INSTREAM FLOW STUDY GUIDELINES

Technical and Habitat Suitability Issues Including Fish Preference Curves

UPDATED, January 25, 2022

Washington Department of FISH and WILDLIFE

WASHINGTON STATE DEPARTMENT OF ECOLOGY

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2022 Updates

- Two habitat suitability studies were added to the juvenile Bull Trout/Dolly Varden rearing analysis increasing fish observations by 19. The associated depth and velocity preference curves were updated.
- Three habitat suitability studies were added to the juvenile Cutthroat Trout rearing analysis increasing fish observations by 117. The associated depth and velocity preference curves were updated.

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. 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 of water shall be maintained and protected and no further degradation shall be allowed. The minimum instream flow may not cause any further degradation of beneficial water uses such as; fish habitat, 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).

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 laws 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 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. 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 as;

1. diverting at least 1.0 cubic foot per second (cfs), and
2. changing flow by at least 10 percent of the monthly 90 percent exceedance flow at any point along the stream channel.

The purposes of WDFW's instream flow recommendation are;

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

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[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.

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 a Physical Habitat Simulation (PHABSIM) study, part of the Instream Flow Incremental Methodology (IFIM), following quality control and model limitations consistent with the Instream Flow Study Guidelines.

Consultation with appropriate WDFW and Ecology staff and adherence to these IFIM study guidelines during all phases of the instream study is crucial. We request proponents document agency consultation at each step through signature of a WDFW Habitat Program employee using the form on the following page.

Primary contacts:

WDFW:
Kiza Gates, PhD
kiza.gates@dfw.wa.gov, 360-701-8763

Ecology:
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WDFW INSTREAM FLOW CONSULTATION

PROJECT:____

STREAM:____

FERC#:______________________

Documentation of consultation with WDFW on instream flow studies - all blanks must be signed by WDFW personnel to complete 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 January 25, 2022

PURPOSE OF AN INSTREAM FLOW STUDY

Washington State resource agencies, including the Washington Department of Ecology (Ecology) and Washington Department of Fish and Wildlife (WDFW), when needing to make decisions or recommendations on a project that will affect stream flows, will often request studies to evaluate the impacts of the altered flow on instream resources, including fish habitat and production. 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, alter fish populations, both numbers and fish species. 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 preserve the fish production potential of a stream.

This study provides information about the relationship between streamflow and fish habitat, which can be used in determining instream flow requirements for fish.

Four key variables of fish habitat are examined:

1. depth
2. velocity
3. substrate
4. 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 WUA habitat indexes at each flow correspond to the biological requirements of the fish species and life stage of interest. Results of an IFIM/PHABSIM study predict how WUA for each species and lifestage change over a range of streamflows. With this fish habitat information and other information, such as the stream's hydrology, resource agencies can recommend instream flows needed to perpetuate or 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 is typically found during the summer/fall 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 varying factors that affect fish survival and productivity. These include fish harvest, ocean survival, water quality, food supply, adult and juvenile fish passage, 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, 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 project delays.

Ramping Rates

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

The impacts of flow fluctuation are mitigated by specifying an amount 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. Until then, interim ramping rates are established according to the following chart by 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		

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 consider which critical flows should be measured.

KEY ELEMENTS OF INSTREAM FLOW STUDY

It is the responsibility of the project proponent to consult with the appropriate personnel in state agencies (Ecology and WDFW) and other resource management agencies (including U.S. Fish and Wildlife Service and National Marine Fisheries Service) and affected Tribal governments at all stages of the study.

Stages of the study include:

- Planning or scoping - develop study plan and obtain approval from all parties;
- Fish habitat preference curve verification or use of default curves;
- Field data collection;
- Hydraulic model calibration; and
- Habitat model runs.

Having approval from all interested agencies on the study plan, model calibration, preference curves, and computer options will prevent surprise delays during 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 two-weeks notice is usually necessary. The purpose of the meeting is to discuss possible project designs and to develop a study plan to assess the potential impacts on all instream resources.

To prepare for the meeting, the project proponent should thoroughly investigate the stream reach to be affected by the project. This should include all the way downstream from the project to the next major confluence.

Documentation that would expedite agency review and planning includes:

- Topographical maps with contour intervals no greater than 20 feet;
- Identification of areas along the stream that exhibit major morphological changes in the stream bed and/or stream banks;
- Graph of elevation plotted against the stream's longitudinal distance;
- Low altitude photo mosaic (preferred) or video tape of entire reach (low-flow in winter is best if canopy closure is an issue);
- On-the-ground photos or video tape of all habitat types and potential barriers to fish migration (include a reference object for scale in pictures of potential barriers);
- List of the fish species known or expected in the stream reach; and
- Available hydrological data such as the 10, 50, and 90 percent exceedance discharges by month; and information on the source of this data.

The proponent should plan to conduct an instream flow study using the PHABSIM or Riverine HABitat SIMulation (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.

The proponent should seek agency approval at each step of the study;

1. site and transect selection,
2. general field work plan including any deviations from standard field protocols,
3. hydraulic model calibration,
4. Habitat Suitability Criteria (HSC) validation studies,
5. final HSC and habitat model use, and
6. any interpretation approaches recommended.

In preparation for the planning meeting or 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 with IFIM experience should select these tentative transects. The follow-up site visit should be done under suitable viewing conditions to allow agency representatives to view, modify as needed, and approve placement of transects (1).

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 amended 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:

- Locations of transects and study sites (1), with maps and photos or videos as documentation;
- Range of flows to be addressed and targeted flows to be measured as calibration flows (2);
- Available hydrographs to be used and any new hydrology to be collected (2);
- Hydraulic model(s) to be used (e.g., IFG4, WSP/ IFG2, MANSQ) (3);
- Habitat preference curve verification study plan (see below) (4);
- Habitat models to be used (HABSIM or similar model, plunge pool, and so on) (5);
- Any limiting factor analysis or time series analysis (6); and
- Ramping rate study plan and sites.

FISH HABITAT SUITABILITY CRITERIA CURVE VERIFICATION

To complete the instream flow study, the project proponent must make a reasonable effort to determine fish habitat suitability or preference at the study site or an approved substitute site. The study outlined here is a reasonable effort. Preference curve verification will be aimed at selected species and lifestages.

The preference curve verification study consists of three parts:

1. Determining proportional habitat availability;
2. Determining fish habitat usage; and
3. Analyzing 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 four 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 velocity 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 on a grid based on evenly spaced transects.

If transects are evenly spaced, no weighting is needed. A weighting factor for the PHABSIM transect in which it is measured or simulated will apply to the frequency of each habitat variable (depth, velocity, cover, substrate) interval. For example, if some PHABSIM transects are taken at 30’ intervals and others at 60’ intervals, the variables measured in the 60’ interval transects would need twice the weight of those measured with the 30’ interval transect. If the preference curve verification study reach is smaller than the IFIM study reach, then different weighting factors may be required for determining habitat availability than were 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. The preferred approach is to conduct fish observations prior to collecting habitat availability measurements. Fish observations and habitat suitability measurements are ideally collected on the same day when possible, or within a relatively short time frame before streamflow changes significantly.

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 taking part, they should coordinate positions to avoid disturbing fish or double-counting them. The snorkeler should determine that an observed fish is not disturbed before recording habitat data (depth, velocity, substrate, and cover) for the location. An observation is good 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 good 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.

Analyzing 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, a 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. As shown below:

Depth Interval (ft)	Frequency(%)	Observations	Expected	Expected >5
0.00-0.09	1.3	O= 0	E= 1.13	
0.10-0.19	1.4	O= 0	E= 1.22	
0.20-0.29	4.3	O= 0	E= 3.74	E= 6.09
0.30-0.39	4.8	O= 0	E= 4.18	
0.40-0.49	5.1	O= 0	E= 4.44	E= 8.62
0.50-0.59	7.8	O= 1	E= 6.79	E= 6.79
0.60-0.69	9.7	O= 3	E= 8.44	E= 8.44
0.70-0.79	14.7	O=23	E=12.79	E=12.79
0.80-0.89	18.2	O=26	E=15.83	E=15.83
0.90-0.99	15.0	O=21	E=13.05	E=13.05
1.00-1.09	11.5	O= 7	E=10.01	E=10.01
1.10-1.19	4.6	O= 3	E= 4.00	
> 1.19	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 (each O/E Ratio value is divided by the highest O/E Ratio in the column; see Bovee, 1986) to create the preference factor so that the maximum value of P is 1.00:

Depth Interval (ft) with E>5	O/E Ratio	Preference
0.00-0.29	0/6.09=0.00	P=0.00
0.30-0.49	0/8.62=0.00	P=0.00
0.50-0.59	1/6.79=0.15	P=0.08
0.60-0.69	3/8.44=0.36	P=0.20
0.70-0.79	23/12.79=1.80	P=1.00
0.80-0.89	26/15.83=1.64	P=0.91
0.90-0.99	21/13.05=1.61	P=0.89
1.00-1.09	7/10.01=0.70	P=0.39
> 1.09	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 (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 preference curve we sample the distribution repeatedly and average the resulting values, then normalize 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 (ft)	Area (%)	Fish	Expected	Observed/Group Expected				
				E>5	E>4	E>3	E>2	E>1
0.00-0.09	1.3	O=0	0.247	0.153	0	0	0	0
0.10-0.19	1.4	O=0	0.266	0.153	0	0	0	0
0.20-0.29	4.3	O=0	0.817	0.153	0	0	0	0
0.30-0.39	4.8	O=0	0.912	0.153	0	0	0	0
0.40-0.49	5.1	O=0	0.969	0.153	0	0	0	0
0.50-0.59	7.8	O=0	1.482	0.153	0	0.301	0	0
0.60-0.69	9.7	O=1	1.843	0.153	1.294	0.301	1.294	0.543
0.70-0.79	14.7	O=5	2.793	1.760	1.294	1.760	1.294	1.790
0.80-0.89	18.2	O=6	3.458	1.760	1.585	1.760	1.735	1.735
0.90-0.99	15.0	O=4	2.85	1.192	1.585	1.192	1.404	1.404
1.00-1.09	11.5	O=2	2.185	1.192	0.862	1.192	0.915	0.915
1.10-1.19	4.6	O=0	0.874	0.562	0.892	0.849	0.849	0.849
> 1.19	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 (ft)	Area (%)	Fish	Expected	Suitability ((Obs/Exp)/Exp_{max})						
				E>5	E>4	E>3	E>2	E>1	Ave.	Final
0.00-0.09	1.3	O=0	0.247	0.087	0	0	0	0	0.017	0.017
0.10-0.19	1.4	O=0	0.266	0.087	0	0	0	0	0.017	0.017
0.20-0.29	4.3	O=0	0.817	0.087	0	0	0	0	0.017	0.017
0.30-0.39	4.8	O=0	0.912	0.087	0	0	0	0	0.017	0.017
0.40-0.49	5.1	O=0	0.969	0.087	0	0	0	0	0.017	0.017
0.50-0.59	7.8	O=0	1.482	0.087	0	0.171	0	0	0.052	0.052
0.60-0.69	9.7	O=1	1.843	0.087	0.816	0.171	0.746	0.303	0.425	0.427
0.70-0.79	14.7	O=5	2.793	1.000	0.816	1.000	0.746	1.000	0.912	0.918
0.80-0.89	18.2	O=6	3.458	1.000	1.000	1.000	1.000	0.969	0.994	1.000
0.90-0.99	15.0	O=4	2.85	0.677	1.000	0.677	0.809	0.784	0.789	0.794
1.00-1.09	11.5	O=2	2.185	0.677	0.563	0.677	0.528	0.511	0.591	0.595
1.10-1.19	4.6	O=0	0.874	0.319	0.563	0.482	0.489	0.474	0.466	0.468
> 1.19	1.6	O=1	0.304	0.319	0.563	0.482	0.489	0.474	0.466	0.468

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

If the project proponent's reasonable effort does not produce enough data to verify or modify agencies' default generalized habitat preference curves, then default curves should be used with agency approval (see below and Appendix for discussion of default preference curves).

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

We initially found a statistically significant difference in the stream specific HSC curves developed for small streams (< 35') and large streams (>35') using the Wilcoxon rank sum test (P<0.05). However, several subsequent verification studies showed that the distribution pattern predicted by the all stream composite preference curve were not statistically different from the patterns observed in the stream.

We studied four streams (3 small and 1 large stream) looking at the depth, velocity and depth*velocity distribution patterns of O.mykiss juveniles. We then tested the hypothesis that the all-stream composite depth and velocity curves could accurately predict this distribution. The 12 chi-squared tests had P values ranging from 0.08 to 0.88 supporting the hypothesis. As a result, we returned to an all-stream composite for juvenile rearing curves.

HYDRAULIC MODEL CALIBRATION

The agencies first choice of hydraulic model is IFG4 using three sets of velocity measurements to establish regressions of velocity with flow and the Dual stage to discharge rating (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 of IFG4 (i.e., more realistic velocities and better velocity adjustment factors at higher and lower than measured flows) without deterioration of interpolation (i.e., flows at and between the measured flows), 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):

- Field notes.

- 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.

- 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).

- Tables of pre-and-post calibration Velocity Adjustment Factors (VAF) for each transect and each simulated flow over the proposed range of the model.

- Tables of "computational details" for each simulated flow, including calibration flows.

- List of options used in the hydraulic model.

- Site map showing placement of numbered transects in relation to pools, riffles, chutes, large boulders, large woody debris, and other channel features.

- Table of stage differences between flows and between transects, such as shown below.

	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 conducted and our model review is prolonged.

Other hydraulic models can be considered 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 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:

- The preference curves used with documentation of agency approval.
- The 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:

- 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.
- 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.
- 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 18).

The field method for plunge pool analysis requires establishment of permanent transects and vertical depth measurement points ("verticals") along the transects. We recommend you use at least three transects and record the 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 transects. 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. You should consider an area as part of the plume if velocity is substantially greater than 1 foot per second unless the plume boundary is 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 that 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:

- Our knowledge of site hydrology and effects of hydrology on fish (e.g., scouring of redds and incubation flows).

- 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).

- Modeled responses to flow of coexisting species.

For a more detailed discussion of agency considerations in interpreting studies and developing 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. The necessary magnitude, frequency, and duration of these flows depend on fish stock and stream conditions. Review of hydrological record and any fish count data available may be required to develop site-specific recommendations.

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 least twice per year, if not provided naturally.

Channel maintenance flows – Channel maintenance flows for geomorphic processes are greater in magnitude and duration than flows necessary for initiation of bedload movement. Ecology and WDFW 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 every two years if not provided naturally.

Please note: The preceding 2-year peak flow rate and the following 10-year peak flow rate should be based on natural hydrology, not hydrology modified by extensive increases in impervious surface, nor other hydrologic modifications. Also, release rates of these high flows should be controlled according to specified ramping rates (Hunter 1992).

Channel forming flows – WDFW 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 least once every 10 years if not provided naturally. In addition, the project should be consistent with guidance provided by Wald (2009).

<u>**Time-series analysis.**</u> Project proponents may wish to do a time-series analysis (Milhous 1986). Evaluation of changes in habitat as well as changing habitat needs over time is an important consideration for rearing fish. <u>The Agencies neither request nor endorse the use of time-series models.</u> However, if requested to consider results of such analysis, agencies will accept them only over the range of flows for which they have approved for the hydraulic model. In addition, any time-series of alternative flow regimes must incorporate temperature-based metabolic factors, i.e., the Habitat-Temperature Index (HTI), 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 Celsius at that season.

The comparison of interest is WUA(A)/HTI vs WUA(B)/HTI. HTI need not be used for spawning or incubation.

If significant temperature modifications are anticipated or if trade-offs of rearing habitat are being considered across seasons (not generally recommended), then it may be appropriate to use a Temperature Suitability Factor (TSF) in conjunction with HTI to generate a Habitat Value index: HabVal = TSF * WUA/HTI. Temperature suitability factors should be based on literature and must be approved by the agencies.

RAMPING RATE STUDIES

Information needed to determine ramping rate includes:

- Identification of critical stranding sites.
- Determination of stage-discharge relationship at critical sites.
- Determination of travel time for a block of water traveling through a reach of interest.
- 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 areas 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 the changes in depth produced by changes 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

APPENDIX

DEFAULT COVER/SUBSTRATE PREFERENCE TABLES AND DEPTH AND VELOCITY PREFERENCE CURVES

List of Tables

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Appendix Notes

Tables and figures in this appendix list the WDFW and Ecology recommended Habitat Suitability Criteria (HSC) or preference codes and values for instream flow modeling using PHABSIM or RHABSIM models. These values are based on habitat suitability studies. WDFW and/or Ecology staff (or individuals following WDFW-Ecology study guidelines) recorded the depth, velocity, substrate, and cover used by fish in a study reach. The results were then compared to the measured percent availability of different depths, velocities, substrates, and cover 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 the 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 9 are calculated from generic preferences in **Table 1** according to the following equation:

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

where RP is the recommended preference, c is the percent presence of the dominant substrate, Pa is the preference factor for the dominant substrate, Pb is the preference factor for the subdominant substrate, and (1-c) is the assumed percent presence of the subdominant substrate. Because there are often more than two substrate types we know the percent subdominant substrate does not usually follow the (1-c) calculation, but because we are limited to the “ab.c” format it is an error we are willing to accept. 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 for salmon and trout spawning, 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-20b show the various recommended preference curves along with the coordinates used to make the curves. When available, sample size and study locations are provided. Recommended preference curves represent smoothed versions of the calculated preference curves. Smoothing of preference coordinates begins with calculated suitabilities that are then adjusted based on actual observations and professional judgment. Such smoothing removed stair-stepped patterns at the upper and lower ends of the hydraulic distributions.

