INSTREAM FLOW STUDY GUIDELINES:

Technical and Habitat Suitability Issues

UPDATED, April 05, 2004

Washington Department of FISH and WILDLIFE

WASHINGTON STATE DEPARTMENT OF ECOLOGY

04-11-007

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INTRODUCTION

The Washington Department of Ecology (Ecology) is charged both with administering state water rights laws and the federal Clean Water Act. Chapters 90.54 and 90.22 RCW require Ecology to maintain instream flows sufficient to protect and preserve fish and wildlife habitat, scenic and aesthetic values, navigation and other environmental values. Water right permits will be conditioned with instream flow requirements to protect these values.

For projects requiring a federal license or permit involving a discharge into navigable waters, a section 401 Water Quality Certification will be required. Ecology is required to condition certifications to ensure compliance with state water quality standards and to prevent the degradation of existing uses such as fish and wildlife habitat, recreation and aesthetics. On hydroelectric projects Ecology has authority under the Clean Water Act to mandate minimum instream flows.

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

a) diverts at least 1.0 cubic feet per second (cfs), and
b) changes flow by at least 10% of the monthly 90% exceedence 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 fish passage upstream and downstream; and
3. to maintain macrohabitat features of the stream channel.

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

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

Primary contacts:

WDFW:	
Hal Beecher, Instream Flow Biologist	360-902-2421
Bob Vadas, Instream Flow Biologist	360-902-2594
Ecology:	
Brad Caldwell, Water Resources Program	360-407-6639
Jim Pacheco, Water Resources Program	360-407-7458
Jeff Marti, Water Resources Program	
Clean Water Act Section 401 certification	
and hydroelectric power project licenses	360-407-6636

PROJECT:____
STREAM:____
FERC#:____________________

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

SCOPING

Study site(s) approved__________________________date__/__/__
Transects approved_______________________date__/__/__
Target measurement flows approved___________date__/__/__

HYDRAULIC MODEL

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

HABITAT PREFERENCE CURVES

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

INSTREAM FLOWS - LIST BY TIME PERIOD:
MONTH/DATE to MONTH/DATE MINIMUM FLOW (cfs)
_____/____ to _____/____ ____________
_____/____ to _____/____ ____________
_____/____ to _____/____ ____________
_____/____ to _____/____ ____________
_____/____ to _____/____ ____________
_____/____ to _____/____ ____________
_____/____ to _____/____ ____________
FLUSHING FLOW REQUIREMENT - >48 HRS/3 YRS ____________________ cfs

Approved by Department of Fish and Wildlife

_________________________date__/__/__
Instream Flow Biologist

_________________________date__/__/__
Regional Habitat Biologist

INSTREAM FLOW STUDY GUIDELINES: Technical and Habitat Suitability Issues DRAFT, June 2003

Evaluating Instream Flows For Fish

When an existing or proposed project affects flow in a river or stream (i.e., hydropower, irrigation, or municipal/industrial diversions), the Washington state resource agencies, including the Washington Department of Ecology (Ecology) and Washington Department of Fish and Wildlife (WDFW), often request studies to evaluate the impacts of altered flow on instream resources, including fish habitat and production, for the purpose of making decisions or recommendations on water use. Instream flow study guidelines are for fish impacts.

Altered stream flows have two types of impacts that affect fish: (1) flow alteration and (2) flow fluctuations. Flow alterations are defined as changes over substantial periods of time (i.e., weeks or longer). Flow alterations change the amount and type of instream habitat and, in turn, change fish production and fish species composition. Direct measurement of this impact in terms of lost fish production is difficult. However, a widely used method called the Instream Flow Incremental Methodology (IFIM) (Bovee 1982, Milhous, et al. 1984, Bovee, et al. 1998) is useful for determining the flows needed to maintain the fish production potential of a stream or river.

IFIM uses several computer models (PHABSIM) to determine how habitat indexes change with changes in flow. The habitat indexes (Weighted Usable Area or WUA) at each flow correspond to biological requirements of the species and life history stage of fish of interest. Results of an IFIM/PHABSIM study are projections of WUA for each sensitive species/life history stage over a broad range of flows. From this information, the resource agencies recommend a flow requirement (usually a minimum flow requirement) needed to maintain the fish production potential of the stream.

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

Other Instream Flow Values

An IFIM/PHABSIM study produces information on the relationship of flow and fish habitat. The quantity and timing of instream flow also affects recreation (boating, fishing, swimming, wading, etc.), aesthetics, water quality, channel maintenance, riparian vegetation and other environmental values. Thus, a project proponent should be prepared to perform other studies as necessary, including monitoring, to determine flow requirements for other values.

In addition, flows deemed suitable for fish habitat may differ from those deemed necessary for another instream value. In some cases, they may be in direct conflict. An interdisciplinary approach to search for ways to reconcile and accommodate different resource needs is recommended (see Jackson et al. 1989).

Ramping Rates and Ramping Rate Studies

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

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

The rate of change of streamflow when diversion is started, stopped, or changed is referred to as the ramping rate. Ramping rate is a concern for fish protection because rapid decrease in flow can strand fish on gravel bars, as well as dewatering fish eggs. Drops in flow, even as little as 1 inch of water surface elevation per hour, can impact fish populations. Other effects, including depletion of aquatic invertebrates on which fish feed, and behavioral responses to changes in flow, may also reduce fish production but are not as well understood.

The impacts of flow fluctuation are mitigated by specifying a rate of flow reduction, the ramping rate, and specifying times during the day and year at which ramping can occur. For most projects, a standard interim ramping rate and ramping schedule are provided early in consultation by the agencies. Studies and agency consultation will assist in identifying ramping transects and critical flows. Ramping transects are evaluated to determine the maximum rate of flow change to meet interim ramping rates, so that engineers have specific design criteria to work with. The type of data needed is similar to that collected for part of the IFIM study, and it may be convenient to collect these data concurrently. IFIM is inappropriate for assessing effects of flow fluctuations because it measures habitat rather than mortality.

PURPOSE OF INSTREAM FLOW STUDY

The instream flow study should produce information on the relationship between flow and fish habitat. This is not the only information that will be considered; it will be used as one of several pieces of information necessary for state natural resource agencies to make recommendations and decisions. Factors to be considered in agency flow recommendations might include (1) fish access to tributaries at proposed flows, (2) other fish passage considerations, (3) proximity of suitable hydraulic conditions to cover for fish, (4) "ground-truthing" and professional judgement of proposed flows indicated as suitable by models, (5) hydrology, (6) watershed-stream channel interactions, and (7) results of monitoring.

