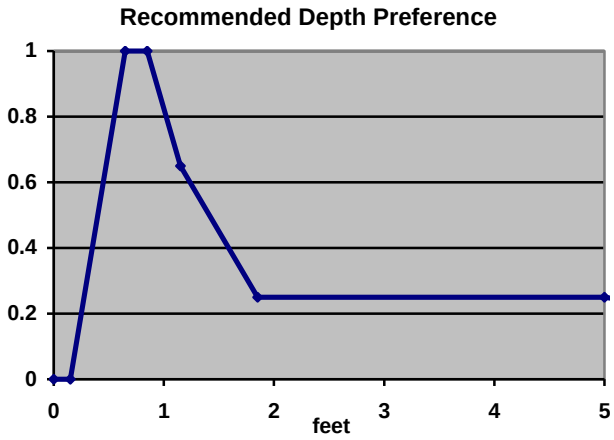
For Cutthroat Trout Winter Velocity Preference, use Figure 13b

For Cutthroat Trout Winter Substrate Preference, use Table 3

FIGURE 16a. Bull Trout and Dolly Varden Spawning Depth Preference
Analysis based on 8 studies and 122 redds (Rock, Phelps and Indian creeks, and Mad, North Fork Skykomish, and Chiwawa rivers). **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.0	0.00	0.0
0.20-0.29	0.24	0.15	0.0
0.30-0.39	0.34	0.65	1.0
0.40-0.49	0.64	0.85	1.0
0.50-0.59	0.84	1.15	0.65
0.60-0.69	0.98	1.85	0.25
0.70-0.79	0.89	5.0	0.25
0.80 0.89	1.0	10	0.0
0.90-0.99	0.80		
1.00 1.09	0.69		
1.10-1.19	0.65		
1.20-1.29	0.62		
1.30-1.39	0.55		
1.40-1.49	0.45		
1.50-1.59	0.37		
1.60-1.69	0.30		
1.70-1.79	0.29		
1.80-2.09	0.24		
2.10-2.19	0.19		
2.20-2.39	0.14		
2.40-2.49	0.06		
2.50-2.59	0.05		
2.6+	0.0		



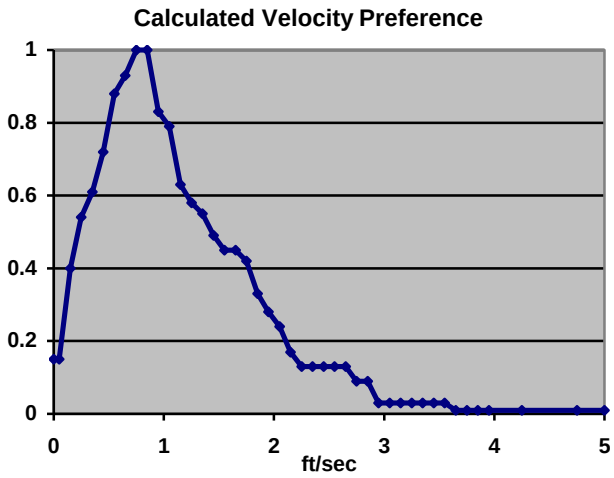


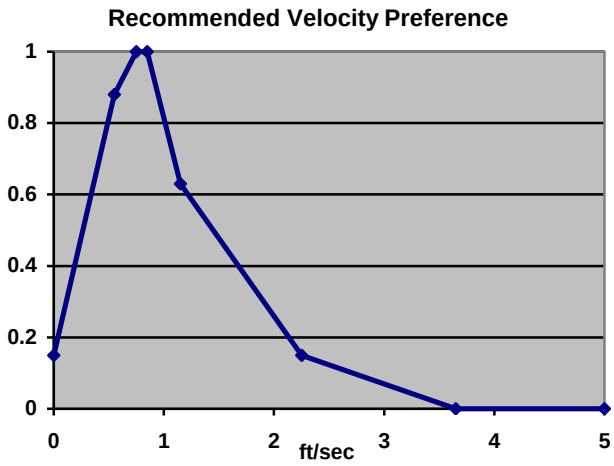
HSC Notes: We analyzed different sized streams and found no difference in Bull Trout depth preference.

For Bull Trout and Dolly Varden Juvenile Spawning Substrate Preference, use Table 6. See Table 11 for calculated substrate preference information.