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.

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 Value[1]

Code	type of cover Note: Cover Codes are not used for spawning						Salmon & Trout Rearing	Whitefish Rearing	
							juvenile & resident adult	juvenile	adult
00.1	undercut bank						1.00	1.00	1.00
00.2	overhanging vegetation near or touching water[2]						1.00	1.00	1.00
00.3	rootwad (including partly undercut)						1.00	1.00	1.00
00.4	log jam/submerged brush pile						1.00	1.00	1.00
00.5	log(s) parallel to bank						0.80	0.80	0.80
00.6	aquatic vegetation						0.80	0.80	0.80
00.7	short (<1') terrestrial grass						0.10	0.10	0.10
00.8	tall (>3') dense grass[3]						0.70	0.70	0.10
00.9	vegetation > 3 vertical ft above SZF						0.20	0.20	0.20
Code	type of substrate	Spawning					Salmon & Trout Rearing	Whitefish Rearing	
		salmon	steelhead[4]	resident trout	native char[5]	whitefish	juvenile & resident adult	juvenile	adult
1	silt, clay, or organic	0.00	0.00	0.00	0.00	00	0.10	0.38	0.15
2	sand	0.00	0.00	0.00	0.00	0.00	0.10	0.38	0.15
3	sm gravel (.1-.5")	0.30	0.50	0.80	1.00	1.00	0.10	0.74	0.76
4	med gravel (.5-1.5")	1.00	1.00	1.00	1.00	1.00	0.30	0.88	0.91
5	lrg gravel (1.5-3")	1.00	1.00	0.80	1.00	1.00	0.30	0.88	0.91
6	sm cobble (3-6")	1.00	1.00	0.50	0.70	1.00	0.50	1.00	1.00
7	lrg cobble (6-12")	0.50	0.30	0.00	0.70	0.50	0.70	1.00	1.00
8	boulder (>12")	0.00	0.00	0.00	0.0	0.0	1.00	1.00	1.00
9	bedrock	0.00	0.00	0.00	0.00	0.00	0.30	0.50	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. Generic Salmon 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	0.30	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	0.50
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	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	0.50
58.9	1.00	0.00	0.90
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. 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* 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
69.5	1.00	0.00	0.00*
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. Generic Juvenile & Resident Adult Salmon and Trout Cover/Substrate Preference[1]

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 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).
* 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. 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
44.9	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 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* 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
77.9	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. 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 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).
* Asterisk indicated deviation from the RP formula.

TABLE 5. Continued

Code (ab.c)	Preference value a	Preferenc e 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. 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*
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*
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*
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
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*

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 20).
* Asterisk indicated deviation form RP formula.

Table 6. Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
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*
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
93.5	0.00	0.00	0.00*
97.9	0.00	1.00	0.00*
99.9	0.00	0.00	0.00

TABLE 7. Mountain Whitefish (*Prosopium williamsoni*) 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
21.9	0.00	0.00	0.00
31.5	1.00	0.00	0.50
31.9	1.00	0.00	0.90
32.5	1.00	0.00	0.50
32.9	1.00	0.00	0.90
33.9	1.00	1.00	1.00
36.9	1.00	1.00	1.00
37.5	1.00	0.50	0.75
37.9	1.00	0.50	0.95
38.5	1.00	0.00	0.50
38.9	1.00	0.00	0.90
39.5	1.00	0.00	0.50
39.9	1.00	0.00	0.90
41.5	1.00	0.00	0.50
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.50
42.9	1.00	0.00	0.90
43.5	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	0.50
48.9	1.00	0.00	0.90
49.5	1.00	0.00	0.50
49.9	1.00	0.00	0.90
51.5	1.00	0.00	0.50
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.50
52.9	1.00	0.00	0.90
53.5	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	0.50
58.9	1.00	0.00	0.90
59.5	1.00	0.00	0.50
59.9	1.00	0.00	0.90
61.5	1.00	0.00	0.50
61.9	1.00	0.00	0.90
62.5	1.00	0.00	0.50
62.9	1.00	0.00	0.90
63.5	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
69.5	1.00	0.00	0.50
69.9	1.00	0.00	0.90
71.5	0.50	0.00	0.25
71.9	0.50	0.00	0.45
72.5	0.50	0.00	0.25
72.9	0.50	0.00	0.45
73.5	0.50	1.00	0.75
73.9	0.50	1.00	0.55
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	0.25
79.9	0.50	0.00	0.45

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* Asterisk indicated deviation from the RP formula.

Table 7. Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
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	1.00	0.50
86.9	0.00	1.00	0.10
87.5	0.00	1.00	0.50
87.9	0.00	1.00	0.10
88.9	0.00	0.00	0.00
92.9	0.00	0.00	0.00
93.5	0.00	1.00	0.50
93.9	0.00	1.00	0.10
94.5	0.00	1.00	0.50
94.9	0.00	1.00	0.10
95.5	0.00	1.00	0.50
95.9	0.00	1.00	0.10
96.5	0.00	1.00	0.50
96.9	0.00	1.00	0.10
97.5	0.00	1.00	0.50
97.9	0.00	1.00	0.10
98.5	0.00	0.00	0.00
99.9	0.00	0.00	0.00

TABLE 8. Mountain Whitefish Adult Rearing Cover/Substrate Preference [1]

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	1.00
00.2			1.00	1.00
00.3			1.00	1.00
00.4			1.00	1.00
00.5			0.80	0.80
00.6			0.80	0.80
00.7			0.10	0.10
00.8			0.10	0.70
00.9			0.20	0.20
11.9[2]	0.15	0.15	0.15	
12.9	0.15	0.15	0.15	
13.5	0.15	0.76	0.46	
13.9	0.15	0.76	0.21	
14.5	0.15	0.91	0.53	
14.9	0.15	0.91	0.23	
15.5	0.15	0.91	0.53	
15.9	0.15	0.91	0.23	
16.5	0.15	1.00	0.58	
16.9	0.15	1.00	0.24	
17.5	0.15	1.00	0.58	
17.9	0.15	1.00	0.24	
18.5	0.15	1.00	0.58	
18.9	0.15	1.00	0.24	
19.5	0.15	0.30	0.23	
19.9	0.15	0.30	0.17	
21.5	0.15	0.15	0.15	
22.9	0.15	0.15	0.15	
23.5	0.15	0.76	0.46	
23.9	0.15	0.76	0.21	
24.5	0.15	0.91	0.53	
24.9	0.15	0.91	0.23	
25.5	0.15	0.91	0.53	
25.9	0.15	0.91	0.23	
26.5	0.15	1.00	0.58	
26.9	0.15	1.00	0.24	
27.5	0.15	1.00	0.58	
27.9	0.15	1.00	0.24	
28.5	0.15	1.00	0.58	
28.9	0.15	1.00	0.24	
29.5	0.15	0.30	0.23	
29.9	0.15	0.30	0.17	
31.5	0.76	0.15	0.46	
31.9	0.76	0.15	0.70	
32.5	0.76	0.15	0.46	
32.9	0.76	0.15	0.70	
33.9	0.76	0.76	0.76	
34.5	0.76	0.91	0.84	
34.9	0.76	0.91	0.78	
35.5	0.76	0.91	0.84	
35.9	0.76	0.91	0.78	
36.5	0.76	1.00	0.88	
36.9	0.76	1.00	0.78	
37.5	0.76	1.00	0.88	
37.9	0.76	1.00	0.78	
38.5	0.76	1.00	0.88	
38.9	0.76	1.00	0.78	
39.5	0.76	0.30	0.53	
39.9	0.76	0.30	0.71	
41.5	0.91	0.15	0.53	
41.9	0.91	0.15	0.83	
42.5	0.91	0.15	0.53	
42.9	0.91	0.15	0.83	
43.5	0.91	0.76	0.84	
43.9	0.91	0.76	0.90	
44.9	0.91	0.91	0.91	
45.9	0.91	0.91	0.91	
46.5	0.91	1.00	0.96	
46.9	0.91	1.00	0.92	
47.5	0.91	1.00	0.96	
47.9	0.91	1.00	0.92	
48.5	0.91	1.00	0.96	
48.9	0.91	1.00	0.92	
49.5	0.91	0.30	0.61	
49.9	0.91	0.30	0.85	
51.5	0.91	0.15	0.53	
51.9	0.91	0.15	0.83	
52.5	0.91	0.15	0.53	
52.9	0.91	0.15	0.83	
53.5	0.91	0.76	0.84	
53.9	0.91	0.76	0.90	
54.5	0.91	0.91	0.91	
55.9	0.91	0.91	0.91	
56.5	0.91	1.00	0.96	
56.9	0.91	1.00	0.92	

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* Asterisk indicated deviation from the RP formula.

Table 8. Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
57.5	0.91	1.00	0.96
57.9	0.91	1.00	0.92
58.5	0.91	1.00	0.96
58.9	0.91	1.00	0.92
59.5	0.91	0.30	0.61
59.9	0.91	0.30	0.85
61.5	1.00	0.15	0.58
61.9	1.00	0.15	0.92
62.5	1.00	0.15	0.58
62.9	1.00	0.15	0.92
63.5	1.00	0.76	0.88
63.9	1.00	0.76	0.98
64.5	1.00	0.91	0.96
64.9	1.00	0.91	0.99
65.5	1.00	0.91	0.96
65.9	1.00	0.91	0.99
66.9	1.00	1.00	1.00
68.9	1.00	1.00	1.00
69.5	1.00	0.30	0.65
69.9	1.00	0.30	0.93
71.5	1.00	0.15	0.58
71.9	1.00	0.15	0.92
72.5	1.00	0.15	0.58
72.9	1.00	0.15	0.92
73.5	1.00	0.76	0.88
73.9	1.00	0.76	0.98
74.5	1.00	0.91	0.96
74.9	1.00	0.91	0.99
75.5	1.00	0.91	0.96
75.9	1.00	0.91	0.99
76.5	1.00	1.00	1.00
78.9	1.00	1.00	1.00
79.5	1.00	0.30	0.65
79.9	1.00	0.30	0.93
81.5	1.00	0.15	0.58
81.9	1.00	0.15	0.92
82.5	1.00	0.15	0.58
82.9	1.00	0.15	0.92
83.5	1.00	0.76	0.88
83.9	1.00	0.76	0.98
84.5	1.00	0.91	0.96
84.9	1.00	0.91	0.99
85.5	1.00	0.91	0.96
85.9	1.00	0.91	0.99
86.5	1.00	1.00	1.00
88.9	1.00	1.00	1.00
89.5	1.00	0.30	0.65
89.9	1.00	0.30	0.93
91.5	0.30	0.15	0.23
91.9	0.30	0.15	0.29
92.5	0.30	0.15	0.23
92.9	0.30	0.15	0.29
93.5	0.30	0.76	0.53
93.9	0.30	0.76	0.35
94.5	0.30	0.91	0.61
94.9	0.30	0.91	0.36
95.5	0.30	0.91	0.61
95.9	0.30	0.91	0.36
96.5	0.30	1.00	0.65
96.9	0.30	1.00	0.37
97.5	0.30	1.00	0.65
97.9	0.30	1.00	0.37
98.5	0.30	1.00	0.65
98.9	0.30	1.00	0.37
99.9	0.30	0.30	0.30

TABLE 9. Mountain Whitefish Juvenile Rearing Cover/Substrate Preference [1]

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	1.00
00.2			1.00	1.00
00.3			1.00	1.00
00.4			1.00	1.00
00.5			0.80	0.80
00.6			0.80	0.80
00.7			0.10	0.10
00.8			0.70	0.70
00.9			0.20	0.20
11.9[2]	0.38	0.38	0.38	
12.9	0.38	0.38	0.38	
13.5	0.38	0.74	0.56	
13.9	0.38	0.74	0.42	
14.5	0.38	0.88	0.63	
14.9	0.38	0.88	0.43	
15.5	0.38	0.88	0.63	
15.9	0.38	0.88	0.43	
16.5	0.38	1.00	0.69	
16.9	0.38	1.00	0.44	
17.5	0.38	1.00	0.69	
17.9	0.38	1.00	0.44	
18.5	0.38	1.00	0.69	
18.9	0.38	1.00	0.44	
19.5	0.38	0.50	0.44	
19.9	0.38	0.50	0.39	
21.5	0.38	0.38	0.38	
22.9	0.38	0.38	0.38	
23.5	0.38	0.74	0.56	
23.9	0.38	0.74	0.42	
24.5	0.38	0.88	0.63	
24.9	0.38	0.88	0.43	
25.5	0.38	0.88	0.63	
25.9	0.38	0.88	0.43	
26.5	0.38	1.00	0.69	
26.9	0.38	1.00	0.44	
27.5	0.38	1.00	0.69	
27.9	0.38	1.00	0.44	
28.5	0.38	1.00	0.69	
28.9	0.38	1.00	0.44	
29.5	0.38	0.50	0.44	
29.9	0.38	0.50	0.39	
31.5	0.74	0.38	0.56	
31.9	0.74	0.38	0.70	
32.5	0.74	0.38	0.56	
32.9	0.74	0.38	0.70	
33.9	0.74	0.74	0.74	
34.5	0.74	0.88	0.81	
34.9	0.74	0.88	0.75	
35.5	0.74	0.88	0.81	
35.9	0.74	0.88	0.75	
36.5	0.74	1.00	0.87	
36.9	0.74	1.00	0.77	
37.5	0.74	1.00	0.87	
37.9	0.74	1.00	0.77	
38.5	0.74	1.00	0.87	
38.9	0.74	1.00	0.77	
39.5	0.74	0.50	0.62	
39.9	0.74	0.50	0.72	
41.5	0.88	0.38	0.63	
41.9	0.88	0.38	0.83	
42.5	0.88	0.38	0.63	
42.9	0.88	0.38	0.83	
43.5	0.88	0.74	0.81	
43.9	0.88	0.74	0.87	
44.9	0.88	0.88	0.88	
45.9	0.88	0.88	0.88	
46.5	0.88	1.00	0.94	
46.9	0.88	1.00	0.89	
47.5	0.88	1.00	0.94	
47.9	0.88	1.00	0.89	
48.5	0.88	1.00	0.94	
48.9	0.88	1.00	0.89	
49.5	0.88	0.50	0.69	
49.9	0.88	0.50	0.84	
51.5	0.88	0.38	0.63	
51.9	0.88	0.38	0.83	
52.5	0.88	0.38	0.63	
52.9	0.88	0.38	0.83	
53.5	0.88	0.74	0.81	
53.9	0.88	0.74	0.87	
54.5	0.88	0.88	0.88	
55.9	0.88	0.88	0.88	
56.5	0.88	1.00	0.94	
56.9	0.88	1.00	0.89	

[1] Assume straight line between codes. Values are derived from RP equation (see pg 23).

[2] Substrate code section begins at 11.9. This is an example of a redundant code (see pg 24).

* Asterisk indicated deviation from the RP formula.

Table 9. Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
57.5	0.88	1.00	0.94
57.9	0.88	1.00	0.89
58.5	0.88	1.00	0.94
58.9	0.88	1.00	0.89
59.5	0.88	0.50	0.69
59.9	0.88	0.50	0.84
61.5	1.00	0.38	0.69
61.9	1.00	0.38	0.94
62.5	1.00	0.38	0.69
62.9	1.00	0.38	0.94
63.5	1.00	0.74	0.87
63.9	1.00	0.74	0.97
64.5	1.00	0.88	0.94
64.9	1.00	0.88	0.99
65.5	1.00	0.88	0.94
65.9	1.00	0.88	0.99
66.9	1.00	1.00	1.00
68.9	1.00	1.00	1.00
69.5	1.00	0.50	0.75
69.9	1.00	0.50	0.95
71.5	1.00	0.38	0.69
71.9	1.00	0.38	0.94
72.5	1.00	0.38	0.69
72.9	1.00	0.38	0.94
73.5	1.00	0.74	0.87
73.9	1.00	0.74	0.97
74.5	1.00	0.88	0.94
74.9	1.00	0.88	0.99
75.5	1.00	0.88	0.94
75.9	1.00	0.88	0.99
76.5	1.00	1.00	1.00
78.9	1.00	1.00	1.00
79.5	1.00	0.50	0.75
79.9	1.00	0.50	0.95
81.5	1.00	0.38	0.69
81.9	1.00	0.38	0.94
82.5	1.00	0.38	0.69
82.9	1.00	0.38	0.94
83.5	1.00	0.74	0.87
83.9	1.00	0.74	0.97
84.5	1.00	0.88	0.94
84.9	1.00	0.88	0.99
85.5	1.00	0.88	0.94
85.9	1.00	0.88	0.99
86.5	1.00	1.00	1.00
88.9	1.00	1.00	1.00
89.5	1.00	0.50	0.75
89.9	1.00	0.50	0.95
91.5	0.50	0.38	0.44
91.9	0.50	0.38	0.49
92.5	0.50	0.38	0.44
92.9	0.50	0.38	0.49
93.5	0.50	0.74	0.62
93.9	0.50	0.74	0.52
94.5	0.50	0.88	0.69
94.9	0.50	0.88	0.54
95.5	0.50	0.88	0.69
95.9	0.50	0.88	0.54
96.5	0.50	1.00	0.75
96.9	0.50	1.00	0.55
97.5	0.50	1.00	0.75
97.9	0.50	1.00	0.55
98.5	0.50	1.00	0.75
98.9	0.50	1.00	0.55
99.9	0.50	0.50	0.50

TABLE 10. 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 11. 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 12. 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 13. 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 14. Bull Trout (*Salvelinus confluentus*) and Dolly Varden (S. malma) Spawning Substrate Preference Data
4 streams, 34 redds. For the full table of 3 digit codes, use Table 6.