KEY ELEMENTS OF INSTREAM FLOW STUDY

Consultation with the appropriate state agency personnel and personnel of other resource management agencies (including U.S. Fish and Wildlife Service, National Marine Fisheries Service) and Indian tribes is the responsibility of the project proponent at all stages of the study. Stages of the study include:

1) planning or scoping - develop study plan & obtain signed approval from all parties;
2) fish habitat preference curve verification based on study plan pre-approved by agencies;
3) field data collection;
4) hydraulic model calibration;
5) habitat model runs;
6) interpretation of habitat models and development of proposed instream flow recommendations, including field review and finalization of proposed instream flow recommendations;
7) monitoring of impacts of project with instream flows in place. Each stage will be discussed below with indications of agency preferences for techniques, programs, and emphasis.

PLANNING

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

In preparation for the meeting, the project proponent should conduct a thorough reconnaissance of the stream reach to be affected by the project. Reconnaissance should include stream reach downstream from project at least to next major confluence. Documentation of the reconnaissance that expedites agency review and planning includes:

1) map with contour intervals no greater than 20 feet;
2) graph of elevation plotted with distance along the stream;

3) low altitude photo mosaic (preferred) or video tape of entire reach (low flow in winter is best);
4) on-the-ground photos or video tape of all habitat types and potential barriers to fish migration (with reference object for scale in pictures of potential barriers);
5) list of fish species known or expected in stream reach;
6) available hydrological data such as 10%, 50%, and 90% exceedence discharges by month; and information on derivation of data.

The proponent should conduct an instream flow study using PHABSIM with the 3-flow (velocity regression) IFG4 as the hydraulic model unless otherwise approved in advance by all agencies. In preparation for the planning meeting or a follow-up site visit, the proponent should select and mark tentative transects to represent all habitats in the affected reach, including ramping rate transects both in the bypass reach and downstream of the powerhouse. Someone with IFIM experience should select these tentative transects. A site visit under suitable viewing conditions allows agency representatives to view, modify as needed, and approve placement of transects.

The final product of the planning meeting is a study plan signed by all parties agreeing to the plan. It should be as specific as possible. It should ensure that all parties understand what is expected from the study. It should ensure the project proponent that the study is not open-ended, thus allowing scheduling and budgeting of the study. It should be amendable only by unanimous agreement of all parties. The following elements should appear in the study plan:

1) hydraulic model(s) to be used;
2) range of flows to be addressed and target calibration flows;
3) hydrographs to be used in analysis;
4) locations of transects and study sites with maps and photos or videos as documentation;
5) habitat preference curve verification study plan (see below);
6) habitat models to be used (HABTAT, HABTAV, HABTAE, plunge pool, other);
7) fish passage flow determination procedure and criteria;
8) channel macrohabitat maintenance flow determination procedure;
9) any limiting factor analysis or time series analysis;
10) ramping rate study plan and sites.

FISH HABITAT PREFERENCE CURVE VERIFICATION

An instream flow study is incomplete if the project proponent has not made a reasonable effort to determine fish habitat preference at the study site or an approved substitute site. The study outlined here is a reasonable effort. If, after making a reasonable effort, the project proponent has not compiled enough data to verify or modify agencies' fallback or generalized habitat preference curves, then fallback curves may be used (see below and Appendix for discussion of fallback preference curves). Agencies will not modify fallback curves unless data collected at the site using a study plan pre-approved by the agencies. Preference curve verification may be aimed at selected species and life stages if those species and life stages will be given more weight in the development of an agency instream flow recommendation.

The preference curve verification study consists of three parts:

1) determine proportional habitat availability;
2) determine fish habitat utilization; and
3) analysis of fish preference or relative density by determining ratios 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), Beecher, Johnson, and Carleton (1993)), and Vadas and Orth (2001)..

Determining habitat availability. In PHABSIM the habitat dimensions of interest are depth, velocity, substrate, and cover. The simplest ways to determine the frequency of different ranges of habitat dimensions are either to map their distributions or to generate a table of their frequencies from PHABSIM based on an hydraulic model for the flow occurring during field measurements of habitat utilization. In either case, the field measurements of these dimensions should follow the procedures used for (and may coincide with) one of the IFG4 calibration flow measurements, as described by Bovee (1982, Instream Flow Information Paper No. 12) and Bovee and Milhous (1978, Instream Flow Information Paper No. 5). This will require measurements of depth and velocities along transects placed to represent the full array of habitat types occurring in the study reach.

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

Determining fish habitat utilization. Fish habitat utilization measurements should not be made during nor immediately after habitat availability measurements. This will minimize disturbance of fish.

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

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

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

0.00-0.09 ft	1.3%	O= 0
0.10-0.19 ft	1.4%	O= 0
0.20-0.29 ft	4.3%	O= 0
0.30-0.39 ft	4.8%	O= 0
0.40-0.49 ft	5.1%	O= 0
0.50-0.59 ft	7.8%	O= 1
0.60-0.69 ft	9.7%	O= 3
0.70-0.79 ft	14.7%	O=23
0.80-0.89 ft	18.2%	O=26
0.90-0.99 ft	15.0%	O=21
1.00-1.09 ft	11.5%	O= 7
1.10-1.19 ft	4.6%	O= 3
> 1.19 ft	1.6%	O= 3.

If the diver 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:

0.00-0.09 ft	E= 1.13
0.10-0.19 ft	E= 1.22
0.20-0.29 ft	E= 3.74
0.30-0.39 ft	E= 4.18
0.40-0.49 ft	E= 4.44
0.50-0.59 ft	E= 6.79
0.60-0.69 ft	E= 8.44
0.70-0.79 ft	E=12.79
0.80-0.89 ft	E=15.83
0.90-0.99 ft	E=13.05
1.00-1.09 ft	E=10.01
1.10-1.19 ft	E= 4.00
> 1.19 ft	E= 1.39.

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 yields the following:

0.00-0.29 ft	E= 6.1
0.30-0.49 ft	E= 8.6
0.50-0.59 ft	E= 6.8
0.60-0.69 ft	E= 8.4
0.70-0.79 ft	E=12.8
0.80-0.89 ft	E=15.8
0.90-0.99 ft	E=13.0

1.00-1.09 ft	E=10.0
> 1.09 ft	E= 5.4.

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

0.00-0.29 ft	O/E= 0.00	P=0.00
0.30-0.49 ft	O/E= 0.00	P=0.00
0.50-0.59 ft	O/E= 0.15	P=0.08
0.60-0.69 ft	O/E= 0.36	P=0.20
0.70-0.79 ft	O/E= 1.80	P=1.00
0.80-0.89 ft	O/E= 1.64	P=0.91
0.90-0.99 ft	O/E= 1.61	P=0.89
1.00-1.09 ft	O/E= 0.70	P=0.39
> 1.09 ft	O/E= 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.

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

<u>Life-stage timing.</u> 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.