FIGURE 16b. Bull Trout and Dolly Varden Spawning Velocity Preference
Analysis based on 8 studies and 122 redds (Rock, Phelps and Indian creeks, and Mad, North Fork Skykomish, and Chiwawa rivers). **Preference has changed from the 2004 edition.**

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.15	0.00	0.15
0.10-0.19	0.40	0.55	0.88
0.20-0.29	0.54	0.75	1.0
0.30-0.39	0.61	0.85	1.0
0.40-0.49	0.72	1.15	0.63
0.50-0.59	0.88	2.25	0.15
0.60-0.69	0.93	3.65+	0.0
0.70-0.89	1.0		
0.90-0.99	0.83		
1.00-1.09	0.79		
1.10-1.19	0.63		
1.20-1.29	0.58		
1.30-1.39	0.55		
1.40-1.49	0.49		
1.50-1.69	0.45		
1.70-1.79	0.42		
1.80-2.09	0.33		
2.10-2.19	0.28		
2.20-2.39	0.24		
2.10-2.19	0.17		
2.20-2.69	0.13		
2.70-2.89	0.09		
2.90-3.59	0.03		
3.60-5.0	0.01		



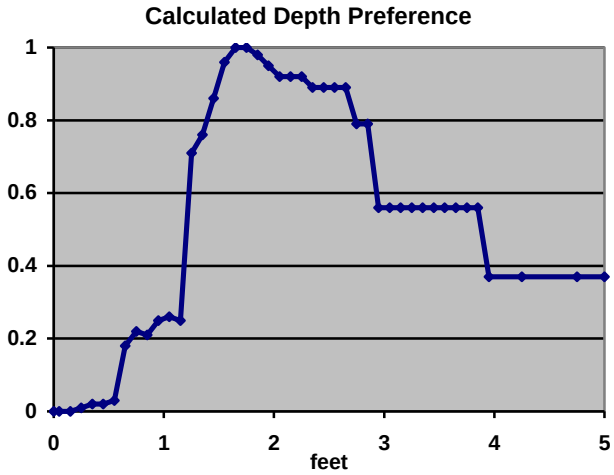


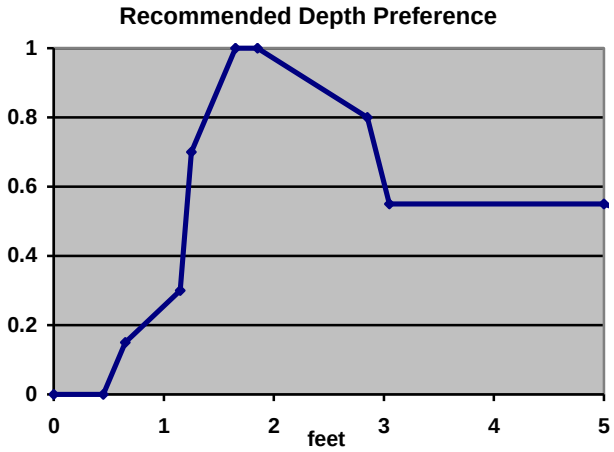
HSC Notes: We analyzed different sized streams and found no difference in Bull Trout velocity preference.

For Bull Trout and Dolly Varden Juvenile Spawning Substrate Preference, use Table 6. See Table 11 for calculated substrate preference information.

FIGURE 17a. Bull Trout and Dolly Varden Juvenile Depth Preference-Large Streams
Use with Streams >= 35' LBTW[1]. Analysis based on 5 studies and 80 fish (Troublesome Creek, and Chiwawa, Dungeness, and Tucannon rivers).
Preference has changed from the 2004 edition.

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.0	0.00	0.0
0.20-0.29	0.01	0.45	0.0
0.30-0.49	0.02	0.65	0.15
0.50-0.59	0.03	1.15	0.30
0.60-0.69	0.18	1.25	0.70
0.70-0.79	0.22	1.65	1.0
0.80-0.89	0.21	1.85	1.0
0.90-0.99	0.25	2.85	0.80
1.00-1.09	0.26	2.95	0.55
1.10-1.19	0.25	4.95	0.55
1.20-1.29	0.71	10	0
1.30-1.39	0.76		
1.40-1.49	0.86		
1.50-1.59	0.96		
1.60-1.79	1.0		
1.80-1.89	0.98		
1.90-1.99	0.95		
2.00-2.29	0.92		
2.30-2.69	0.86		
2.70-2.89	0.79		
2.90-3.89	0.56		
3.90-5.0	0.37		