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 15. Mountain Whitefish (*Prosopium williamsoni*) Spawning Substrate Preference Data
4 sources. For the full table of 3 digit codes, use Table 7.

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

***:** If silt or sand is the dominant substrate, the final preference should be 0.0 regardless of the preference of the subdominant substrate.

TABLE 16. Mountain Whitefish (*Prosopium williamsoni*) Adult Rearing Substrate Preference Data

3 sources. For the full table of 3 digit codes, use Table 8.

Dominant substrate	Calculated preference	Recommended Preference
1-silt	0.00-0.30	0.15
2-sand	0.00-0.30	0.15
3-small gravel	0.30-1.00	0.76
4-medium gravel	0.50-1.00	0.91
5-large gravel	0.50-1.00	0.91
6-small cobble	0.65-1.0	1.00
7-large cobble	0.65-1.0	1.00
8-boulder	1.00	1.00
9-bedrock	0.10-0.50	0.30

TABLE 17. Mountain Whitefish (*Prosopium williamsoni*) Juvenile Rearing Substrate Preference Data

3 sources. For the full table of 3 digit codes, use Table 9.

Dominant substrate	Calculated preference	Recommended Preference
1-silt	0.30-0.40	0.38
2-sand	0.30-0.40	0.38
3-small gravel	0.30-1.00	0.74
4-medium gravel	0.50-1.00	0.88
5-large gravel	0.50-1.00	0.88
6-small cobble	0.70-1.00	1.00
7-large cobble	0.70-1.00	1.00
8-boulder	1.00	1.00
9-bedrock	0.40-0.50	0.50

TABLE 18. Preference Factors for Ratios of Turbulence

Plume to Calm, Deep Area in Plunge Pool Method (from page 15)

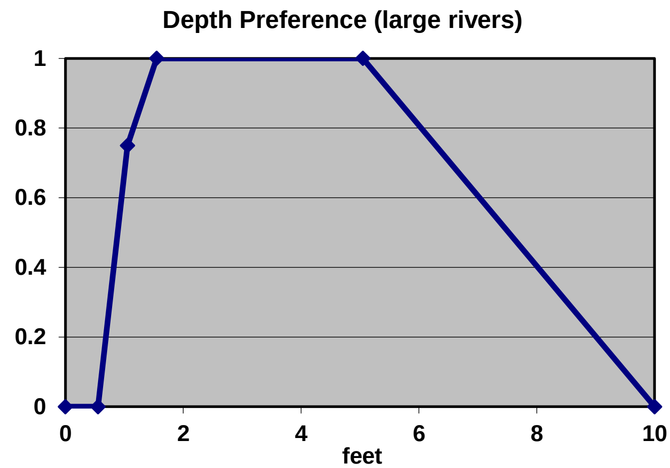
Ratio (plume to calm, deep)	Preference Factor
0.0	0.10
0.25	0.40
0.5	0.80
1.0	1.00
2.0	0.50
4.0	0.25
8.0	0.125
16.0	0.06
32.0	0.03

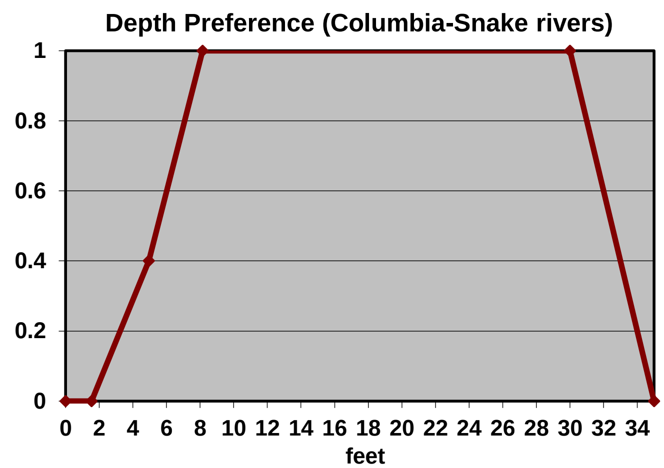
FIGURE 1a. Chinook Salmon (Oncorhynchus tshawytscha) Large River Spawning Depth Preference

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 is unchanged from the 2016 edition.

Plotted depth (feet)	Recommended depth preference	
	large rivers	Columbia – Snake
0.00	0.00	0.00
0.55	0.00	-
1.05	0.75	-
1.55	1.00	0.00
5.05	1.00	0.40
8.15		1.00
10	0.00	-
30	0.00	1.00
35	0.00	0.00
99	0.00	0.00



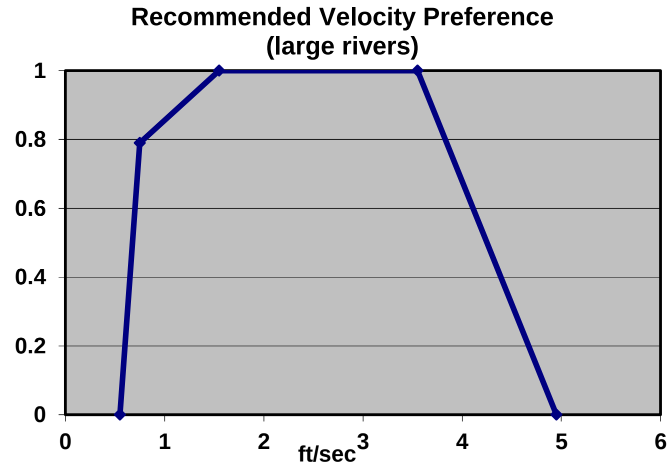


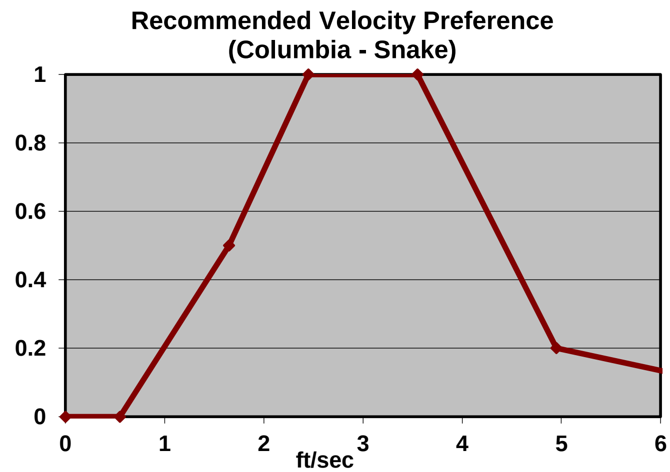
HSC notes: Large river examples include the Skagit and Snohomish rivers. If your stream is close to the 3000 cfs break point, please contact Ecology or WDFW biologists for help in selecting the proper curve.

For Chinook Salmon Spawning Substrate Preference, use Table 2.

FIGURE 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 is unchanged from the 2016 edition.

Plotted velocity (ft/sec)	Recommended velocity suitability	
	large rivers	Columbia – Snake
0.00	0.00	0.00
0.35	-	0.00
0.55	0.00	-
0.75	0.79	-
1.55	1.00	
1.65		0.50
2.45	-	1.00
3.55	1.00	1.00
4.95	0.00	0.20
6.55	0.00	0.10
7.0	0.00	0.00
99	0.00	0.00



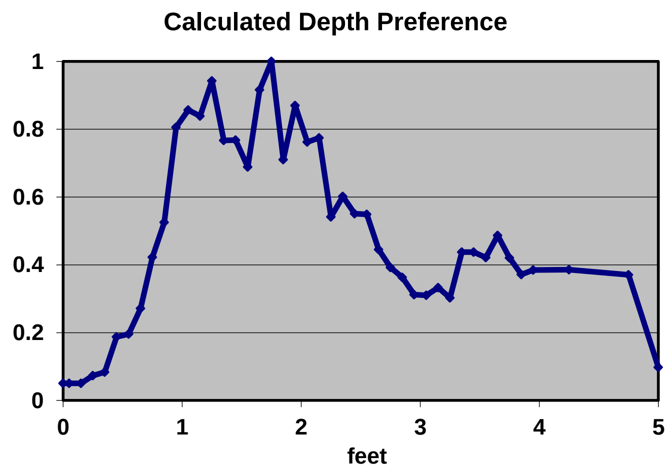


HSC notes: Large river examples include the Skagit and Snohomish rivers. If your stream is close to the 3000 cfs break point, please contact Ecology or WDFW biologists for help in selecting the proper curve.

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 8 studies and 440 redds (American, upper Chehalis, Chelan, Little Naches, Similkameen, Sultan, Yakima, and West Fork Humptulips rivers). **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.35	0.00
0.95	0.80
1.25	0.94
1.75	1.00
2.75	0.40
99	0.40



HSC notes: The calculated preference from 0.0 to 0.39 ft was based on averages from the binning process, not observations. We decided to use a 0.0 preference from 0.0 to 0.35 ft to reflect a physical minimum depth needed for spawning fish.

For Chinook Salmon Spawning Substrate Preference, use Table 2.

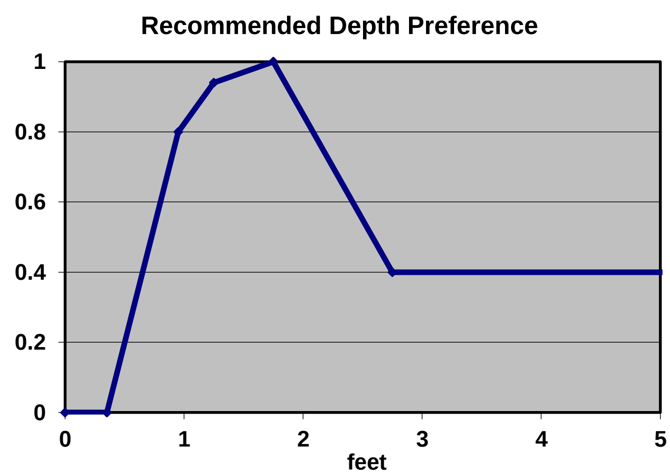
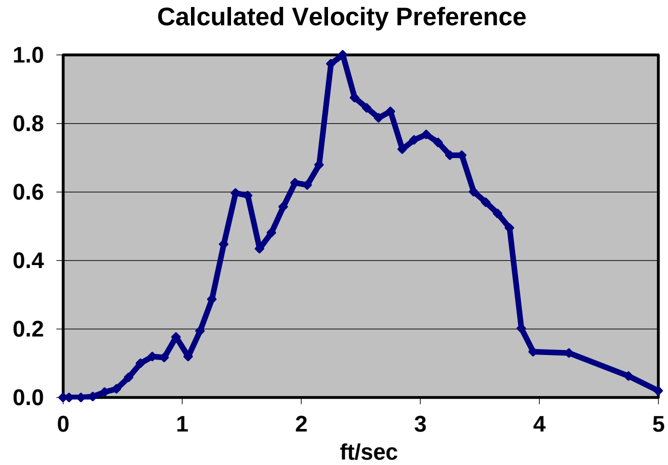
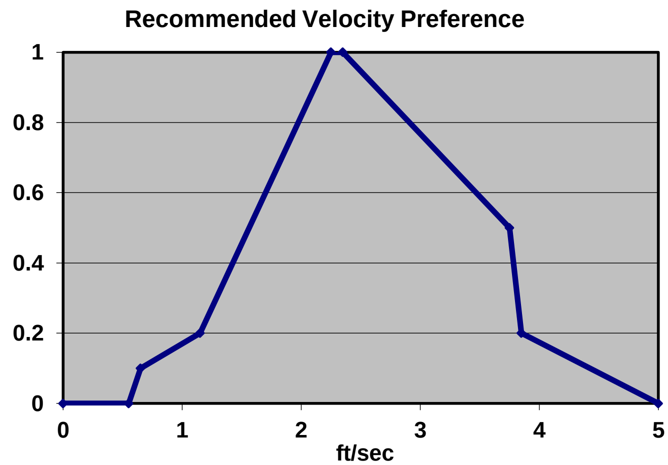


FIGURE 2b. Chinook Salmon Stream and River Spawning Velocity Preference
For all stocks: Streams and rivers have a MAF <3,000 cfs. Analysis based on 8 studies and 440 redds (American, upper Chehalis, Chelan, Little Naches, Similkameen, Sultan, Yakima, and West Fork Humptulips rivers). **Preference is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.00
0.55	0.00
0.65	0.10
1.15	0.20
2.25	1.00
2.35	1.00
3.75	0.50
3.85	0.20
5.0	0.00
99	0.00



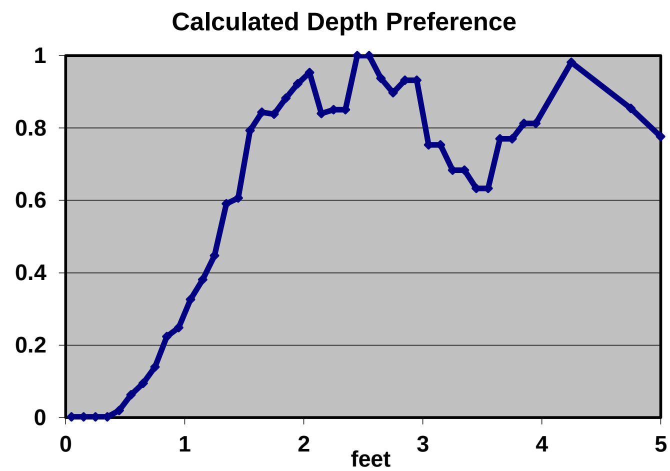


HSC notes: The calculated preference from 0.0 to 0.59 ft was based on averages from the binning process, not observations. We decided to use a 0.0 preference from 0.0 to 0.55 ft.

For Chinook Salmon Spawning Substrate Preference, use Table 2.

FIGURE 3a. Chinook Salmon Juvenile Rearing Depth Preference
Analysis based on 9 studies (Dungeness, Chiwawa, Mad & Similkameen, and Tucannon Rivers and Kendall Creek) and 5615 fish. Kendall Creek was a utilization study with 5055 observations. **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.45	0.00
1.05	0.30
1.65	0.85
2.05	0.95
2.45	1.00
99	1.00



HSC Notes: High preference at depths greater than 5' is only associated with suitable cover or proximity to water's edge. If none of these conditions are present, use a substrate/cover code with a 0.1 preference factor to in the cover/substrate component to adjust the WUA calculation.

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

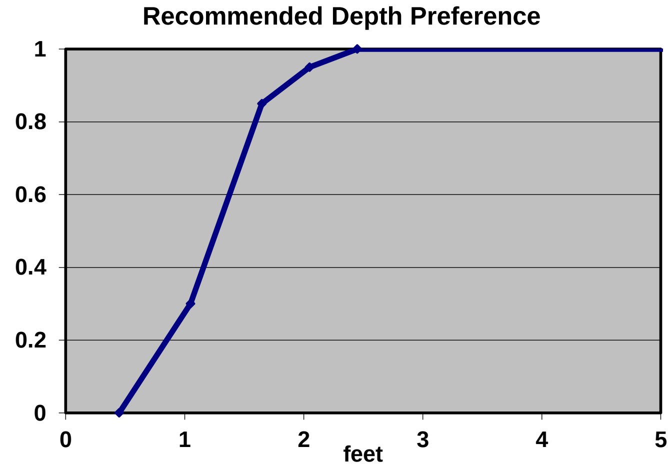
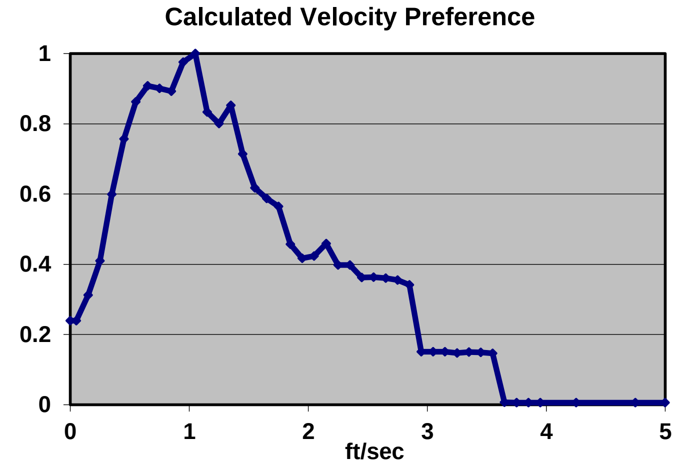


FIGURE 3b. Chinook Salmon Juvenile Rearing Velocity Preference
Analysis based on 9 studies (Dungeness, Chiwawa, Mad & Similkameen, and Tucannon Rivers and Kendall Creek) and 5615 fish. Kendall Creek was a utilization study with 5055 observations.
Preference is unchanged from the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.24
0.15	0.30
0.55	0.85
0.95	1.00
1.05	1.00
1.85	0.45
3.65	0.00
99	0.00