HYDRAULIC MODEL CALIBRATION

The agencies' first choice of hydraulic models is IFG4 using 3 sets of velocity measurements to establish regressions of velocity with flow. Agencies expect to review an 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, 2-D and 3-D hydraulic models have been developed (Leclerc et al. 1995, Hardy 1998) which involve different calibration approaches that have considerable promise over a wide range of flows.

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

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

(2) input file (bed elevations, water surface elevations, velocities, substrate/cover, and calibration discharges for IFG4; bed elevations, water surface elevations, roughness coefficients, substrate/cover, and calibration discharge for WSP or IFG2);

(3) table 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); or, if several "1-flow IFG4" models are being run, table of each velocity calibration flow measured velocities with predicted velocities (e.g., measured high flow velocities with extrapolated high flow velocities from medium flow and low flow models, and similar treatments of medium flow and low flow calibration measurements);

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

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

(6) list of options used in hydraulic model;

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

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

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

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

Where possible, tie benchmarks together. We review stages of zero flow in different transects and expect them to make a normal upstream progression. If transects are modeled separately, this does not happen and our model review is prolonged.

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

HABITAT MODEL

A major product of an instream flow study is a set of tables and graphs relating an index of habitat, such as weighted usable area (WUA), to flow. In PHABSIM, this is produced by HABTAT or similar program, with results being listed in TAPE 8. In the plunge pool analysis, which will be discussed below, an index comparable to WUA will be calculated manually.

Separate runs of HABTAT should be run for spawning and rearing or holding. Use cover for rearing and substrate for spawning in those cells where both are recorded.

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 area it represents.

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

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

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 12).

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

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

<u>Feeding Station Analysis.</u> The unvalidated feeding station analysis of hydraulic model results from PHABSIM to evaluate habitat for rearing territorial trout (Beecher 1987) was initially an additional method for determining or confirming suitable instream flows. <u>The state agencies no</u>

longer consider this method to be a suitable alternative to calculation of WUA (see also Annear et al., 2002). With this method, trout feeding stations were tallied as number of measurement points (cells) where depth $\geq$0.5 foot, velocity <1.0 ft/sec, and velocity in at least one of the adjacent cells $\geq$1.0 ft/sec and $\geq$0.5 ft/sec faster than in the cell of interest. Thus, a cell was considered a good feeding station if it was deep, slow, and adjacent to faster food-transporting current. Numbers of feeding stations were tallied at different flows. Use of this method is no longer recommended because it has had less validation of assumptions than PHABSIM and it relies on lateral velocity gradient even though most of our observations of trout behavior include vertical velocity gradient.

INTERPRETATION OF HABITAT MODELS AND DEVELOPMENT OF INSTREAM FLOW RECOMMENDATIONS

The agencies will recommend instream flows which will not reduce habitat for the most flow-sensitive species and life stage. Flow recommendations based on model results (PHABSIM, plunge pool, and/or other) 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 hydrology of the site and effects of hydrology on fish (e.g., scouring of redds, incubation flows), agency management objectives and risk to species (e.g., greater emphasis on rainbow trout than on whitefish even though the more numerous whitefish typically occupy deeper, faster water), and on modeled responses of coexisting species to flow. For a more detailed discussion of agency considerations in interpretation of studies and development of recommendations, see Annear, et al. (2002).

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

> If two different flow regimes, A and B, lead to two different amounts of WUA, WUA(A) and WUA(B), at a given time, we can calculate a difference, DWUA = WUA(A) - WUA(B). DWUA can be plotted against time and can be positive, negative, or zero. HTI = 2**(T/10)*DWUA, where T is water temperature in degrees C at that season. HTI need not be used for spawning or incubation.

RAMPING RATE STUDIES

Information needed for ramping rate determination includes: (1) identification of critical sites, (2) determination of stage-discharge relationship at critical sites, (3) determination of travel time for a block of water traveling through a reach of interest, and (4) determination of attenuation of stage change over distance at different flows. Much of this information can be gathered conveniently concurrently with PHABSIM studies.

Critical sites are sites where juvenile fish are most likely to be stranded if stage is reduced rapidly. This can happen where the stream is wide and the cross section has a relatively flat slope, typically at a gravel bar or sand bar.

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

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

Dye studies should be used to give a preliminary estimate of travel time for a block of water from a release point, either 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.

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 of effects of flow regime (fish population response, attainment of flows, channel condition) will be required. The agencies may recommend changes in flow regime based upon results of monitoring.

REFERENCES

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Beecher, H.A. 1987. Simulating trout feeding stations in instream flow models. Pp. 71-82 in: J.F. Craig and J.B. Kemper (eds), Regulated Streams: Advances in Ecology. Plenum Press, New York and London.

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

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

Cover/Substrate preference tables and coding

Table 1 lists codes 00.1 through 00.9, 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. Cover/Substrate codes use the format ab.c.

For substrate codes, “a” is the component code for dominant particle size (i.e. the substrate that covers greatest bottom surface, 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 same format as the composite substrate code (ab.c), but “a” & “b” are always 0 and “c” define the type of cover. For example, 00.1 is an undercut bank, 00.2 is overhanging vegetation, etc.

Since PHABSIM and RHABSIM can only accept 1 Cover/Substrate code, best professional judgment is needed to determine if substrate or cover should used. In general, we use the code with the highest value. To insure this option, both categories must be noted during fieldwork.

Recommended Preference (RP) in substrate tables (2-4, & 8,-11) are calculated from generic preferences in **Table 1** according to the following equation:

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

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

Many exceptions are listed for spawning substrate. 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 more than 20% of the substrate (i.e. c = 7, 6 or 5), the substrate was assigned a RP of 0.00, regardless of the quality of the dominant substrate, due to the smothering effect of fine substrates.

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

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

Every code combination is not listed and not 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 are only listed in the form ab.9.

Depth and velocity preference curves

Figures 1a-21b show the various recommended preference curves along with the coordinates used to make the curves. When available, the calculated preference curve and coordinates are provided to show the Observed/Expected calculations discussed on pages 8&9 under the heading Analysis of fish habitat preference and sample size and study locations are listed. In these cases, Recommended Preference curves represent smoothed versions of the calculated preference curves. Smoothing of preference coordinates is based on professional judgment and observations from studies of wild fish.

When listed alone, Recommended Preference either come from independent published studies where a calculated preference was not given or were values derived from unrecorded observations and best professional judgment. These are noted as well.

Some initial depth preference curves show habitat value in a depth interval that includes 0.00 ft. This is a consequence of grouped observations and weighting calculations. No fish were spawning or rearing at 0.00 ft depth.