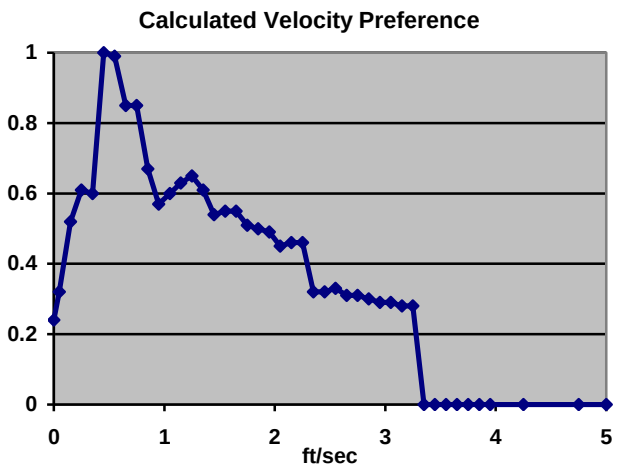


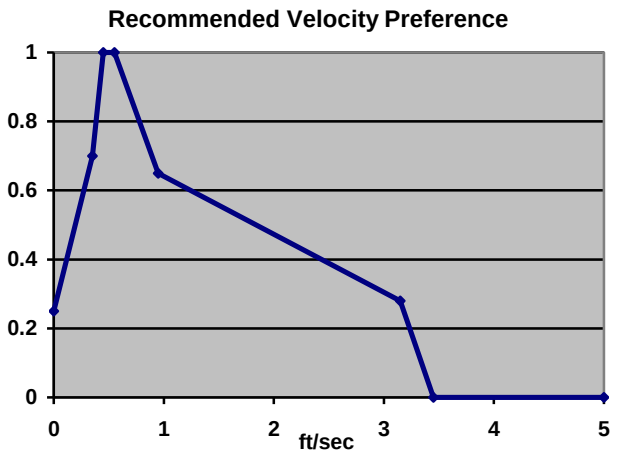
For Bull Trout and Dolly Varden Juvenile Cover/Substrate Preference, use Table 3.

[1] The median HSC peak in groups Small (<35') and Large (>=35') were 0.95 and 1.35 ft. The distributions of the groups differed significantly (Wilcoxon rank sum test U_1=11, U_2=34, n_1=4, n_2=5, P<0.05 two tailed).

FIGURE 17b. Bull Trout and Dolly Varden Juvenile Velocity Preference-Large Streams
Use with Streams >= 35' LBTW[1]. Analysis based on 5 studies and 80 fish (Troublesome Creek, and Chiwawa, Dungeness, and Tucannon rivers).
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity suitability
0.00-0.09	0.24	0.00	0.25
0.10 0.19	0.52	0.35	0.70
0.20 0.29	0.61	0.45	1.0
0.30-0.39	0.60	0.55	1.0
0.40-0.49	1.0	0.95	0.65
0.50-0.59	0.99	3.15	0.28
0.60-0.79	0.85	3.45+	0.00
0.80-0.89	0.67		
0.90-0.99	0.57		
1.00-1.09	0.60		
1.10-1.19	0.63		
1.20-1.29	0.65		
1.30-1.39	0.61		
1.40-1.49	0.54		
1.50-1.69	0.55		
1.70-1.79	0.51		
1.80-1.89	0.50		
1.90-1.99	0.49		
2.00-2.09	0.45		
2.10-2.29	0.46		
2.30-3.49	0.32		
2.50-2.59	0.33		
2.60-2.79	0.31		
2.80-2.89	0.30		
2.90-3.09	0.29		
3.10-3.29	0.28		
3.30+	0.0		



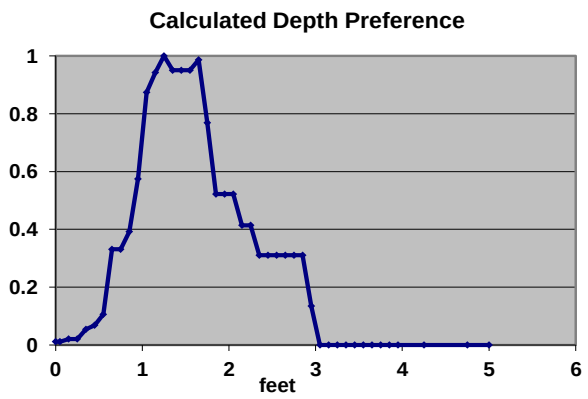


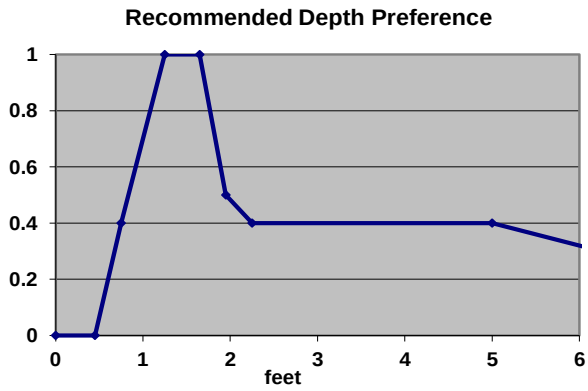
For Bull Trout and Dolly Varden Juvenile Cover/Substrate Preference, use Table 3.

[1] The median HSC peak in groups Small (<35') and Large (>=35') LBTW were 0.10 and 0.45 ft/sec respectively. The distributions of the groups differed significantly (Wilcoxon rank sum test U_1=11, U_2=34, n_1=4, n_2=5, P<0.05 two tailed).