HSC Notes: None

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

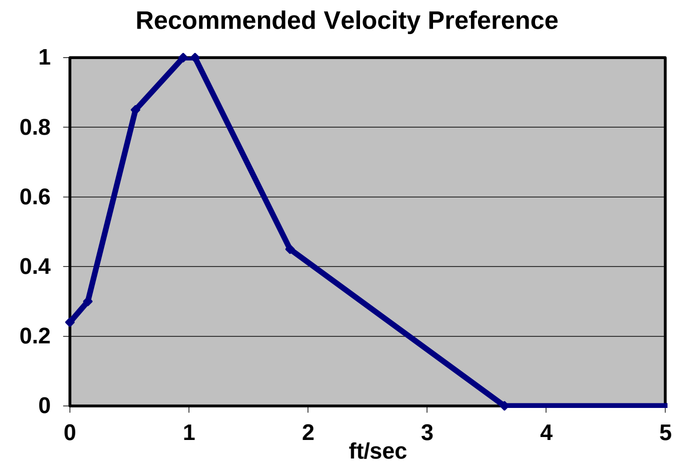
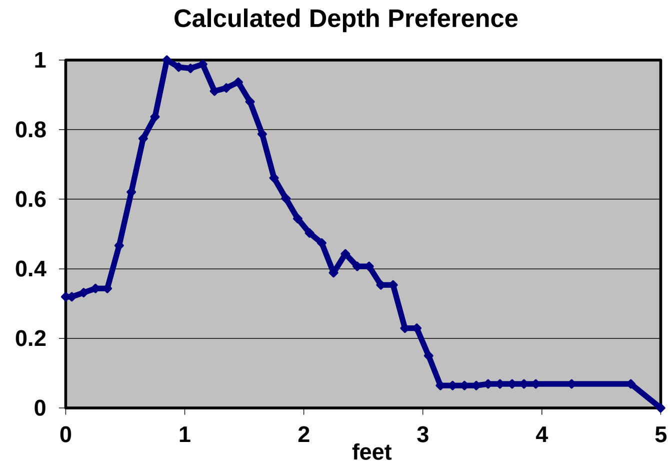
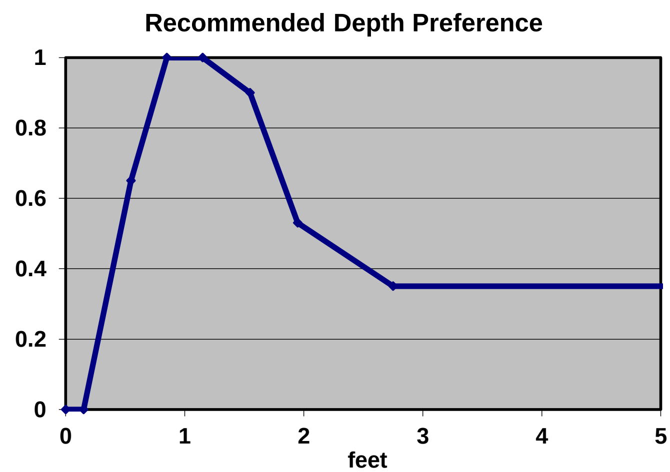


FIGURE 4a. Coho Salmon (*O. kisutch*) Spawning Depth Preference
Analysis based on 5 studies and 66 redds (Fletcher Canyon and Irely creeks, and Humptulips and Dewatto rivers). **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth Preference
0.00	0.00
0.15	0.00
0.55	0.65
0.85	1.00
1.15	1.00
1.55	0.90
1.95	0.53
2.75	0.35
99	0.35



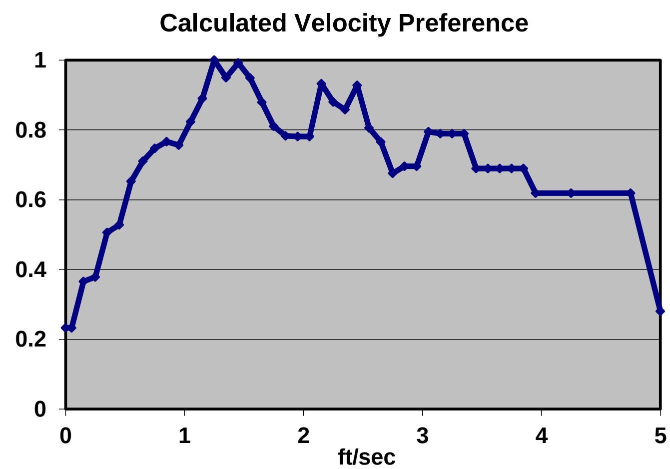


HSC Notes: The calculated preference from 0.0 to 0.39 ft was based on averages from the binning process. There was a redd identified at 0.15 ft, but it was not made on the day of observation and is suspect. Other redds started at 0.4 ft. We decided to use a 0.0 preference from 0.0 to 0.15 ft. The calculated preference decrease reduction after 2.75 ft comes from a study with 1.0 preference dropping out due to a lack of habitat availability. We chose to maintain a 0.35 preference out to 99'.

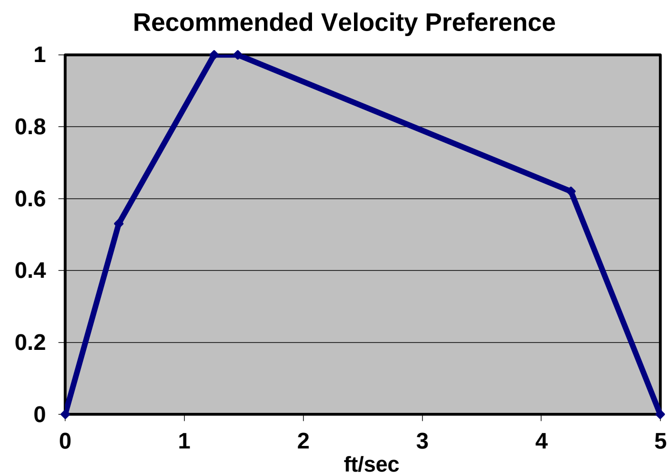
For Coho Salmon Spawning Substrate Preference, use Table 2. See Table 11 for calculated preference information.

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 is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference
0.00	0.00
0.45	0.53
1.25	1.00
1.45	1.00
4.25	0.62
5.0	0.00
99	0.00



HSC notes: None



For Coho Salmon Spawning Substrate Preference, use Table 2. See Table 11 for calculated preference information

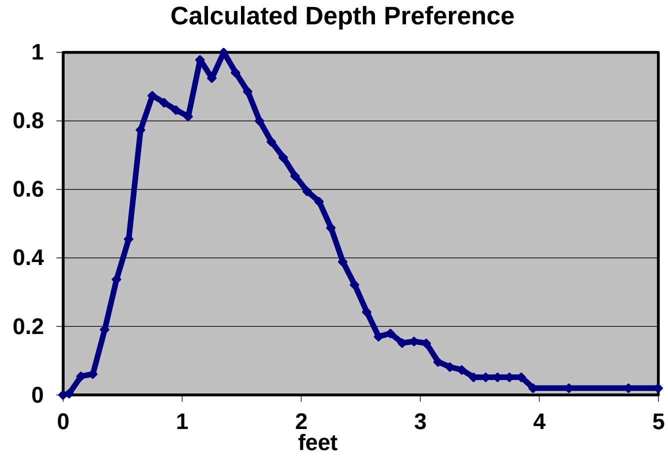
Coho Salmon Juvenile Depth Preference (No Longer Recommended)
Coho Salmon Juvenile Velocity Preference (No Longer Recommended)
Analysis based on 4 studies and 451 fish (Dungeness, Satsop Rivers and Kennedy Creek) and (Beecher, et al. 2010).

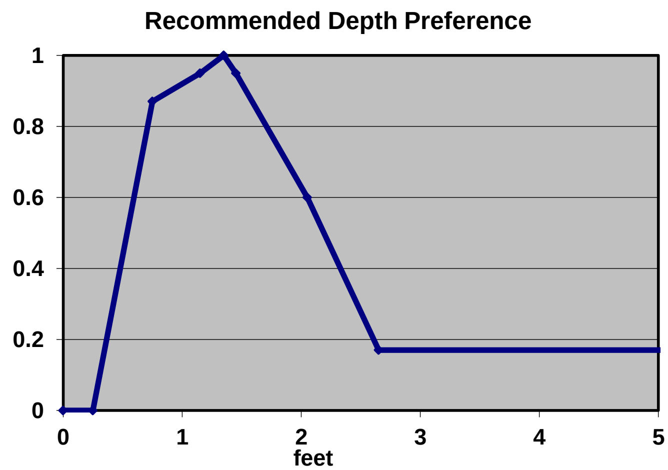
Versions of the Instream Flow Study Guidelines prior to 2013 provided default coho juvenile depth and velocity curves based on Beecher et al 2002. Subsequent research has shown that despite validation of the habitat suitability criteria and hydraulic model, the stream flow relating to peak coho rearing 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 and Summer Chum salmon (*O. keta*) Spawning Depth Preference
Analysis based on 16 studies and 225 redds (Hill Creek, Kennedy Creek (3), Duckabush (9) and Dosewallips rivers (3)). **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted Depth (feet)	Depth preference
0.00	0.00
0.25	0.00
0.75	0.87
1.15	0.95
1.35	1.00
1.45	0.95
2.05	0.60
2.65	0.17
99	0.17



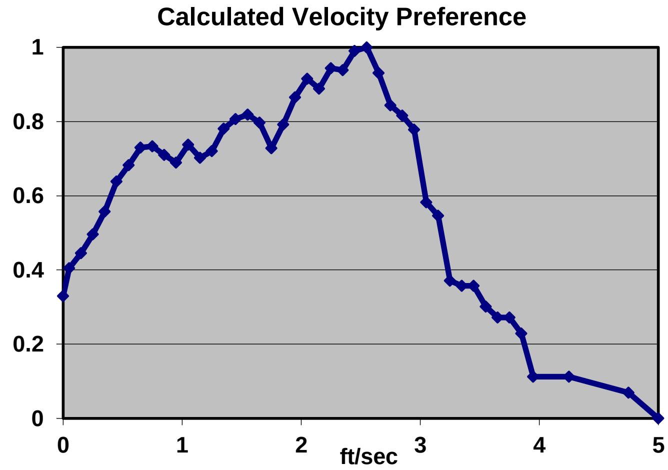


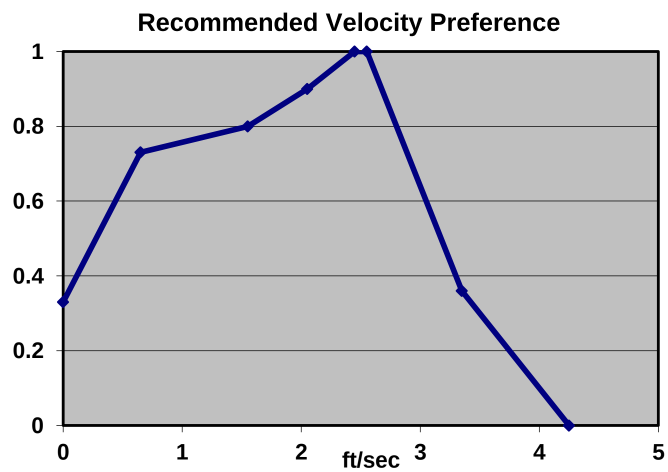
HSC Notes: Fall chum and summer chum are distinctly different stocks. However, they had similar HSC curves. We tested the hypothesis that the two stocks used the same preference curve by testing the predicted depth (using the combined preference curve) against the observed depth pattern recorded from the 16 studies (8 for fall chum and 8 for summer). The hypothesis was supported 7/8 times for fall chum (P values ranged from 0.02 to 0.72) and rejected once (P value 0.02). For summer chum the hypothesis was supported 5/8 times (P values ranged from 0.99 to 0.11) and rejected 3 times (P values were 0.04, 0.02, and 0.0008).
In a similar test with only the summer chum studies and a composite summer chum preference curve, the summer chum curve was supported 4/8 times (P values ranged from 0.99 to 0.11), and rejected 4 times (P values ranges from 0.01 to .008).
Based on these results we accepted the hypothesis that depth preference of fall and summer chum are best described with a single preference curve.

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

FIGURE 5b. Fall and Summer Chum Salmon Spawning Velocity Preference
Analysis based on 16 studies and 225 redds (Hill Creek, Kennedy Creek (3), Duckabush (9) and Dosewallips rivers (3)). **Preference is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Plotted Velocity (ft/sec)	Velocity preference
0.00	0.33
0.65	0.73
1.55	0.80
2.05	0.90
2.45	1.00
2.55	1.00
3.35	0.36
4.25	0.00
99	0.00



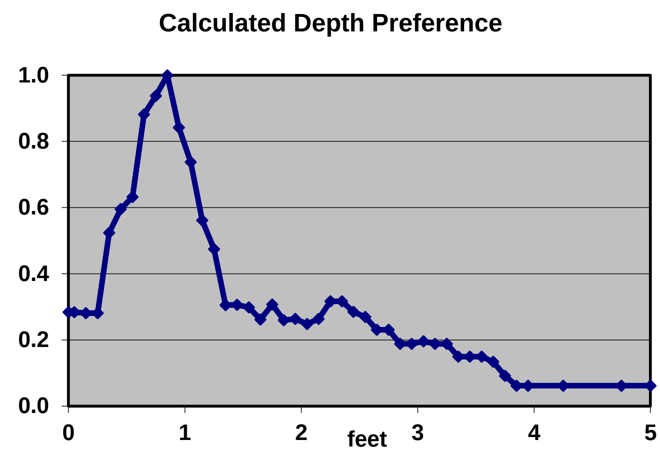


HSC Notes: Fall chum and summer chum are distinctly different stocks. However, they had similar HSC curves. We tested the hypothesis that the two stocks used the same preference curve by testing the predicted velocity (using the combined preference curve) against the observed velocity pattern recorded from the 16 studies (8 for fall chum and 8 for summer). The hypothesis was supported 8/8 times for fall chum (P values ranged from 0.07 to 0.95). For summer chum the hypothesis was supported 5/8 times (P values ranged from 0.99 to 0.11) and rejected 3 times (P values were 0.03, 0.01, and 0.007).
In a similar test with only the summer chum studies and a composite summer chum velocity preference curve, the summer chum curve was supported 6/8 times (P values ranged from 0.36 to 0.06), and rejected 2 times (P values were .002 and .006).
The summer chum only curve has a slightly better acceptance rate (6 studies vs. 5), but based on high variability of summer chum observations and the acceptance of the general preference curve for depth, we decided to accept the hypothesis that velocity preference of fall and summer chum are best described with a single preference curve.

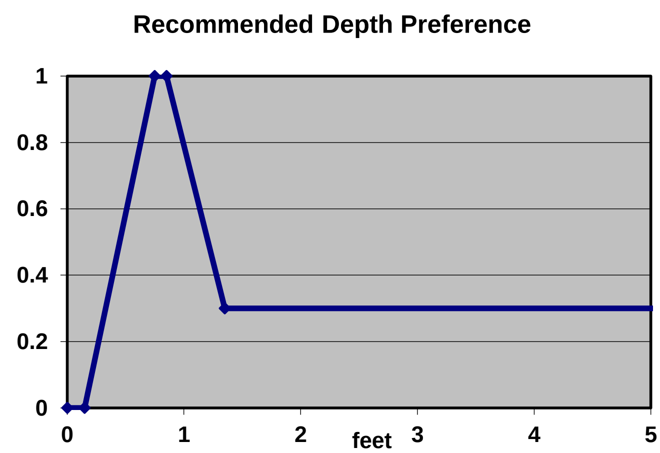
For Chum Salmon Spawning Substrate Preference, use Table 2. See Table 10 for calculated preference information.

FIGURE 6a. Pink Salmon (*O. gorbuscha*) Spawning Depth Preference
Analysis based on 6 studies and 104 redds (Squire Creek/North Fork Stillaguamish, Dosewallips (3), and Duckabush (2) rivers). **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.15	0.00
0.75	1.00
0.85	1.00
1.35	0.30
99	0.30



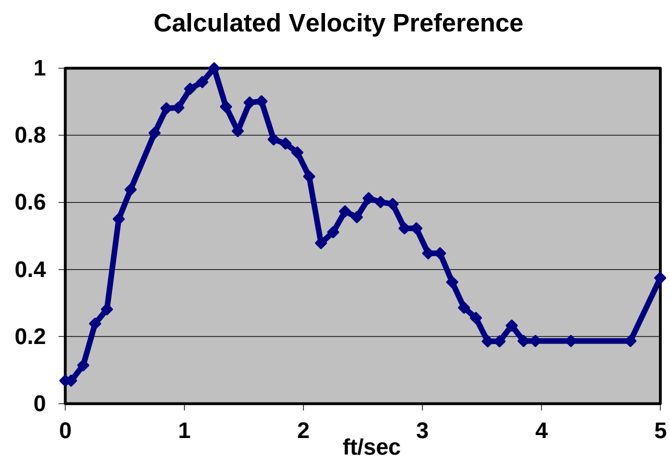
HSC Notes: The calculated preference from 0.0 to 0.29 ft was based on averages from the binning process, not observations. We decided use a 0.0 preference from 0.0 to 0.15 ft to reflect a physical minimum depth needed for spawning fish.