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

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

Code	type of cover Note: Cover Codes are not used for spawning	Rearing fry	Rearing juvenile	Holding adult
00.1	undercut bank	1.00	1.00	1.00
00.2	overhanging vegetation[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	0.30	0.80	0.80
00.6	aquatic vegetation	1.00	0.80	0.80
00.7	short (<1') terrestrial grass	0.40	0.10	0.10
00.8	tall (>3') dense grass[3]	0.70	0.70	0.10
00.9	vegetation beyond the bank-full waters edge	0.20	0.20	0.20

Code	type of substrate	Spawning salmon	Spawning steelhead	Spawning resident trout	Spawning bull & dolly[4]	Rearing fry	Rearing juvenile	Holding adult
1	silt, clay, or organic	0.00	0.00	0.00	0.00	0.10	0.10	0.10
2	sand	0.00	0.00	0.00	0.00	0.10	0.10	0.10
3	sm gravel (.1-.5")	0.30	0.50	0.80	1.00	0.10	0.10	0.10
4	med gravel (.5-1.5")	1.00	1.00	1.00	1.00	1.00	0.30	0.30
5	lrg gravel (1.5-3")	1.00	1.00	0.80	1.00	1.00	0.30	0.30
6	sm cobble (3-6")	1.00	1.00	0.50	0.70	1.00	0.50	0.30
7	lrg cobble (6-12")	0.50	0.30	0.00	0.70	1.00	0.70	0.30
8	boulder (>12")	0.00	0.00	0.00	0.00	1.00	1.00	1.00
9	bedrock	0.00	0.00	0.00	0.00	0.10	0.30	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) 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 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*
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	0.30	0.00*
24.5	0.00	1.00	0.00*
26.9	0.00	1.00	0.00*
27.5	0.00	0.50	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	0.00*
38.9	0.30	0.00	0.00*
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	0.00*
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	0.30	0.65
53.9	1.00	0.30	0.93
54.5	1.00	1.00	1.00

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

Table 2 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
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	0.00*
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	0.30	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	0.00*
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	0.50	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	0.00*
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*
83.9	0.00	0.30	0.00*
84.5	0.00	1.00	0.00*
84.9	0.00	1.00	0.00*
85.5	0.00	1.00	0.00*
85.9	0.00	1.00	0.00*
86.5	0.00	1.00	0.00*
86.9	0.00	1.00	0.00*
87.5	0.00	0.50	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*
93.9	0.00	0.30	0.00*
94.5	0.00	1.00	0.00*
94.9	0.00	1.00	0.00*
95.5	0.00	1.00	0.00*
95.9	0.00	1.00	0.00*
96.5	0.00	1.00	0.00*
96.9	0.00	1.00	0.00*
97.5	0.00	0.50	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 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 19).
[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 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*
83.9	1.00	0.10	1.00*
84.5	1.00	0.30	1.00*
85.9	1.00	0.30	1.00*
86.5	1.00	0.50	1.00*
86.9	1.00	0.50	1.00*
87.5	1.00	0.70	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. Adult Holding 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			0.10
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	0.30	0.20
16.9	0.10	0.30	0.12
17.5	0.10	0.30	0.20
17.9	0.10	0.30	0.12
18.5	0.10	1.00	0.55
18.9	0.10	1.00	0.19
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	0.30	0.20
26.9	0.10	0.30	0.12
27.5	0.10	0.30	0.20
27.9	0.10	0.30	0.12
28.5	0.10	1.00	0.55
28.9	0.10	1.00	0.19
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	0.30	0.20
36.9	0.10	0.30	0.12
37.5	0.10	0.30	0.20
37.9	0.10	0.30	0.12
38.5	0.10	1.00	0.55
38.9	0.10	1.00	0.19
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
47.9	0.30	0.30	0.30
48.5	0.30	1.00	0.65
48.9	0.30	1.00	0.37
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
57.9	0.30	0.30	0.30
58.5	0.30	1.00	0.65
58.9	0.30	1.00	0.37
59.5	0.30	0.30	0.30
59.9	0.30	0.30	0.30
61.5	0.30	0.10	0.20
61.9	0.30	0.10	0.28
62.5	0.30	0.10	0.20
62.9	0.30	0.10	0.28
63.5	0.30	0.10	0.20
63.9	0.30	0.10	0.28

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

Table 4 Continued

Code (ab.c)	Preference value a	Preference value b	Recommended Preference
64.5	0.30	0.30	0.30
67.9	0.30	0.30	0.30
68.5	0.30	1.00	0.65
68.9	0.30	1.00	0.37
69.5	0.30	0.30	0.30
69.9	0.30	0.30	0.30
71.5	0.30	0.10	0.20
71.9	0.30	0.10	0.28
72.5	0.30	0.10	0.20
72.9	0.30	0.10	0.28
73.5	0.30	0.10	0.20
73.9	0.30	0.10	0.28
74.5	0.30	0.30	0.30
77.9	0.30	0.30	0.30
78.5	0.30	1.00	0.65
78.9	0.30	1.00	0.37
79.5	0.30	0.30	0.30
79.9	0.30	0.30	0.30
81.5	1.00	0.10	0.55
81.9	1.00	0.10	0.91
82.5	1.00	0.10	0.55
82.9	1.00	0.10	0.91
83.5	1.00	0.10	0.55
83.9	1.00	0.10	0.91
84.5	1.00	0.30	0.65
84.9	1.00	0.30	0.93
85.5	1.00	0.30	0.65
85.9	1.00	0.30	0.93
86.5	1.00	0.30	0.65
86.9	1.00	0.30	0.93
87.5	1.00	0.30	0.65
87.9	1.00	0.30	0.93
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	0.10	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
97.9	0.30	0.30	0.30
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 5. 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*
24.5	0.00	1.00	0.00*
26.9	0.00	1.00	0.00*
27.5	0.00	0.30	0.00*
27.9	0.00	0.30	0.00*
28.5	0.00	0.00	0.00
29.9	0.00	0.00	0.00
31.5	0.50	0.00	0.00*
31.7	0.50	0.00	0.00*
31.8	0.50	0.00	0.40
31.9	0.50	0.00	0.45
32.5	0.50	0.00	0.00*
32.7	0.50	0.00	0.00*
32.8	0.50	0.00	0.40
32.9	0.50	0.00	0.45
33.9	0.50	0.50	0.50
34.5	0.50	1.00	0.75
34.9	0.50	1.00	0.55
35.5	0.50	1.00	0.75
35.9	0.50	1.00	0.55
36.5	0.50	1.00	0.75
36.9	0.50	1.00	0.55
37.5	0.50	0.30	0.40
37.9	0.50	0.30	0.48
38.5	0.50	0.00	0.00*
38.9	0.50	0.00	0.00*
39.5	0.50	0.00	0.00*
39.9	0.50	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	0.50	0.75
43.9	1.00	0.50	0.95
44.5	1.00	1.00	1.00
44.9	1.00	1.00	1.00
46.9	1.00	1.00	1.00
47.5	1.00	0.30	0.65
47.9	1.00	0.30	0.93
48.5	1.00	0.00	0.00*
48.9	1.00	0.00	0.00*
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	0.50	0.75
53.9	1.00	0.50	0.95
54.5	1.00	1.00	1.00
56.9	1.00	1.00	1.00
57.5	1.00	0.30	0.65
57.9	1.00	0.30	0.93