FIGURE 18a. Bull Trout and Dolly Varden Juvenile Depth Preference in Small Streams
Use on Streams with < 35' LBTW[1]. Analysis based on 4 studies and 28 fish (Rock, Early Winters, and Phelps creeks and Mad River). **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.09	0.01	0.00	0.00
0.10-0.29	0.02	0.45	0.00
0.30-0.39	0.05	0.75	0.40
0.40-0.49	0.07	1.25	1.0
0.50-0.59	0.11	1.65	1.0
0.60-0.69	0.33	1.95	0.50
0.70-0.89	0.39	2.25	0.40
0.90-0.99	0.57	5.0	0.40
1.00-1.09	0.87	10.0+	0.00
1.10-1.19	0.94		
1.20-1.29	1.0		
1.30-1.59	0.95		
1.60-1.69	0.99		
1.70-1.79	0.77		
1.80-2.09	0.52		
2.10-2.29	0.41		
2.30-2.89	0.31		
2.90-2.99	0.13		
3.00+	No data		



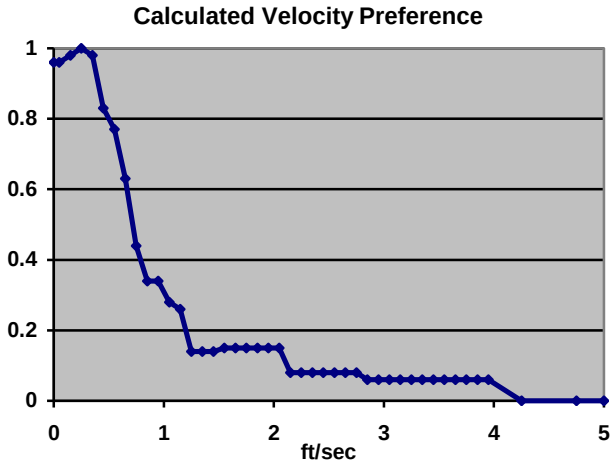


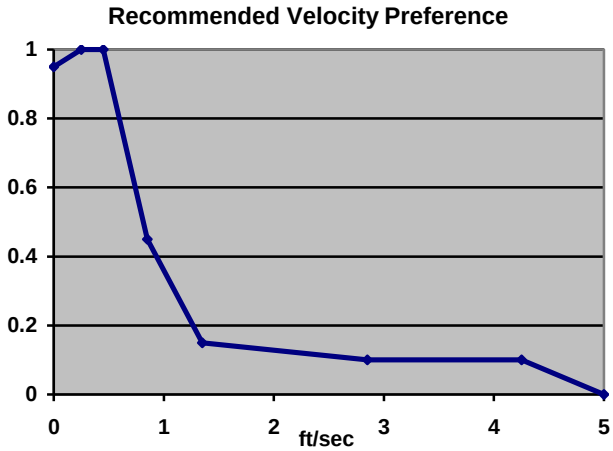
For Bull Trout and Dolly Varden Juvenile Cover/Substrate Preference, use Table 3.

[1] The median HSC peak in groups Small (<35') and Large (>=35') LBTW were 0.95 and 1.35 ft respectively. The distributions of the groups differed significantly (Wilcoxon rank sum test U_1=11, U_2=34, n_1=4, n_2=5, P<0.05 two tailed).

FIGURE 18b. Bull Trout and Dolly Varden Juvenile Velocity Preference-Small Streams
Use on Streams with < 35' LBTW[1]. Analysis based on 4 studies and 28 fish (Rock, Early Winters, and Phelps creeks and Mad River). **Preference has changed from the 2004 edition.**

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity suitability
0.00-0.09	0.96	0.00	0.95
0.10 0.19	0.98	0.25	1.0
0.20 0.29	1.0	0.45	1.0
0.30-0.39	0.98	0.85	0.45
0.40-0.49	0.83	1.35	0.15
0.50-0.59	0.77	2.85	0.10
0.60-0.69	0.63	4.25	0.10
0.70-0.79	0.44	5.0	0
0.80-0.89	0.34		
0.90-1.09	0.28		
1.10-1.19	0.26		
1.20-1.49	0.14		
1.50-2.09	0.15		
2.10-2.79	0.08		
2.80-3.99	0.06		
4.00+	No data		