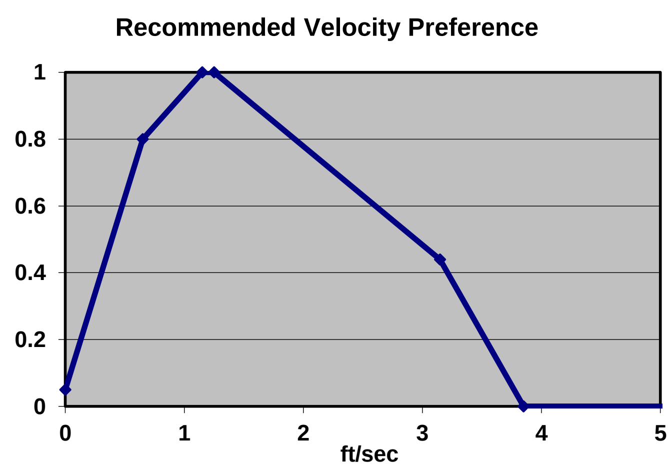
For Pink Salmon Spawning Substrate Preference, use Table 2. See Table 12 for calculated preference information.

FIGURE 6b. Pink Salmon Spawning Velocity Preference
Analysis based on 6 studies and 104 redds (Squire Creek/North Fork Stillaguamish, Dosewallips (3), and Duckabush (2) rivers). **Preference is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.05
0.65	0.80
1.15	1.00
1.25	1.00
3.15	0.44
3.85	0.00
99	0.00



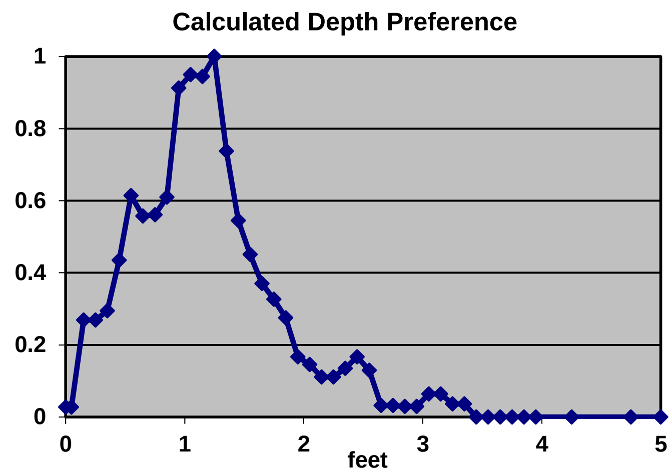
HSC Notes: The highest velocity observation was at 3.35 ft/sec. The calculated preferences from 3.5 to 5.0 ft/sec were based on averages from the binning process, not observations. We chose to continue the slope down from 3.15 ft/sec.



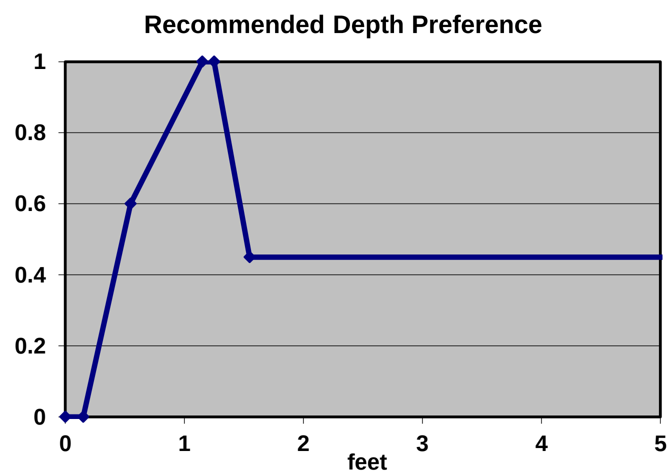
For Pink Salmon Spawning Substrate Preference, use Table 2. See Table 12 for calculated preference information.

FIGURE 7a. Sockeye Salmon (*O. nerka*) Spawning Depth Preference
Analysis based on 4 studies and 1,053 redds (Cedar River (3) and Big Creek (Quinault basin)).
Preference is unchanged from the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.15	0.00
0.55	0.60
1.15	1.00
1.25	1.00
1.55	0.45
99	0.45



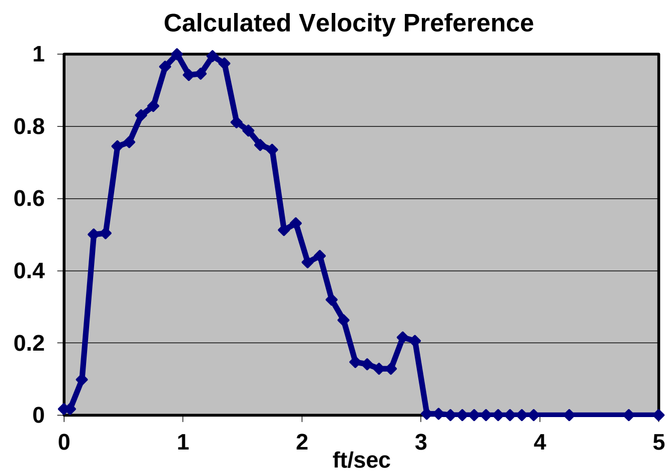
HSC Notes: For depth preference after 1.55 ft we chose to maintain a 0.45 preference out to 99' to maintain a potential for known deep water spawning.

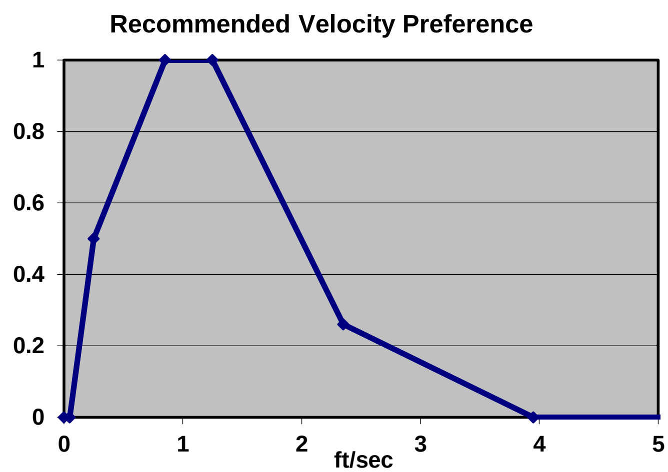


For Sockeye Salmon Spawning Substrate Preference, use Table 2. See Table 13 for calculated substrate preference information.

FIGURE 7b. Sockeye Salmon Spawning Velocity Preference
Analysis based on 4 studies and 1,053 redds (Cedar River & Big Creek (Quinault basin)).
Preference is unchanged from the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.00
0.05	0.00
0.25	0.50
0.85	1.00
1.25	1.00
2.35	0.26
3.95	0.00
99	0.00



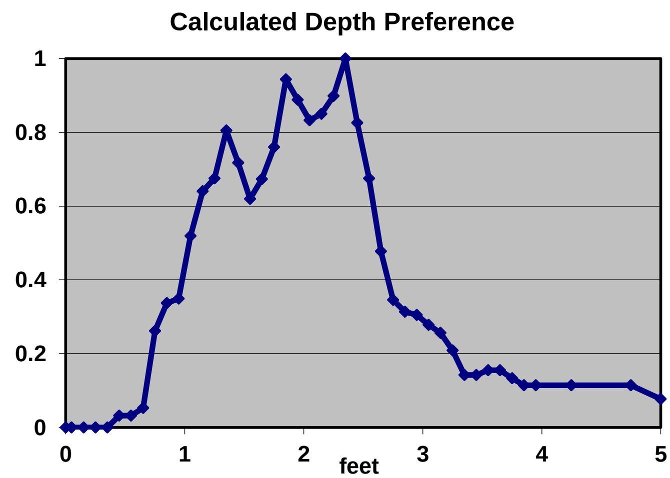


HSC Notes: None

For Sockeye Salmon Spawning Substrate Preference, use Table 2. See Table 13 for calculated substrate preference information.

FIGURE 8a. Steelhead (*O. mykiss*) Spawning Depth Preference
Analysis based on 6 studies, 108 redds (Rock Creek (WRIA 31), Cedar (2) and Sultan rivers and Chelan Fish Channel (2)). **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.65	0.00
0.75	0.25
1.25	0.68
1.85	1.00
2.35	1.00
2.75	0.34
99	0.34



HSC Notes: For depth preference after 2.90 ft, we chose to maintain a 0.34 preference out to 99'.

For Steelhead Spawning Substrate Preference, use Table 4.

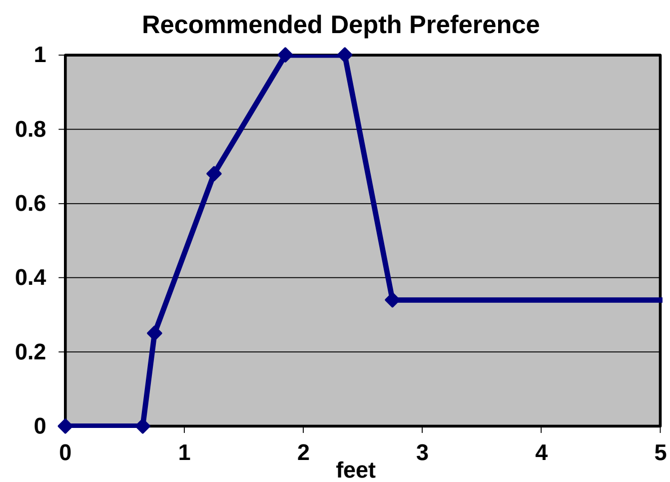
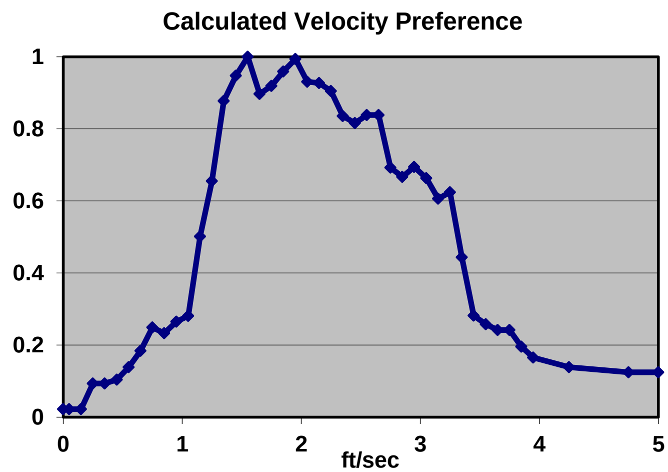
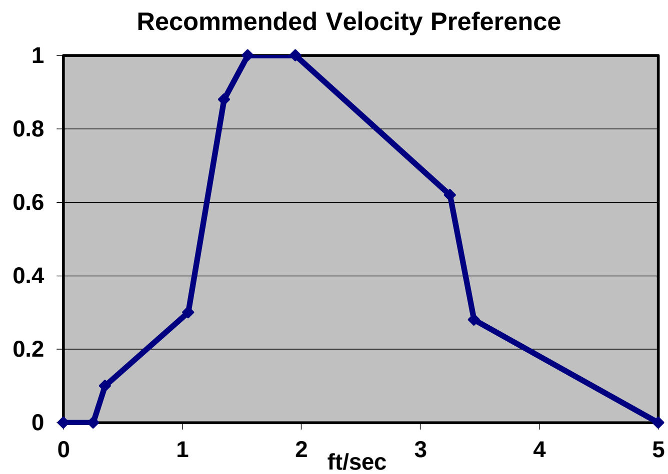


FIGURE 8b. Steelhead Spawning Velocity Preference
Analysis based on 6 studies, 108 redds (Rock Creek (WRIA 31), Cedar (2) and Sultan rivers and Chelan Fish Channel (2)). **Preference is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.00
0.25	0.00
0.35	0.10
1.05	0.30
1.35	0.88
1.55	1.00
1.95	1.00
3.25	0.62
3.45	0.28
5.0	0.00
99	0.00



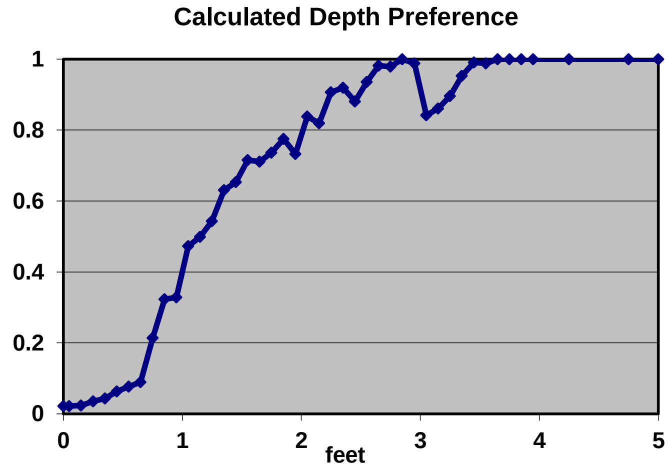
HSC Notes: The highest velocity observation was at 3.55 ft/sec. The calculated preferences from 3.5 to 5.0 ft/sec were based on averages from the binning process, not observations. We chose to continue the slope down from 3.95 ft/sec.



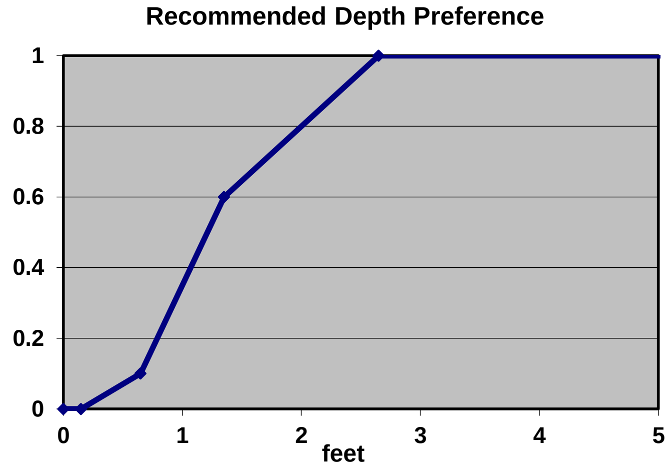
For Steelhead Spawning Substrate Preference, use Table 4.

FIGURE 9a. O.mykiss Juvenile Depth Preference
Analysis based on 32 studies and 1954 fish and combines steelhead and resident rainbow juvenile observations (multiple Washington streams of differing sizes and stream types).
This was a new composite curve for the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.15	0.00
0.65	0.10
1.35	0.63
2.65	1.00
99	1.00



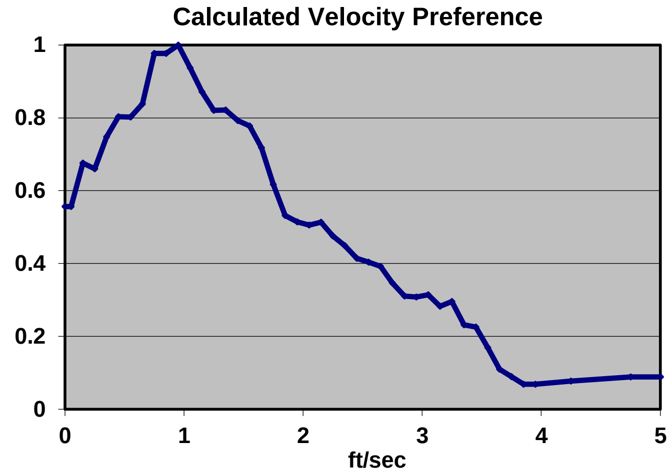
HSC Notes: Smaller streams lack the availability at deeper depths reducing the number of streams used in the composite average preference calculation. This didn't affect the peak in other curves, but it did here. The highest combined composite preference occurred at 2.85 ft involving 25 streams. The highest composite average occurred at 3.85 ft, but only involved 15 streams. We decided to renormalize the calculated preference using the value at 2.85 ft.

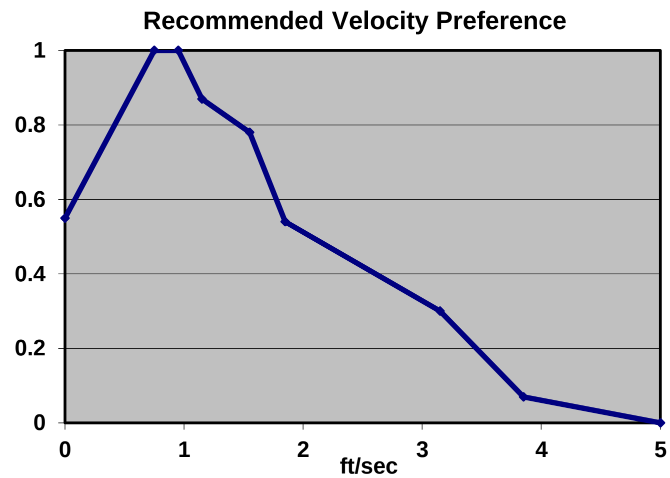


For Steelhead and Rainbow Juvenile Substrate Preference, use Table 3.