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

Table 5 Continued

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

TABLE 6. Generic Trout Spawning Substrate Preference[1]

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

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

TABLE 6 Continued

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

TABLE 7. Bull Trout (Salvelinus confluentus) and Dolly Varden (S. malma) Spawning Substrate Preference[1] [2]

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[3]	0.00	0.00	0.00
31.7	1.00	0.00	0.00*
31.8	1.00	0.00	0.80
31.9	1.00	0.00	0.90
32.5	1.00	0.00	0.00*
32.7	1.00	0.00	0.00*
32.8	1.00	0.00	0.80
32.9	1.00	0.00	0.90
33.9	1.00	1.00	1.00
35.9	1.00	1.00	1.00
36.5	1.00	0.70	0.85
36.9	1.00	0.70	0.97
37.5	1.00	0.70	0.85
37.9	1.00	0.70	0.97
38.5	1.00	0.00	0.50
38.9	1.00	0.00	0.90
39.5	1.00	0.00	0.00*
39.9	1.00	0.00	0.00*
41.5	1.00	0.00	0.00*
41.7	1.00	0.00	0.00*
41.8	1.00	0.00	0.80
41.9	1.00	0.00	0.90
42.5	1.00	0.00	0.00*
42.7	1.00	0.00	0.00*
42.8	1.00	0.00	0.80
42.9	1.00	0.00	0.90
43.5	1.00	1.00	1.00
45.9	1.00	1.00	1.00
46.5	1.00	0.70	0.85
46.9	1.00	0.70	0.97
47.5	1.00	0.70	0.85
47.9	1.00	0.70	0.97
48.5	1.00	0.00	0.50
48.9	1.00	0.00	0.90
49.5	1.00	0.00	0.00*
49.9	1.00	0.00	0.00*
51.5	1.00	0.00	0.00*
51.7	1.00	0.00	0.00*
51.8	1.00	0.00	0.80
51.9	1.00	0.00	0.90
52.5	1.00	0.00	0.00*
52.7	1.00	0.00	0.00*
52.8	1.00	0.00	0.80
52.9	1.00	0.00	0.90
53.5	1.00	1.00	1.00
55.9	1.00	1.00	1.00
56.5	1.00	0.70	0.85
56.9	1.00	0.70	0.97
57.5	1.00	0.70	0.85
57.9	1.00	0.70	0.97
58.5	1.00	0.70	0.85
58.9	1.00	0.70	0.97
59.5	1.00	0.00	0.00*
59.9	1.00	0.00	0.00*
61.5	0.70	0.00	0.00*
61.7	0.70	0.00	0.00*
61.8	0.70	0.00	0.56
61.9	0.70	0.00	0.63
62.5	0.70	0.00	0.00*
62.7	0.70	0.00	0.00*
62.8	0.70	0.00	0.56
62.9	0.70	0.00	0.63
63.5	0.70	1.00	0.85
63.9	0.70	1.00	0.73
64.5	0.70	1.00	0.85
64.9	0.70	1.00	0.73
65.5	0.70	1.00	0.85
65.9	0.70	1.00	0.73
66.9	0.70	0.70	0.70
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 19).
[2] Native charr include Bull Trout (*Salvelinus confluentus*) and Dolly Varden (*S. malma*)
[3] 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 7 Continued

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

TABLE 8. Chum Salmon (O. keta) Spawning Substrate Preference
Kennedy Creek, Duckabush and Dosewallips rivers (8 studies, 138 redds).

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

For the full table of 3 digit codes, use Table 2. Generic Salmon Spawning Preference

TABLE 9. Coho Salmon (O. kisutch) Spawning Substrate Preference
Dewatto River and Fletcher Canyon Creek (2 studies, 30 redds).

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

For the full table of 3 digit codes, use Table 2. Generic Salmon Spawning Preference

TABLE 10. Pink Salmon (O. gorbuscha) Spawning Substrate Preference
Squire Creek, N. Fork Stillaguamish, Dosewallips, and Duckabush rivers (3 studies, 46 redds).

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

For the full table of 3 digit codes, use Table 2. Generic Salmon Spawning Preference

TABLE 11. Sockeye Salmon (O. nerka) Spawning Substrate Preference
(Cascades 1990)

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

For the full table of 3 digit codes, use Table 2. Generic Salmon Spawning Preference

TABLE 12. Bull Trout and Dolly Varden Spawning Substrate Preference
4 streams (34 redds)

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

For the full table of 3 digit codes, use Table 7. Bull Trout and Dolly Varden Spawning Substrate Preference

TABLE 13. Cutthroat Trout (O. clarki) Spawning Substrate Preference
Not yet finalized

TABLE 14. Preference Factors for Ratios of Turbulence

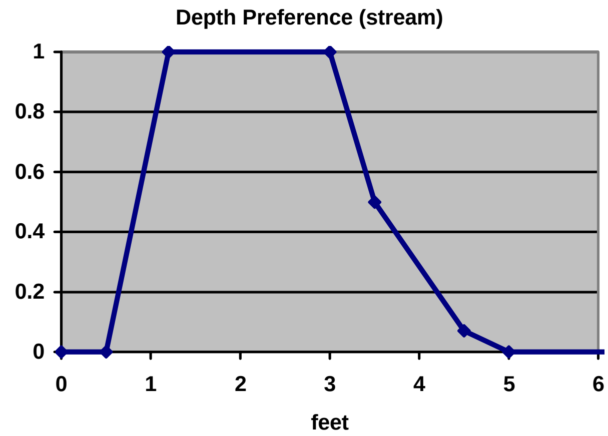
Plume to Calm, Deep Area in Plunge Pool Method (from page 12)

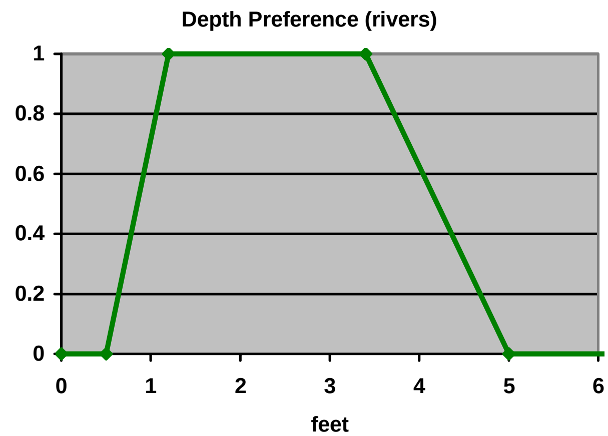
Ratio (plume to calm, deep)	Preference Factor
0.0	0.10
0.25	0.40
0.5	0.80
1.0	1.00
2.0	0.50
4.0	0.25
8.0	0.125
16.0	0.06
32.0	0.03