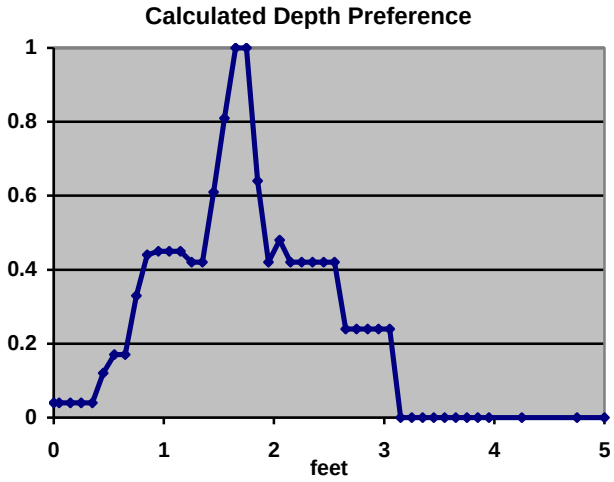


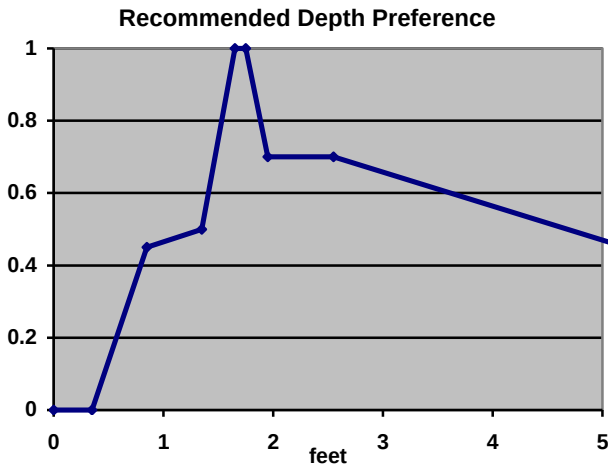
For Bull Trout and Dolly Varden Juvenile Cover/Substrate Preference, use Table 3.

[1] The median HSC peak in groups Small (<35') and Large (>=35') LBTW were 0.10 and 0.45 ft/sec respectively. The distributions of the groups differed significantly (Wilcoxon rank sum test U_1=11, U_2=34, n_1=4, n_2=5, P<0.05 two tailed).

FIGURE 19a. Brook Trout Juvenile Rearing Depth Preference
Analysis based on 4 studies and 39 fish (Ohanapecosh River and Leech Creek).
Preference has changed from the 2004 edition.

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.39	0.04	0.00	0.00
0.40-0.49	0.12	0.35	0.00
0.50-0.69	0.17	0.85	0.45
0.70-0.79	0.33	1.35	0.50
0.80-0.89	0.44	1.65	1.0
0.90-1.19	0.45	1.75	1.0
1.20-1.39	0.42	1.95	0.70
1.40-1.49	0.61	2.55	0.70
1.50-1.59	0.81	10+	0
1.60-1.79	1.0		
1.80-1.89	0.64		
1.90-1.99	0.42		
2.00-2.09	0.48		
2.10-2.59	0.42		
2.60-3.09	0.24		
3.10+	No data		



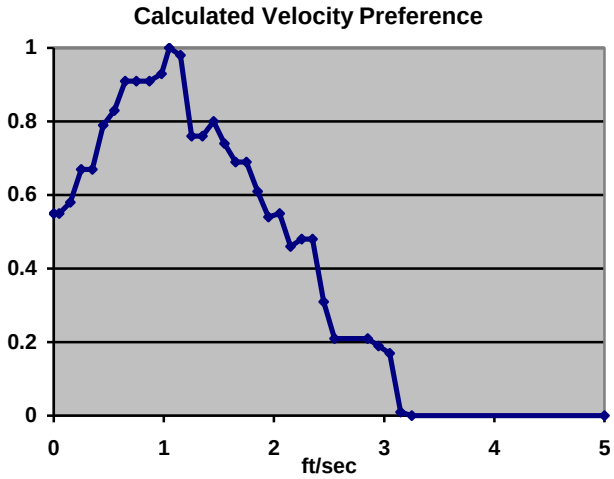


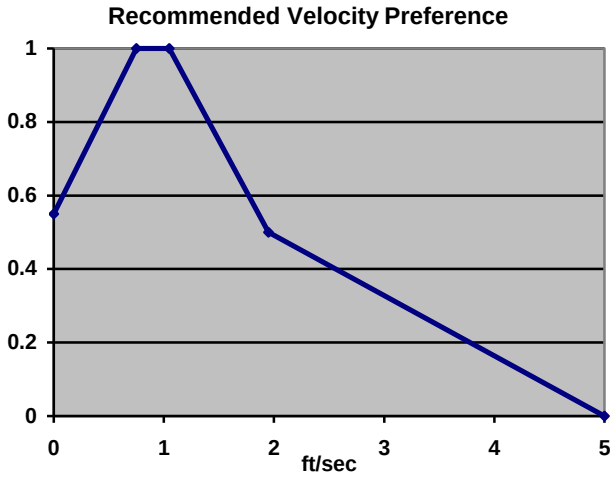
HSC Notes: The calculated preference reduction after 1.7 ft comes from studies with 1.0 preference dropping to 0.0 due to a lack of habitat availability. We chose to maintain a 0.70 preference out to 2.55 ft then reduced it to 0.0 at 10'

For Brook Trout Juvenile Rearing Cover/Substrate Preference, use Table 3.

FIGURE 19b. Brook Trout Juvenile and Adult Rearing Velocity Preference
Analysis based on 4 studies and 39 fish (Ohanapecosh River and Leech Creek).
Preference has changed from the 2004 edition.