FIGURE 9b. O.mykiss Juvenile Velocity Preference
Analysis based on 32 studies and 1954 fish and combines steelhead and resident rainbow juvenile observations (multiple Washington streams of differing sizes and stream types).
This was a new composite curve for the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.55
0.75	1.00
0.95	1.00
1.15	0.87
1.55	0.78
1.85	0.54
3.15	0.30
3.85	0.07
5.00	0.00
99	0.00



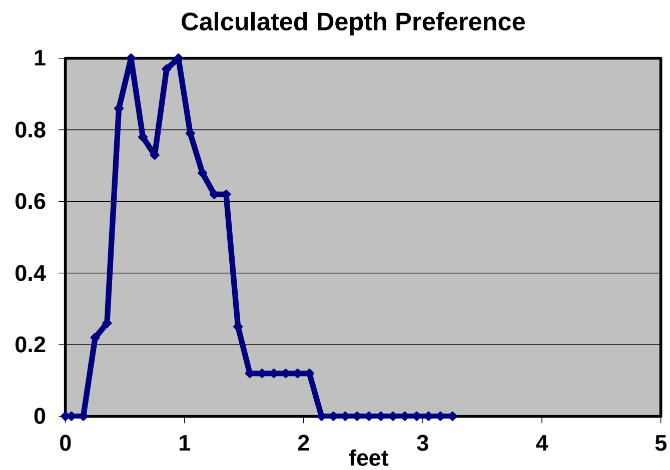


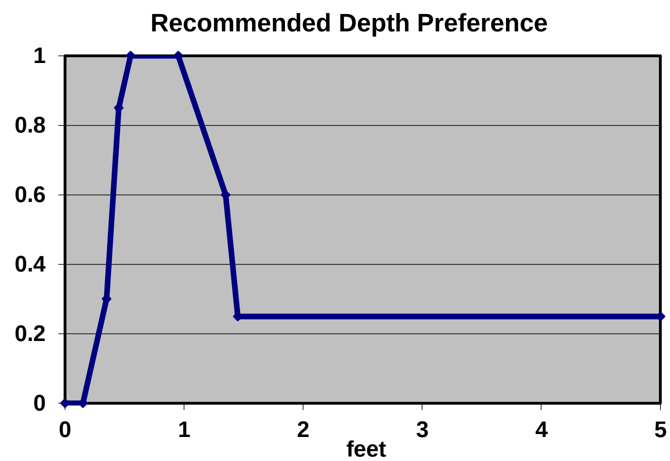
HSC Notes: The highest velocity observation was at 4.05 ft/sec. The calculated preferences from 4.15 to 5.0 ft/sec were based on averages from the binning process, not observations. We chose to slope down to 0.0 at 5.0 ft/sec.

For Steelhead and Rainbow Juvenile Substrate Preference, use Table 3.

FIGURE 10a. Resident Rainbow Trout (*O. mykiss*) Spawning Depth Preference
Analysis based on 2 studies and 27 redds (upper Lake and Muller Creek).
Preference is unchanged from the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.15	0.00
0.35	0.30
0.45	0.85
0.55	1.00
0.95	1.00
1.35	0.60
1.45	0.25
99	0.25



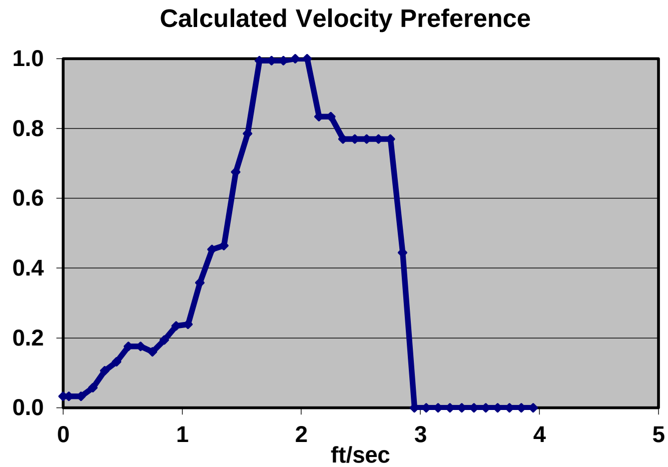


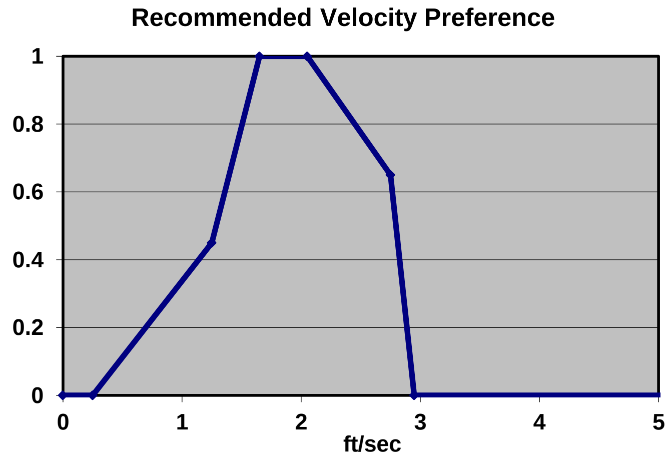
HSC Notes: We chose to maintain a 0.25 preference out to 99’.

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

FIGURE 10b. Resident Rainbow Trout Spawning Velocity Preference
Analysis based on 2 studies and 27 redds (upper Lake and Muller Creek).
Preference is unchanged from the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.00
0.25	0.00
1.25	0.45
1.65	1.00
2.05	1.00
2.75	0.65
2.95	0.00
99	0.00



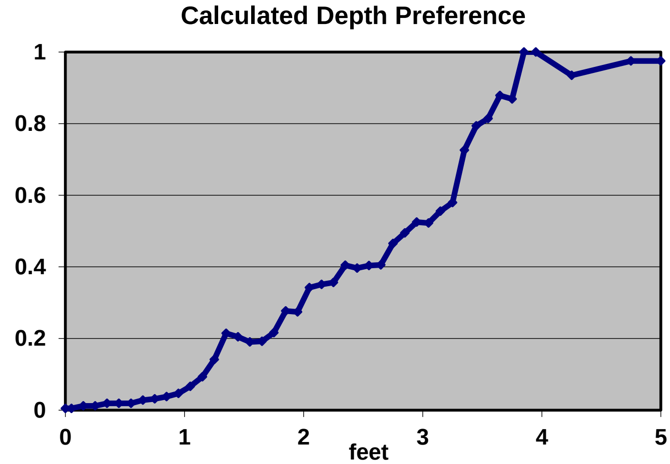


HSC Notes: None

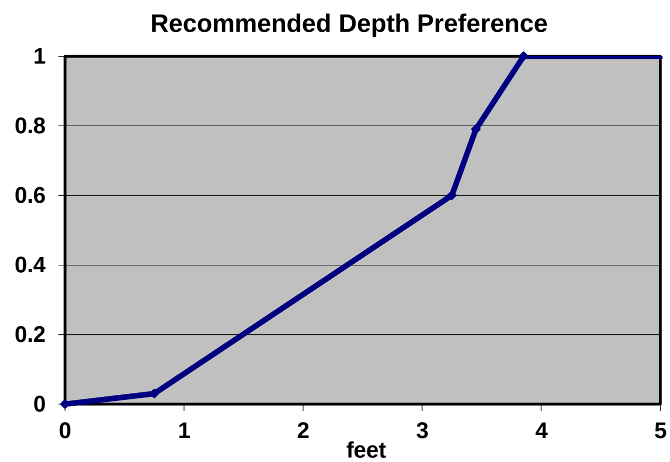
For Resident Rainbow Trout Spawning Substrate Preference, use Table 5.

FIGURE 11a. Resident Rainbow Trout (*O. mykiss*) Adult Rearing Depth Preference
Analysis based on 15 studies and 638 fish (mostly west side streams but includes Yakima River, upper Yakima, Mill Creek (WRIA 32) and Douglas (2) (WRIA 44) creeks.
This was a new composite curve for the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.75	0.03
3.25	0.60
3.45	0.79
3.85	1.00
99	1.00



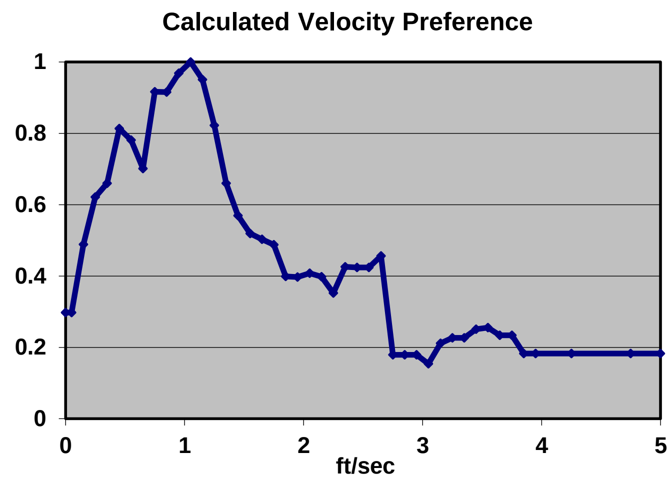
HSC Notes: None

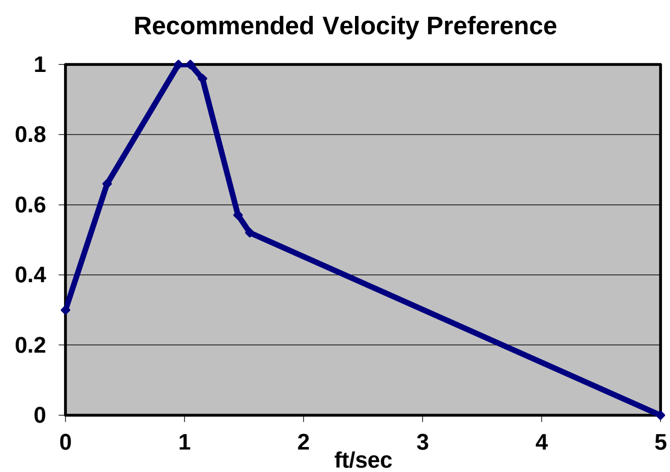


For Resident Adult Rainbow Trout Rearing Substrate Preference, use Table 3.

FIGURE 11b. Resident Rainbow Trout Adult Rearing Velocity Preference
Analysis based on 15 studies and 638 fish (Mostly west side streams but includes Yakima River, upper Yakima, Mill Creek (WRIA 32) and Douglas (2) (WRIA 44) creeks.
This was a new composite curve for the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.30
0.35	0.66
0.95	1.00
1.05	1.00
1.15	0.96
1.45	0.57
1.55	0.52
5.00	0.00
99	0.00



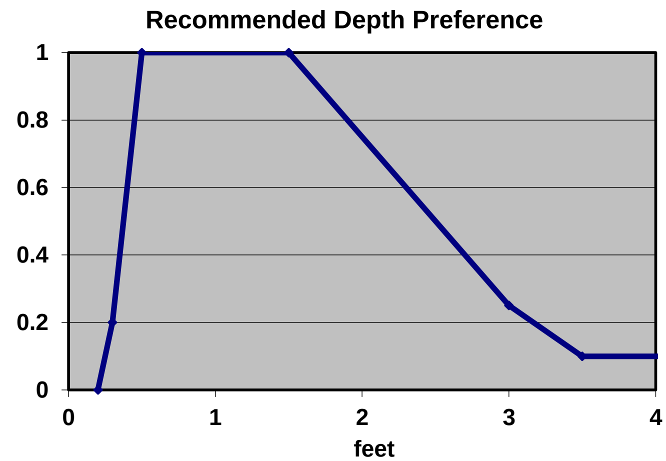


HSC Notes: None

For Resident Adult Rainbow Trout Rearing Substrate Preference, use Table 3.

FIGURE 12a. Resident Rainbow Trout Winter Depth Preference
Campbell and Neuner (1985)[1]. **Preference is unchanged from the 2016 edition.**

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
99	0.10



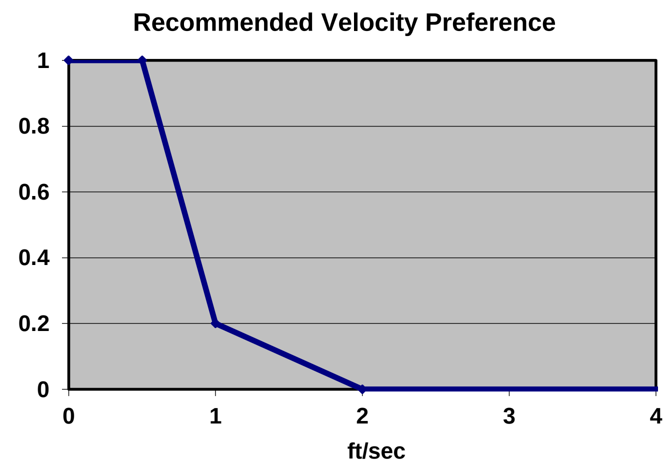
HSC Notes: None

FIGURE 12b. Resident Rainbow Trout Winter Velocity Preference
Campbell and Neuner (1985). **Preference is unchanged from the 2016 edition.**

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

HSC Notes: None

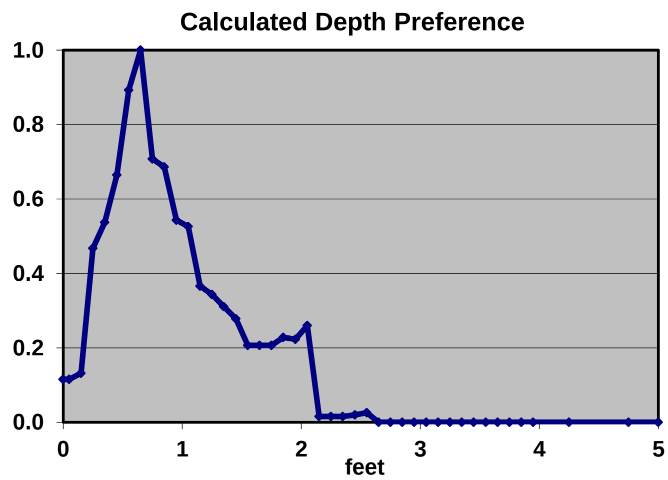
For Winter Substrate Preference, use Table 3.



[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 13a. Cutthroat Trout (*O. clarki*) Spawning Depth Preference
Analysis based on 7 studies and 123 redds (Irely (4) and Skookum (3) creeks).
Preference is unchanged from the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.15	0.00
0.25	0.50
0.65	1.00
1.15	0.35
1.55	0.25
99	0.25



HSC Notes: We decided to continue the 0.25 preference out to 99'.

For Cutthroat Trout Spawning Substrate Preference, use Table 5.

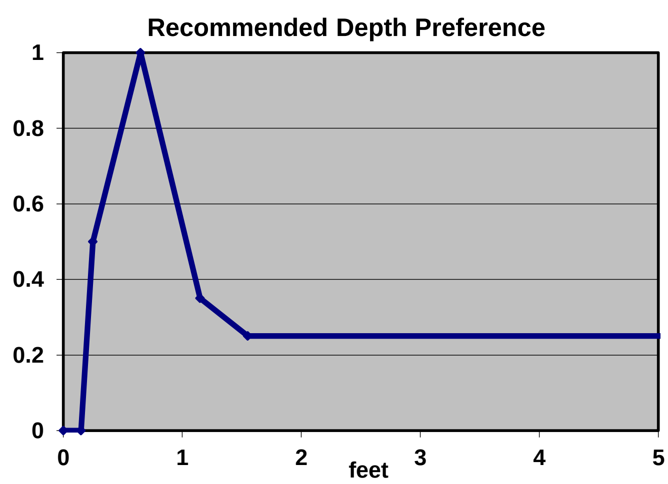
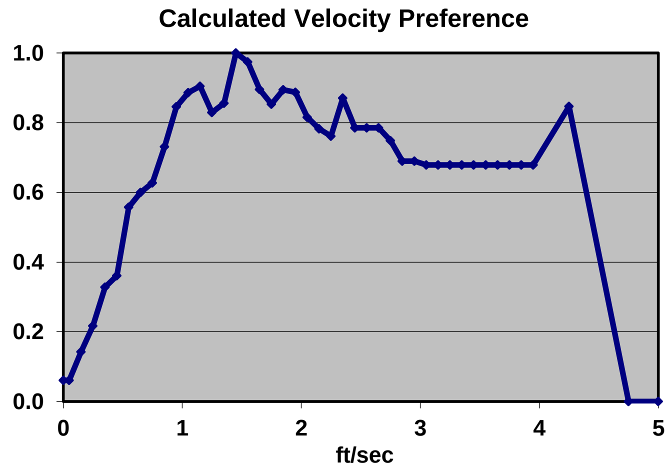
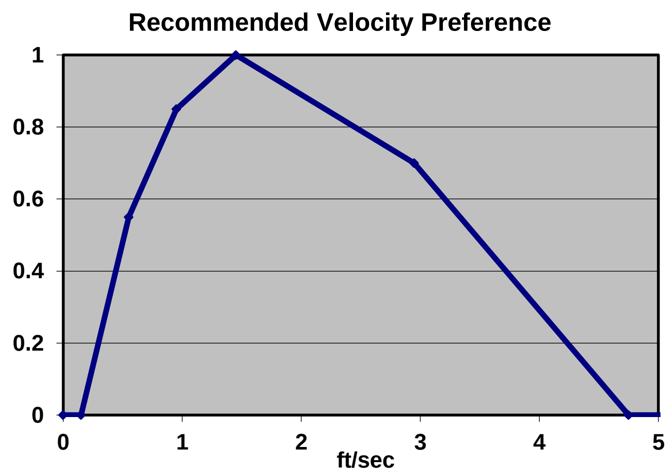


FIGURE 13b. Cutthroat Spawning Velocity Preference
Analysis based on 7 studies and 123 redds (Irely (4) and Skookum (3) creeks).
Preference is unchanged from the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.00
0.15	0.00
0.55	0.55
0.95	0.85
1.45	1.00
2.95	0.70
4.75	0.00
99	0.00



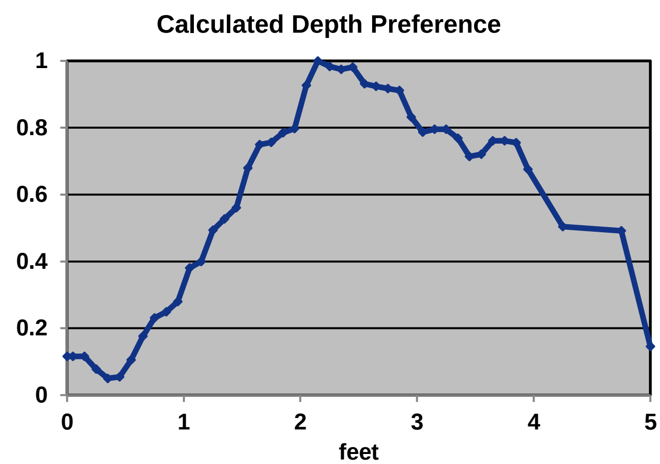


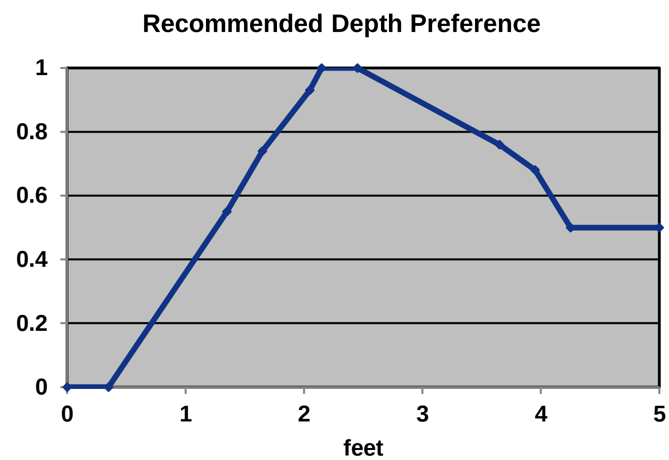
HSC Notes: The calculated preference from 3.15 to 4.25 ft/sec was based on averages from the binning process, not observations. We decided to slope down from 0.70 at 2.95 ft/sec to 0.0 at 4.75 ft/sec.