FIGURE 1a. Chinook Salmon (Oncorhynchus tshawytscha) Spawning Depth Preference
In streams (mean annual undiverted flow <100 cfs), rivers (flow 100-1,000 cfs), and large rivers (flow >1,000 cfs). (Caldwell, Caldwell & Bruya 1987)

Plotted depth (feet)	Recommended depth preference		
	streams	rivers	large rivers
0.00	0.00	0.00	0.00
0.50	0.00	0.00	0.00
1.00	-	-	0.75
1.20	1.00	1.00	-
1.50	-	-	1.00
3.00	1.00	-	-
3.40	-	1.00	-
3.50	0.50	-	-
4.50	0.07	-	-
5.00	0.00	0.00	1.00
10.00	-	-	0.00
99	0.00	0.00	0.00

In mainstem Columbia or Snake rivers, depth preference is open-ended.





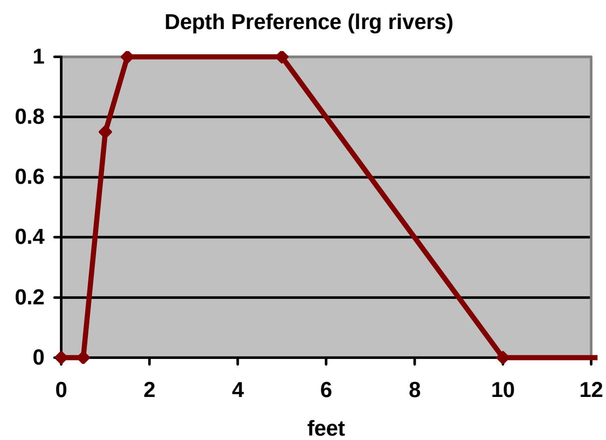
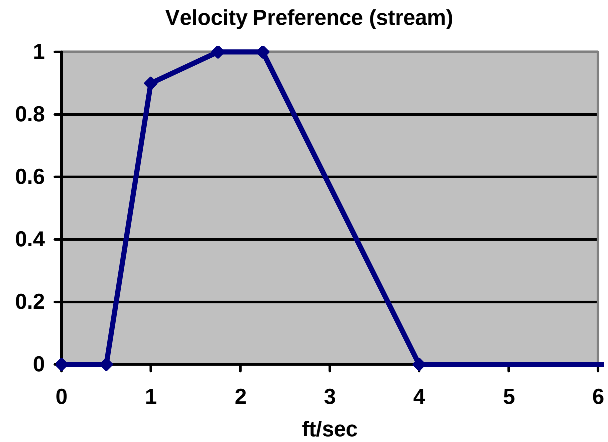
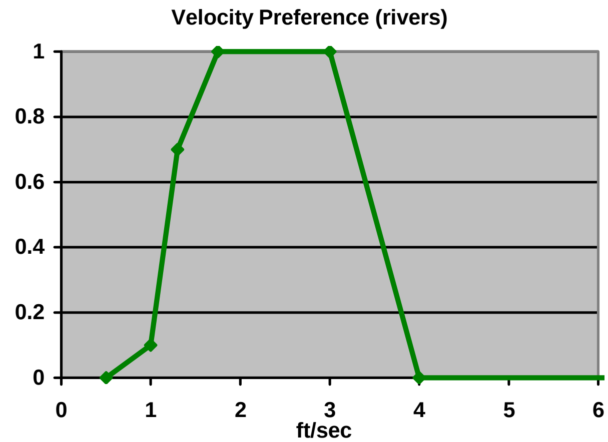


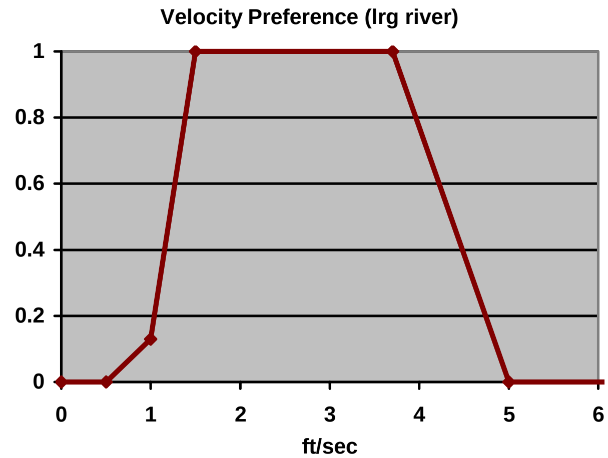
FIGURE 1b. Chinook Salmon Spawning Velocity Preference

In streams (mean annual undiverted flow <100 cfs), rivers (flow 100-1,000 cfs), and large rivers (flow >1,000 cfs). (Caldwell, Caldwell & Bruya 1987)

Plotted velocity (ft/sec)	Recommended velocity suitability		
	streams	rivers	large rivers
0.00	0.00	0.00	0.00
0.50	0.00	0.00	0.00
1.00	0.90	0.10	0.13
1.30	-	0.70	-
1.50	-	-	1.00
1.75	1.00	1.00	-
2.25	1.00	-	-
3.00	-	1.00	-
3.70	-	-	1.00
4.00	0.00	0.00	-
5.00	-	-	0.00
99	0.00	0.00	0.00





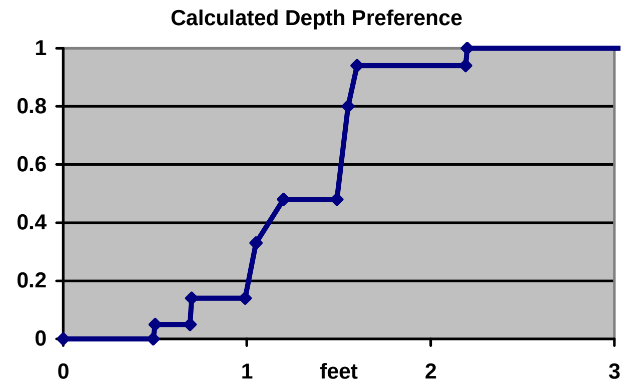


For Chinook Salmon Spawning Substrate Preference, use Table 2.