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00 0.09	0.55	0.00	0.55
0.10 0.19	0.58	0.75	1.0
0.20 0.39	0.67	1.05	1.0
0.40-0.49	0.79	1.95	0.50
0.50-0.59	0.83	3.25+	0.00
0.60-0.89	0.91		
0.90-0.99	0.93		
1.00-1.09	1.0		
1.10-1.19	0.98		
1.20-1.39	0.76		
1.40-1.49	0.80		
1.50-1.59	0.74		
1.60-1.79	0.69		
1.80-1.89	0.61		
1.90-1.99	0.54		
2.00-2.09	0.55		
2.10-2.19	0.46		
2.20-2.39	0.48		
2.40-2.49	0.31		
2.50-2.89	0.21		
2.90-2.99	0.19		
3.00-3.09	0.17		
3.10-3.19	0.01		
3.20+	0.0		



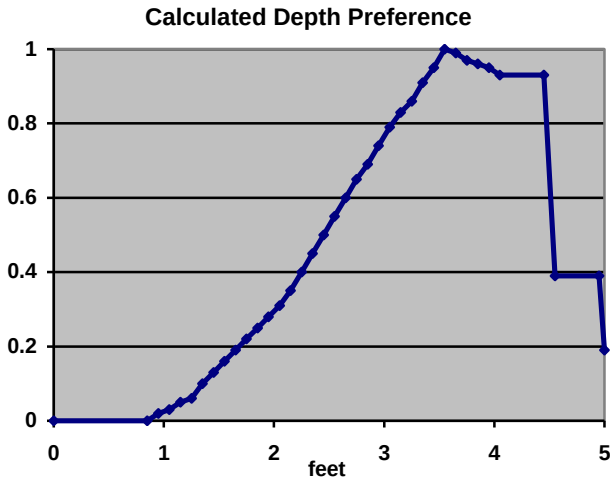


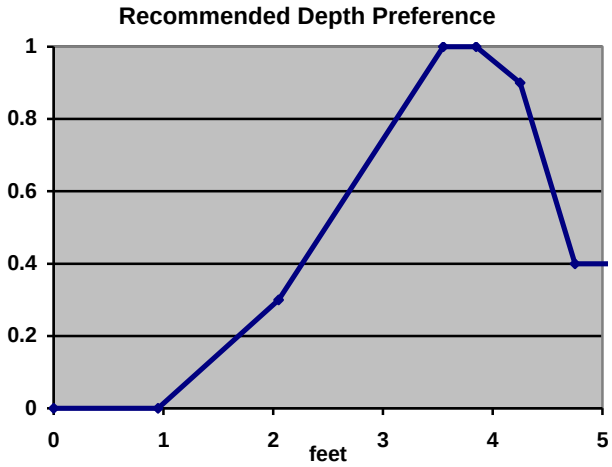
HSC Notes: There were not enough studies to analyse stream size differences

For Brook Trout Juvenile Rearing Cover/Substrate Preference, use Table 3.

FIGURE 20a. Mountain Whitefish Adult Spawning and Rearing Depth Preference
Analysis based on a composite of 7 Canadian studies (Sheep, Bow, Kananaskis, Red Deer and Highwood rivers)*. **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-1.09	0.00	0.00	0.00
1.10-1.29	0.01	1.35	0.20
1.30-1.49	0.02	1.95	0.30
1.50-1.59	0.04	2.95	1.0
1.60-1.69	0.08	3.35*	1.0
1.70-1.79	0.12	3.95*	0.73
1.80-1.89	0.17	5.0*	0.60
1.90-1.99	0.22	10.0*	0.00
2.00-2.09	0.29		
2.10-2.19	0.36		
2.20-2.29	0.42		
2.30-2.39	0.49		
2.40-2.49	0.60		
2.50-2.59	0.71		
2.60-2.69	0.81		
2.70-2.79	0.90		
2.80-2.89	0.95		
2.90-2.99	0.97		
3.00-3.09	0.99		
3.10-3.29	1.0		
3.30-3.39	0.96		
3.40-3.49	0.92		
3.50-3.59	0.89		
3.60-3.69	0.72		
3.70-3.79	0.81		
3.80-3.89	0.77		
3.90-3.99	0.73		
4.00-4.49	0.69		
4.50-4.99	0.65		
5.0+	0.49		

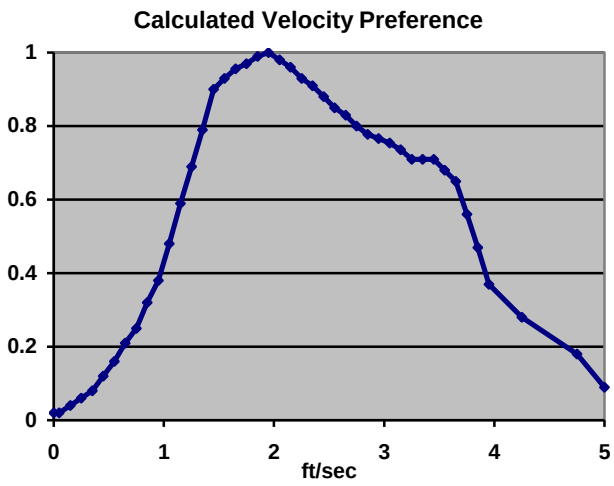




HSC Notes: *The studies analyzed have a mix of spawning and rearing fish. The recommended table is designed for spawning. If an adult rearing is needed, continue the 1.0 preference at 3.35 ft out to 99 feet.