For Cutthroat Trout Spawning Substrate Preference, use Table 5.

FIGURE 14a. Cutthroat Trout Juvenile Depth Preference
Analysis based on 11 studies and 518 fish (Ohanapecosh and Kachess rivers, Warm, Grade, Martin, Olson, Perry (2), Skookum, Box Canyon, and Mineral creeks). **Preference has changed from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.35	0.00
1.35	0.55
1.65	0.74
2.05	0.93
2.15	1.00
2.45	1.00
3.65	0.76
3.95	0.68
4.25	0.50
99	0.50





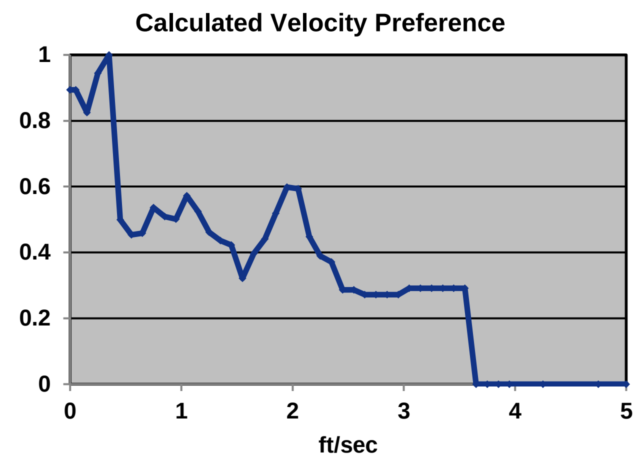
HSC Notes: We decided to continue the 0.50 preference out to 99'.

For all Cutthroat Trout Substrate Preference, use Table 3.

For Cutthroat Trout Winter Depth Preference, use Figure 12a. Resident Rainbow Trout Winter Depth Preference as a surrogate.

FIGURE 14b. Cutthroat Trout Juvenile Velocity Preference
Analysis based on 11 studies and 517 fish (Ohanapecosh and Kachess rivers, Warm, Grade, Martin, Olson, Perry (2), Skookum creeks, Box Canyon, and Mineral creeks). **Preference has changed from the 2016 edition.**

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.89
0.25	1.00
0.35	1.00
1.95	0.60
3.05	0.29
3.95	0.00
99	0.00



HSC Notes: None

For all Cutthroat Trout Rearing Substrate Preference, use Table 3.

For Cutthroat Trout Winter Velocity Preference, use Figure 12b. Resident Rainbow Trout Winter Velocity Preference as a surrogate.

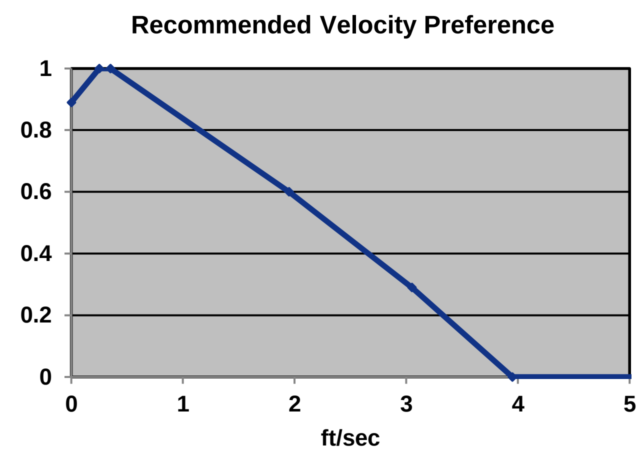
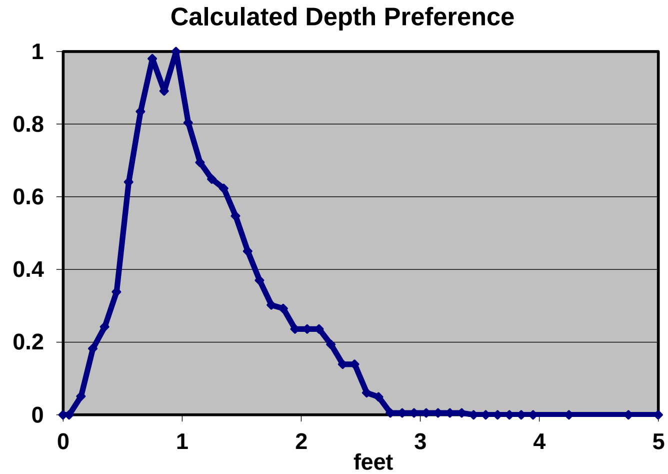


FIGURE 15a. Bull Trout and Dolly Varden (*Salvelinus confluentus* and *S. malma*) Spawning Depth Preference

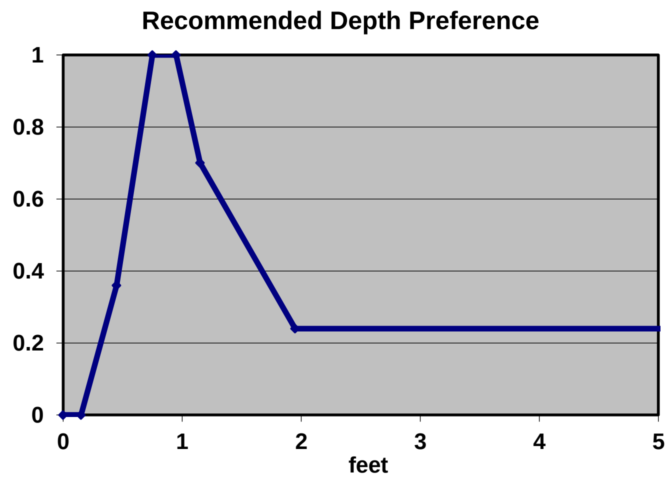
Analysis based on 8 studies and 122 redds (WRIA 7, WRIA 38, WRIA 45 (5), and WRIA 46).

Preference is unchanged from the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.15	0.00
0.45	0.36
0.75	1.00
0.95	1.00
1.15	0.70
1.95	0.24
99	0.24



HSC Notes: We decided to continue the 0.24 preference out to 99'.

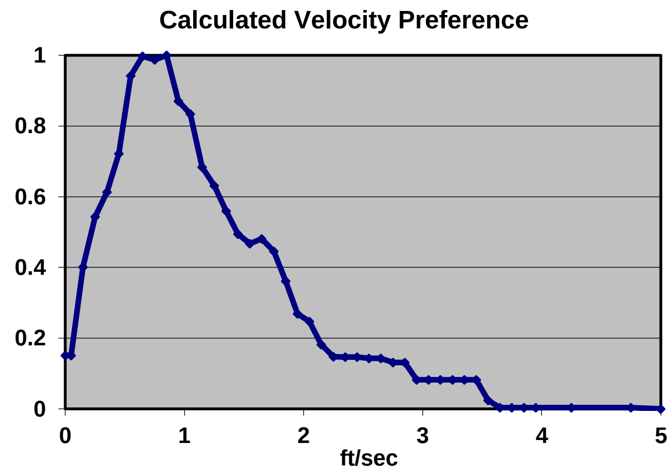


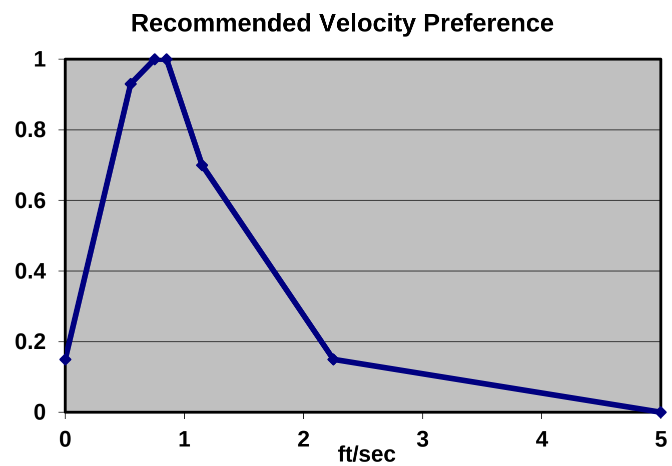
For Bull Trout and Dolly Varden Spawning Substrate Preference, use Table 6.

See Table 14 for calculated substrate preference information.

FIGURE 15b. Bull Trout and Dolly Varden Spawning Velocity Preference
Analysis based on 8 studies and 122 redds (WRIA 7, WRIA 38, WRIA 45 (5), and WRIA 46).
Preference is unchanged from the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.15
0.55	0.93
0.65	1.00
0.85	1.00
1.15	0.70
2.25	0.15
5.00	0.00
99	0.00





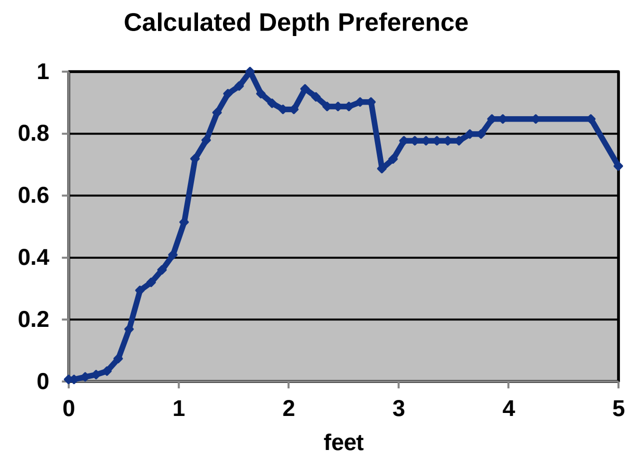
HSC Notes: None

For Bull Trout and Dolly Varden Spawning Substrate Preference, use Table 6.

See Table 14 for calculated substrate preference information.

FIGURE 16a. Bull Trout and Dolly Varden Juvenile Depth Preference
Analysis based on 11 studies and 127 fish (Mad, Chiwawa (2), Dungeness, Tucannon, and Kachess rivers, Rock, Early Winters, Phelps, Troublesome, and Box Canyon creeks).
Preference has changed from the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.15	0.00
0.45	0.07
1.55	1.00
1.65	1.00
2.75	0.90
3.05	0.80
99	0.80



HSC Notes: We decided to continue the 0.80 preference out to 99'.

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

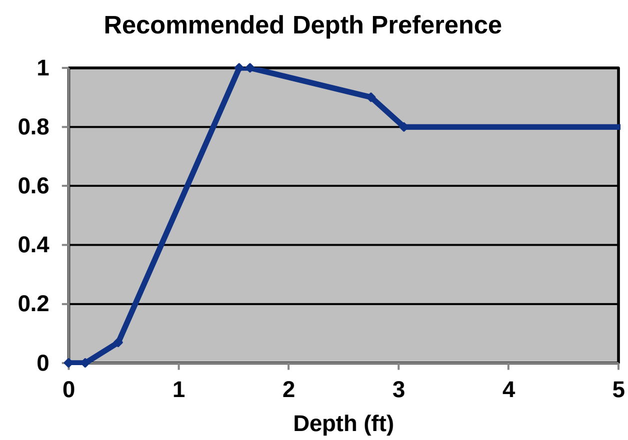
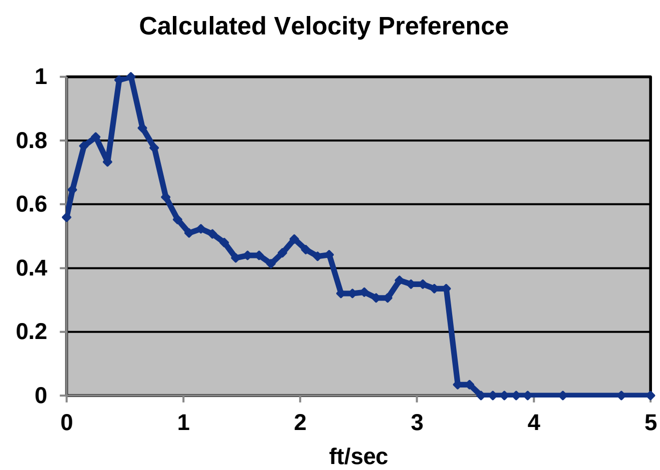
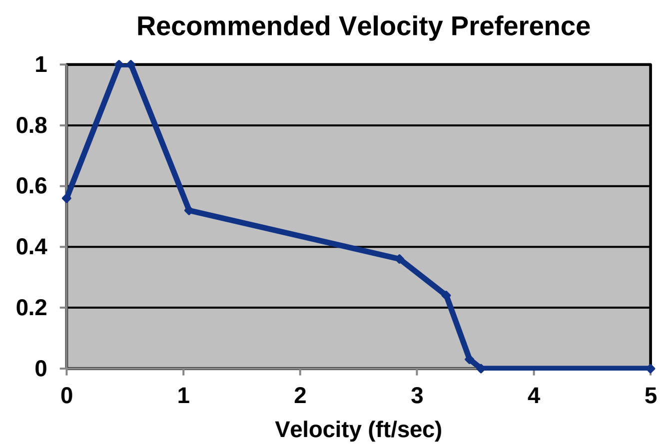


FIGURE 16b. Bull Trout and Dolly Varden Juvenile Velocity Preference
Analysis based on 11 studies and 127 fish (Mad, Chiwawa (2), Dungeness, Tucannon, and Kachess rivers, Rock, Early Winters, Phelps, Troublesome, and Box Canyon creeks).
Preference has changed from the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.56
0.45	1.00
0.55	1.00
1.05	0.52
2.85	0.36
3.25	0.24
3.45	0.03
3.55	0.00
99	0.00



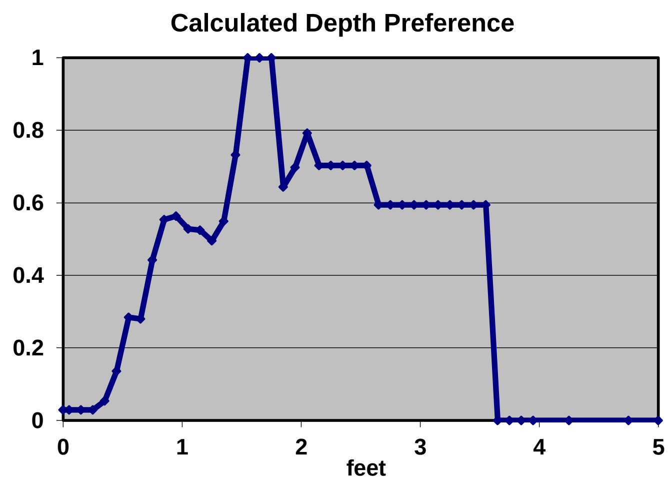


HSC Notes: None

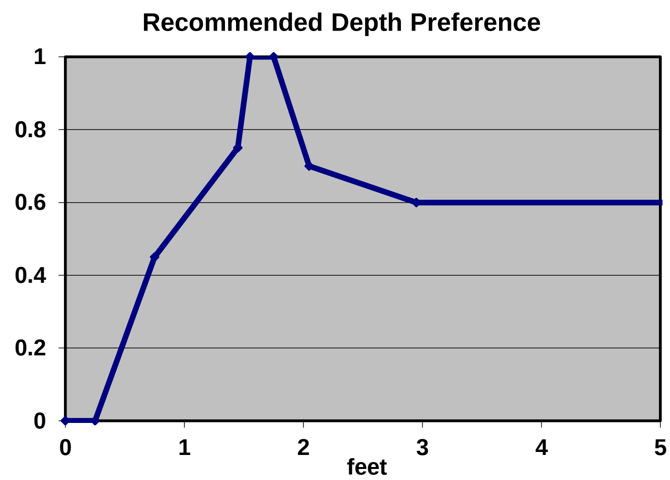
For Bull Trout and Dolly Varden Juvenile Substrate Preference, use Table 3.