FIGURE 2a. Chinook Salmon Juvenile Rearing Depth Preference
Dungeness, Chiwawa, Mad & Tucannon Rivers (4 studies, 173 fish)

Calculated depth preference curve	
Depth interval (feet)	Depth preference
0.00-0.39	0.00
0.40-0.49	0.00
0.50-0.69	0.05
0.70-0.79	0.14
0.80-0.99	0.14
1.00-1.09	0.33
1.10-1.19	0.37
1.20-1.49	0.48
1.50-1.59	0.80
1.60-2.19	0.94
2.20+	1.00

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.45	0.00
1.35	0.50
1.55	0.80
2.20	1.00
99	1.00



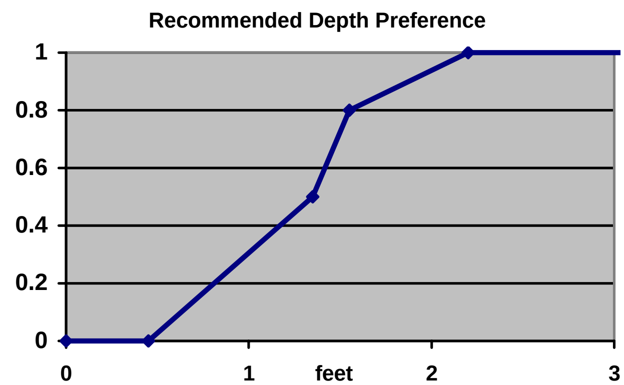
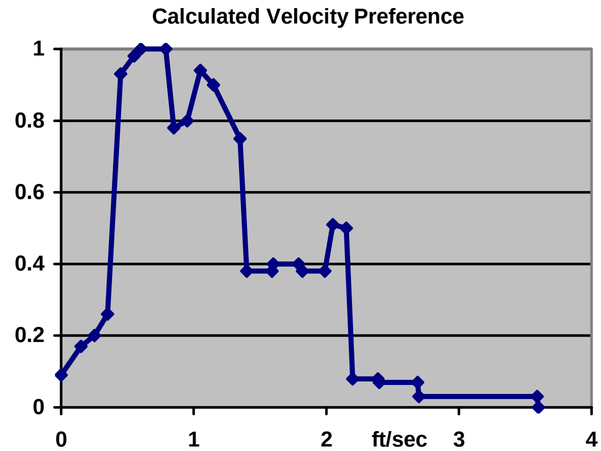
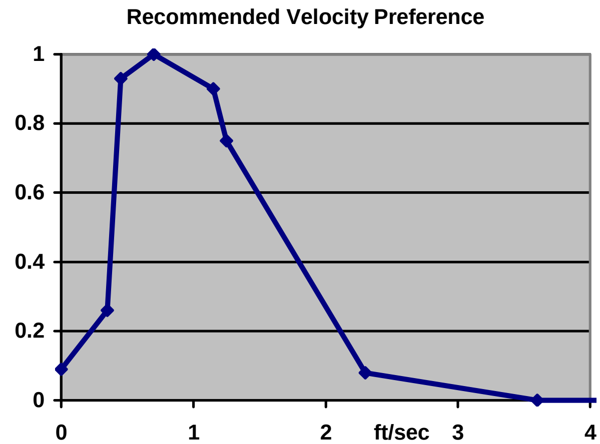


FIGURE 2b. Chinook Salmon Juvenile Rearing Velocity Preference
Dungeness, Chiwawa, Mad & Tucannon Rivers (4 studies, 173 fish)

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.09	0.00	0.09
0.10-0.19	0.17	0.35	0.26
0.20-0.29	0.20	0.45	0.93
0.30-0.39	0.26	0.70	1.00
0.40-0.49	0.93	1.15	0.90
0.50-0.59	0.98	1.25	0.75
0.60-0.79	1.00	2.30	0.08
0.80-0.89	0.78	3.60	0.00
0.90-0.99	0.80	99	0.00
1.00-1.09	0.94		
1.10-1.19	0.90		
1.20-1.29	0.76		
1.30-1.39	0.74		
1.40-1.59	0.38		
1.60-1.79	0.40		
1.80-1.99	0.38		
2.00-2.09	0.51		
2.10-2.19	0.50		
2.20-2.39	0.08		
2.40-2.69	0.07		
2.70-3.59	0.03		
3.60+	0.00		





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

FIGURE 3a. Spring Chinook Salmon Holding Depth Preference
In streams (mean annual undiverted flow <100 cfs), rivers (flow 100-1,000 cfs), and large rivers (flow >1,000 cfs). (Caldwell, Caldwell & Bruya 1987)

Plotted depth (feet)	Recommended holding depth preference		
	streams	rivers	large rivers
0.00	NA	0.00	0.00
0.80	NA	0.00	0.00
2.00	NA	0.10	0.10
6.50	NA	1.00	1.00
99	NA	1.00	1.00

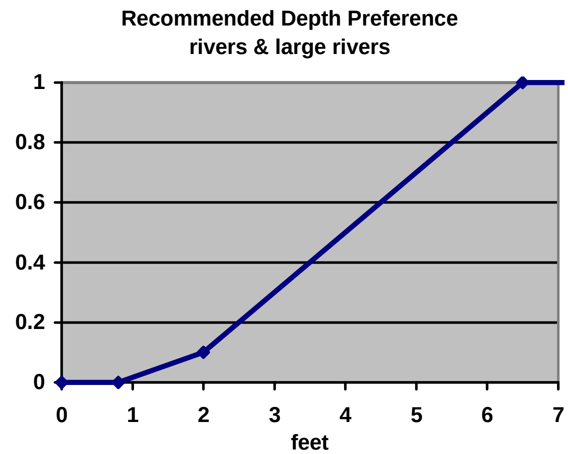
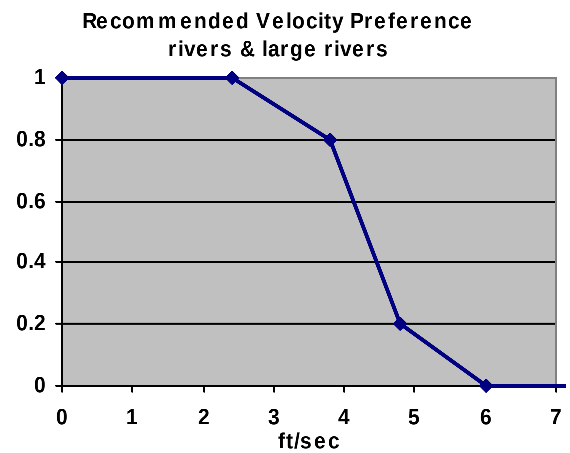


FIGURE 3b. Spring Chinook Salmon Holding Velocity Preference
In streams (mean annual undiverted flow <100 cfs), rivers (flow 100-1,000 cfs), and large rivers (flow >1,000 cfs). (Caldwell, Caldwell & Bruya 1987)

Plotted velocity (ft/sec)	Recommended holding velocity preference		
	streams	rivers	large rivers
0.00	NA	1.00	1.00
2.40	NA	1.00	1.00
3.80	NA	0.80	0.80
4.80	NA	0.20	0.20
6.00	NA	0.00	0.00
99	NA	0.00	0.00

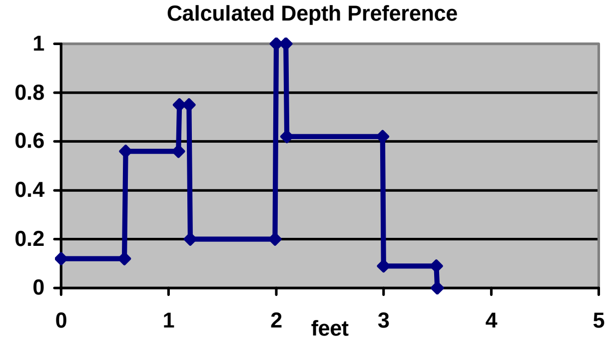


For Spring Chinook Salmon Holding Substrate Preference, use Table 4.