FIGURE 20b. Mountain Whitefish Adult Spawning and Rearing Velocity Preference
Analysis based on a composite of 7 Canadian studies (Sheep, Bow, Kananaski, Red Deer and Highwood rivers). **Preference has changed from the 2004 edition.**

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.02	0.00	0.00
0.10-0.19	0.04	1.25	0.45
0.20-0.29	0.06	1.55	1.0
0.30-0.39	0.08	1.95	1.0
0.40-0.49	0.12	3.75	0.75
0.50-0.59	0.16	4.25	0.60
0.60-0.69	0.21	5.0+	0.00
0.70-0.79	0.25		
0.80-0.89	0.32		
0.90-0.99	0.38		
1.00-1.09	0.48		
1.10-1.19	0.59		
1.20-1.29	0.69		
1.30-1.39	0.76		
1.40-1.49	0.90		
1.50-1.59	0.93		
1.60-1.79	0.96		
1.80-1.89	0.99		
1.90-1.99	1.0		
2.00-2.09	0.98		
2.10-2.19	0.96		
2.20-2.29	0.93		
2.30-2.39	0.91		
2.40-2.49	0.88		
2.50-2.59	0.85		
2.60-2.69	0.83		
2.70-2.79	0.80		
2.80-2.99	0.78		
3.00-3.19	0.74		
3.20-3.49	0.71		
3.50-3.59	0.68		
3.60-3.69	0.65		
3.70-3.79	0.56		
3.80-3.89	0.47		
3.90-3.99	0.37		
4.00-4.99	0.28		
4.50-4.99	0.18		
5.0	0.09		



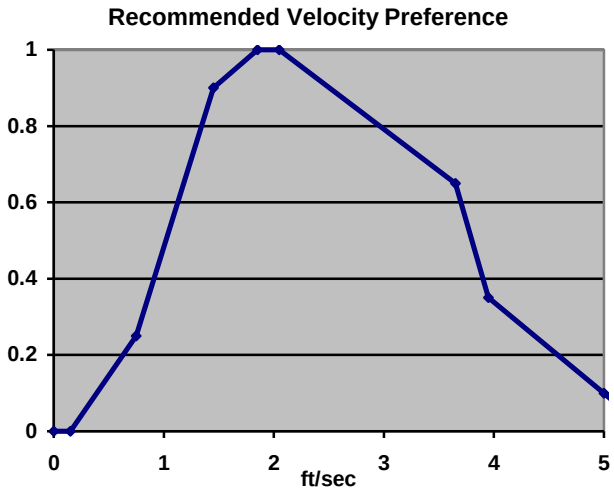
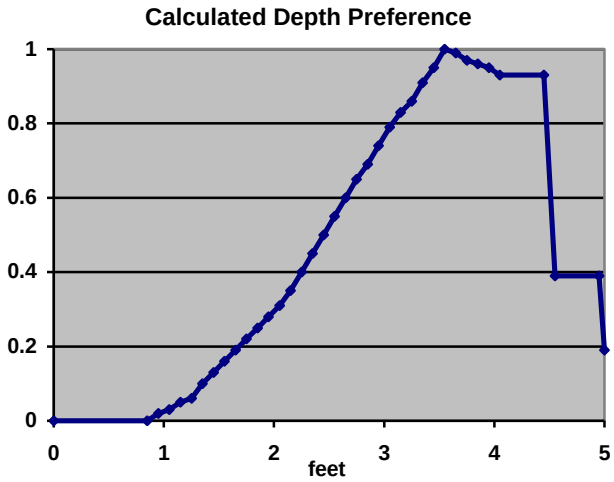


FIGURE 21a. Mountain Whitefish Juvenile Depth Preference
Analysis based on a composite of 4 Canadian studies (Sheep, Bow, Kananaskis, and Red Deer rivers). **Preference has changed from the 2004 edition.**

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.89	0.00	0.00	0.00
0.90-0.99	0.02	0.95	0.00
1.00-1.09	0.03	2.05	0.30
1.10-1.19	0.05	3.55	1.0
1.20-1.29	0.06	3.85	1.0
1.30-1.39	0.10	4.25	0.90
1.40-1.49	0.13	4.75	0.40
1.50-1.59	0.61	10.0	0.40
1.60-1.69	0.19	30.0+	0.00
1.70-1.79	0.22		
1.80-1.89	0.25		
1.90-1.99	0.28		
2.00-2.09	0.31		
2.10-2.19	0.35		
2.20-2.29	0.40		
2.30-2.39	0.45		
2.40-2.49	0.50		
2.50-2.59	0.55		
2.60-2.69	0.60		
2.70-2.79	0.65		
2.80-2.89	0.69		
2.90-2.99	0.74		
3.00-3.09	0.79		
3.10-3.19	0.83		
3.20-3.29	0.86		
3.30-3.39	0.91		
3.40-3.49	0.95		
3.50-3.59	1.0		
3.60-3.69	0.99		
3.70-3.79	0.97		
3.80-3.89	0.96		
3.90-3.99	0.95		
4.00-4.49	0.93		
4.50-4.99	0.39		
5.0+	0.19		