FIGURE 17a. Brook Trout (*S. fontinalis*) Adult and Juvenile Rearing Depth Preference
Analysis based on 4 studies and 39 fish (Ohanapecosh River and Leech Creek).
Preference is unchanged from the 2016 edition.

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.25	0.00
0.75	0.45
1.45	0.75
1.55	1.00
1.75	1.00
2.05	0.70
2.95	0.60
99	0.60



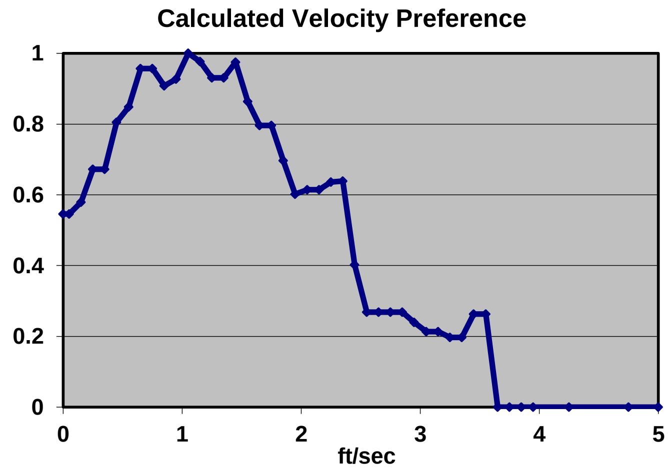
HSC Notes: We decided to maintain a 0.60 preference out to 99'.



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

FIGURE 17b. Brook Trout Juvenile and Adult Rearing Velocity Preference
Analysis based on 4 studies and 39 fish (Ohanapecosh River and Leech Creek).
Preference is unchanged from the 2016 edition.

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.55
0.75	1.00
1.05	1.00
1.45	0.95
3.65	0.00
99	0.00



HSC Notes: None

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

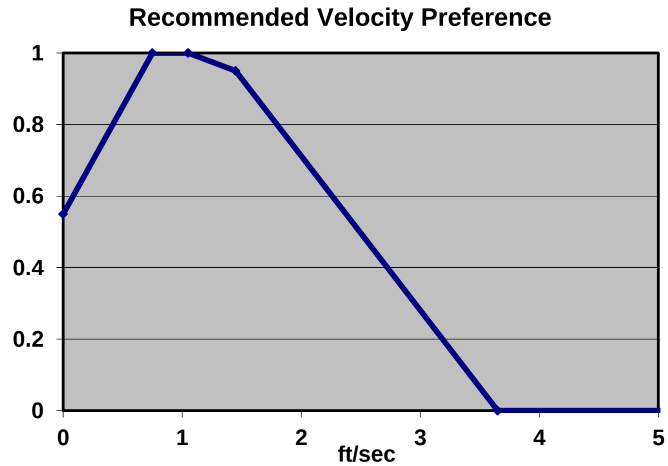
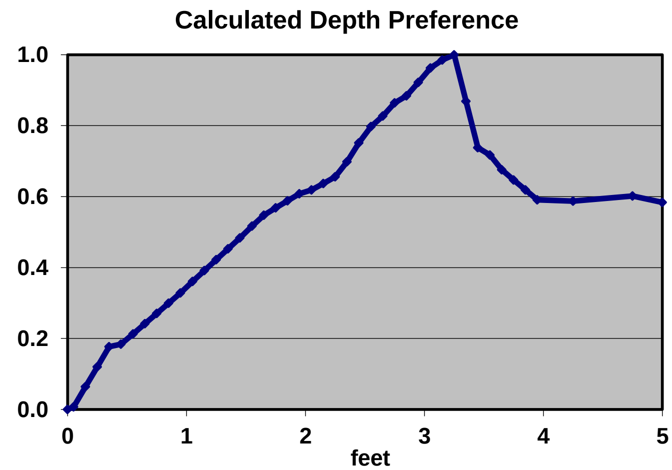
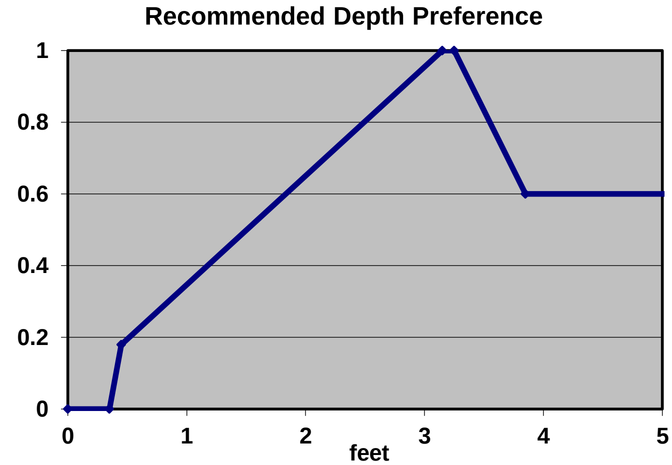


FIGURE 18a. Mountain Whitefish (*Prosopium williamsoni*) Adult Spawning Depth Preference

Analysis based on a composite of 8 Canadian studies and 3789 fish (Oldman, Bow, Sheep, Kananaskis, Red Deer (2) and Highwood rivers). **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.35	0.00
0.45	0.18
3.15	1.00
3.25	1.00
3.85	0.60
99	0.60



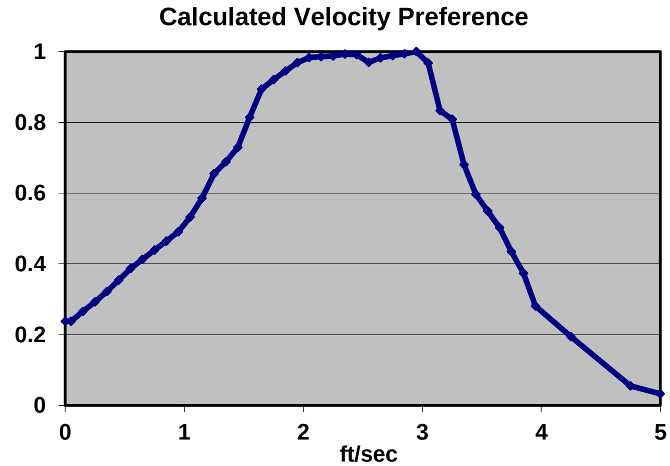


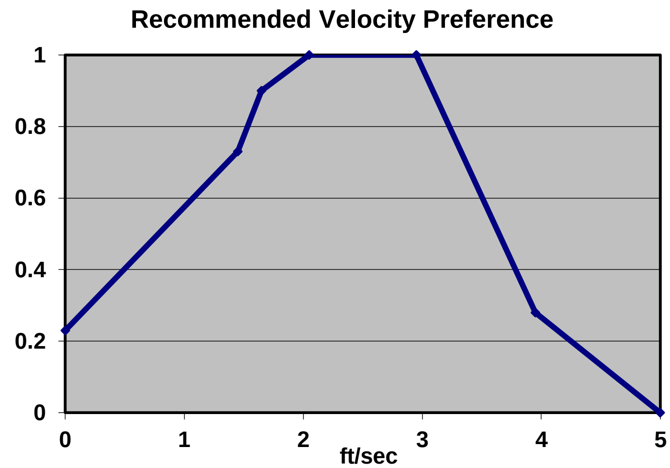
HSC Notes: The calculated preference from 0.0 to 0.39 ft was based on averages from the binning process, not observations. We decided to use a 0.0 preference from 0.0 to 0.35 ft to reflect a physical minimum depth needed for spawning fish.

For Mountain Whitefish Spawning Substrate Preference, use Table 7.

FIGURE 18b. Mountain Whitefish Adult Spawning Velocity Preference
Analysis based on a composite of 8 Canadian studies and 3789 fish (Oldman, Bow, Sheep, Kananaskis, Red Deer (2) and Highwood rivers). **Preference is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.23
1.45	0.73
1.65	0.90
2.05	1.00
2.95	1.00
3.95	0.28
5.00	0.00
99	0.00



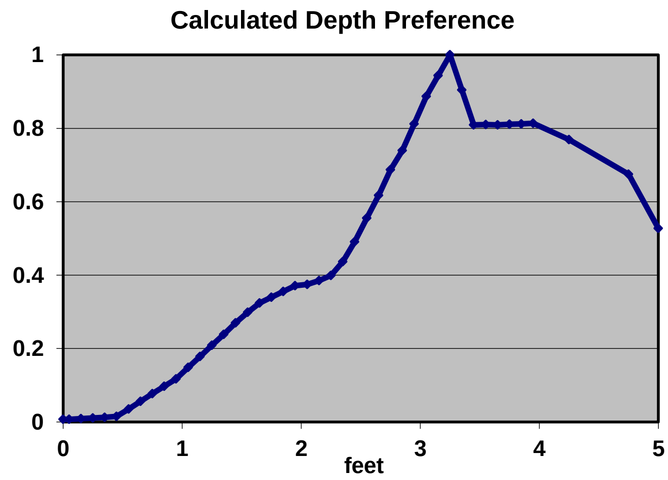


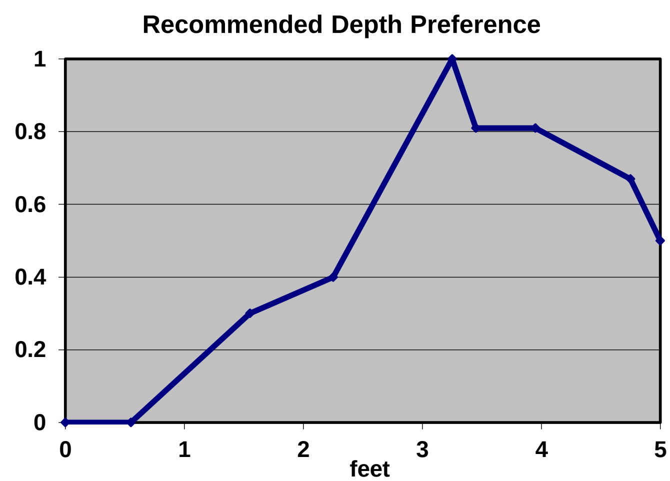
HSC Notes: None

For Mountain Whitefish Spawning Substrate Preference, use Table 7.

FIGURE 19a. Mountain Whitefish Adult Rearing Depth Preference
Analysis based on a composite of 8 Canadian studies and 1616 fish (Oldman, Sheep, Bow, Kananaskis, Red Deer (2), Highwood and Fraser rivers)*. **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.55	0.00
1.55	0.30
2.25	0.40
3.25	1.00
3.45	0.81
3.95	0.81
4.75	0.67
5.00	0.50
99	0.50



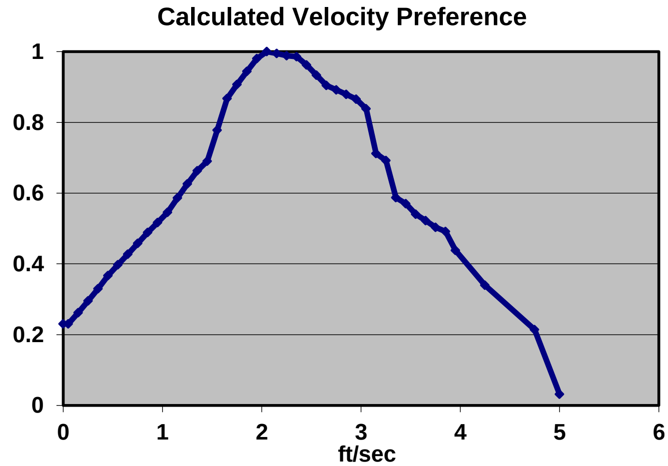


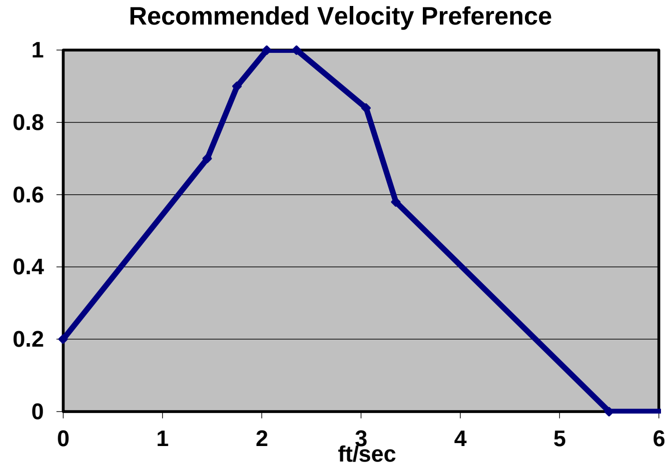
HSC Notes: We decided to continue the 0.50 preference out to 99'.

For Mountain Whitefish Adult Rearing Substrate Preference, use Table 8.

FIGURE 19b. Mountain Whitefish Adult Rearing Velocity Preference
Analysis based on a composite of 8 Canadian studies and 1616 fish (Oldman, Sheep, Bow, Kananaskis, Red Deer (2), Highwood and Fraser rivers). **Preference is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.20
1.45	0.70
1.75	0.90
2.05	1.00
2.35	1.00
3.05	0.84
3.35	0.58
5.50	0.00
99	0.00



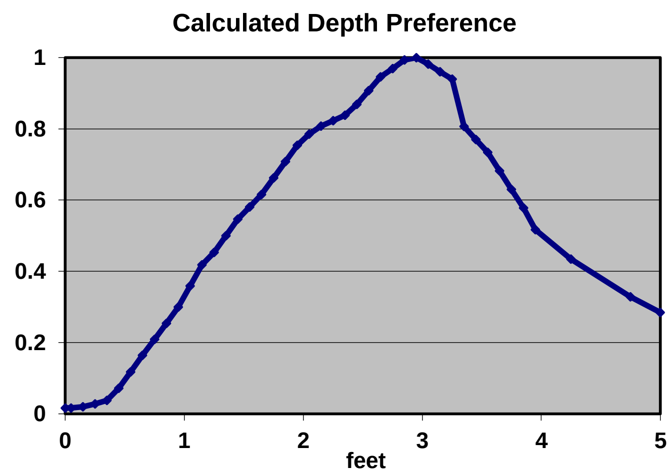


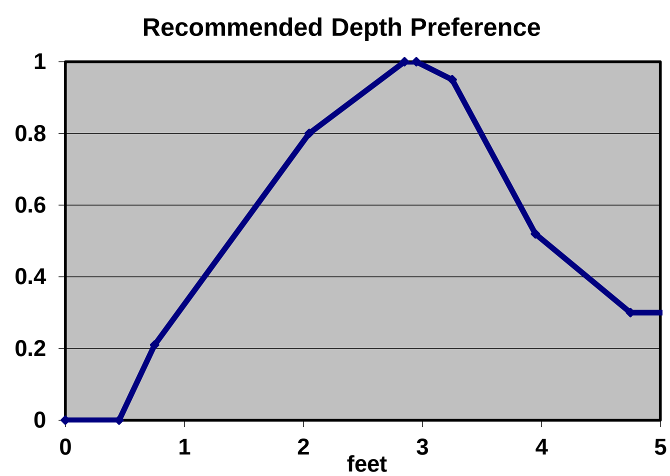
HSC Notes: None

For Mountain Whitefish Adult Rearing Substrate Preference, use Table 8.

FIGURE 20a. Mountain Whitefish Juvenile Depth Preference
Analysis based on a composite of 6 Canadian studies and 2306 fish (Oldman, Bow, Kananaskis, Fraser, Red Deer, and Highwood rivers). **Preference is unchanged from the 2016 edition.**

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.45	0.00
0.75	0.21
2.05	0.80
2.85	1.00
2.95	1.00
3.25	0.95
3.95	0.52
4.75	0.30
99	0.30



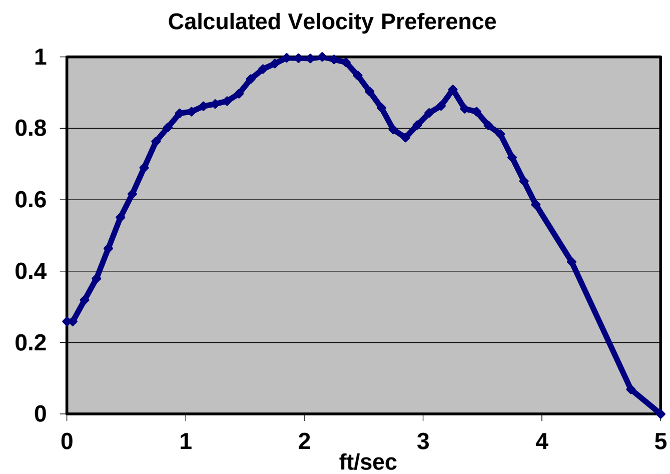


HSC Notes: We decided to continue the 0.30 preference out to 99'.

For Mountain Whitefish Juvenile Rearing Substrate Preference, use Table 9.

FIGURE 20b. Mountain Whitefish Juvenile Velocity Preference
Analysis based on a composite of 6 Canadian studies and 2306 fish (Oldman, Bow, Kananaskis, Fraser, Red Deer, and Highwood rivers). **Preference is unchanged from the 2016 edition.**

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.25
0.85	0.80
1.85	1.00
2.25	1.00
3.45	0.85
5.00	0.00
99	0.00



HSC Notes: None

For Mountain Whitefish Juvenile Rearing Substrate Preference, use Table 9.