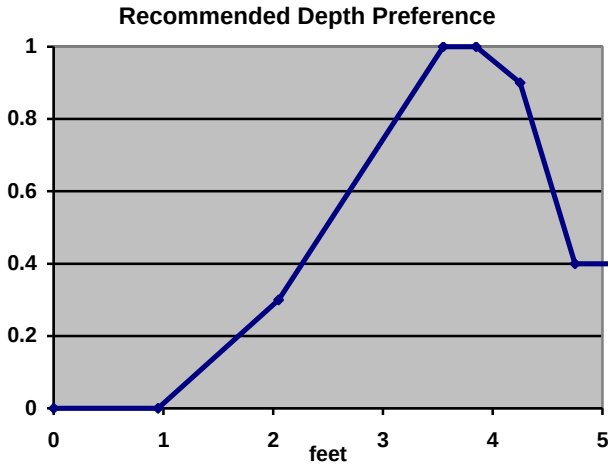
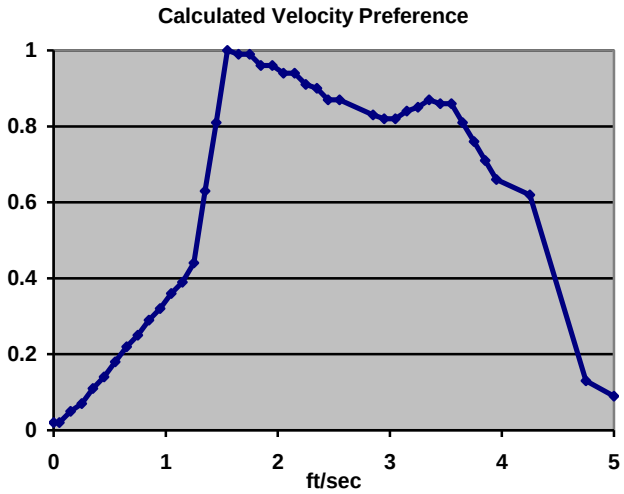
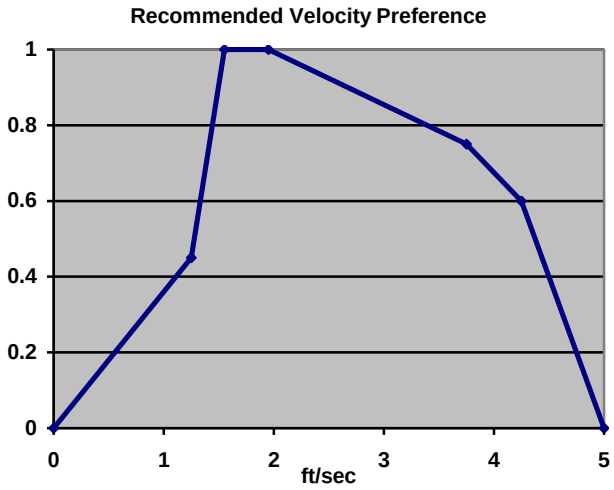


FIGURE 21b. Mountain Whitefish Juvenile Velocity Preference
Analysis based on a composite of 4 Canadian studies (Sheep, Bow, Kananaskis, and Red Deer rivers). **Preference has changed from the 2004 edition.**

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.02	0.00	0.00
0.10-0.19	0.05	1.25	0.45
0.20-0.29	0.07	1.55	1.0
0.30-0.39	0.11	1.95	1.0
0.40-0.49	0.14	3.75	0.75
0.50-0.59	0.18	4.25	0.60
0.60-0.69	0.22	5.0+	0.00
0.70-0.79	0.25		
0.80-0.89	0.29		
0.90-0.99	0.32		
1.00-1.09	0.36		
1.10-1.19	0.39		
1.20-1.29	0.44		
1.30-1.39	0.63		
1.40-1.49	0.81		
1.50-1.59	1.0		
1.60-1.79	0.99		
1.80-1.99	0.96		
2.00-2.19	0.94		
2.20-2.29	0.91		
2.30-2.39	0.90		
2.40-2.59	0.87		
2.60-2.79	0.85		
2.80-2.89	0.83		
2.90-3.09	0.82		
3.10-3.19	0.84		
3.20-3.29	0.85		
3.30-3.39	0.87		
3.40-3.59	0.86		
3.60-3.69	0.81		
3.70-3.79	0.76		
3.80-3.89	0.71		
3.90-3.99	0.66		
4.00-4.49	0.62		
4.50-4.99	0.13		
5.0+	0.09