FIGURE 4a. Coho Salmon (*O. kisutch*) Spawning Depth Preference
Dewatto River and Fletcher Canyon Creek (Quinault tributary) (2 studies, 30 redds)

Calculated depth preference curve	
Depth interval (feet)	Depth preference
0.00-0.59	0.12
0.6-1.09	0.56
1.10-1.19	0.75
1.2-1.99	0.20
2.00-2.09	1.00
2.10-2.99	0.62
3.00-3.49	0.09
3.50 +	0.0

Recommended depth preference curve	
Plotted depth (feet)	Depth Preference
0.00	0.00
0.45	0.00
1.15	0.75
2.05	1.00
3.25	0.09
4.00	0.01
99	0.01



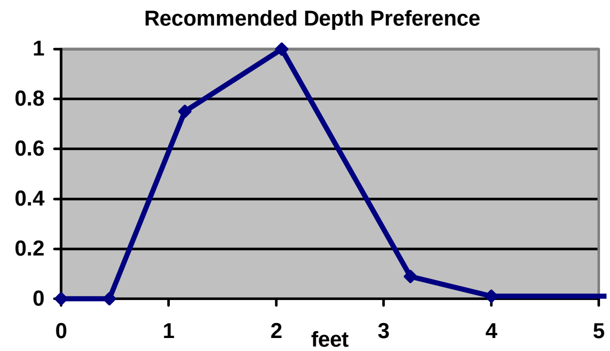
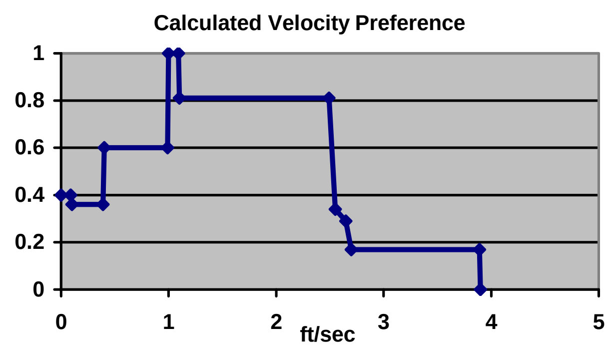
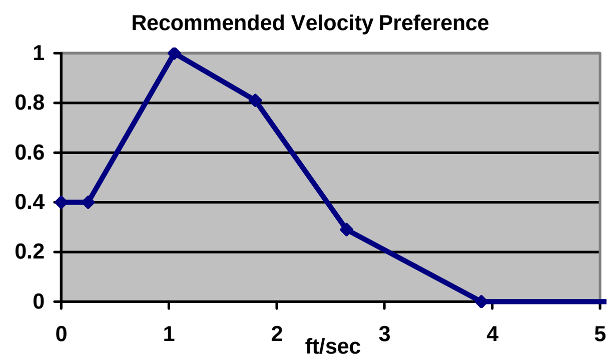


FIGURE 4b. Coho Salmon Spawning Velocity Preference

Calculated velocity preference curve	
Velocity interval (ft/sec)	Velocity preference
0.00 0.09	0.49
0.10-0.39	0.36
0.4-0.99	0.60
1.00-1.09	1.00
1.10-2.49	0.81
2.5-2.59	0.34
2.6-2.69	0.29
2.70-3.89	0.17
3.90 +	0.00

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.40
0.25	0.40
1.05	1.00
1.80	0.81
2.65	0.29
3.90	0.00
99	0.00

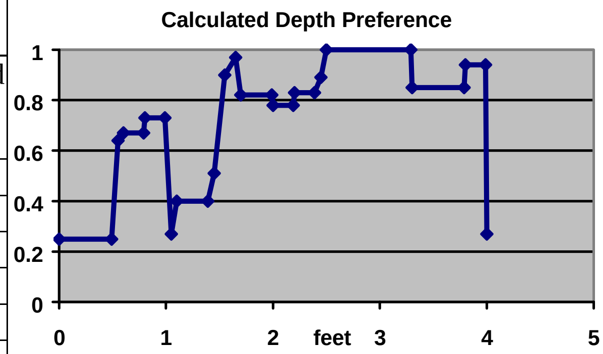




For Coho Salmon Spawning Substrate Preference, use Table 2.
Additional studies on the Dewatto River and Fletcher Canyon Creek support the values found in Table 2.

FIGURE 5a. Coho Salmon Juvenile Depth Preference
Dungeness, Satsop Rivers and Kenedy Creek (4 studies, 451 fish) (Beecher, et al. 2002)

Calculated velocity preference curve		Recommended velocity preference curve	
Depth interval (feet)	Calculated depth preference	Plotted depth (feet)	Recommended depth preference
0.00-0.49	0.25	0.00	0.00
0.50-0.59	0.64	0.10	0.00
0.60-0.79	0.67	0.25	0.25
0.80-0.99	0.73	1.55	0.90
1.00-1.09	0.27	2.50	1.00
1.10-1.39	0.40	3.25	1.00
1.40-1.49	0.51	3.90	0.90
1.50-1.59	0.90	4.00	0.27
1.60-1.69	0.97	99	0.27
1.70-1.99	0.82		
2.00-2.19	0.78		
2.20-2.39	0.83		
2.40-2.49	0.89		
2.50-3.29	1.00		
3.30-3.79	0.85		
3.80-3.99	0.94		
4.00+	0.27		



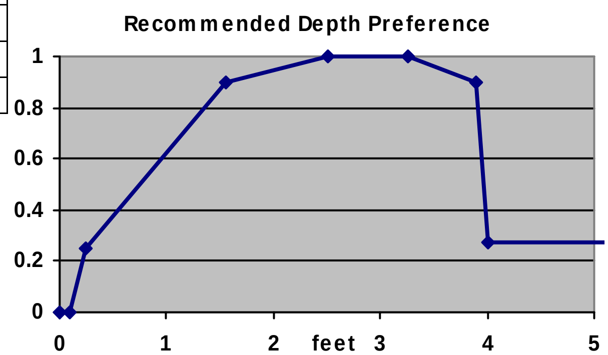
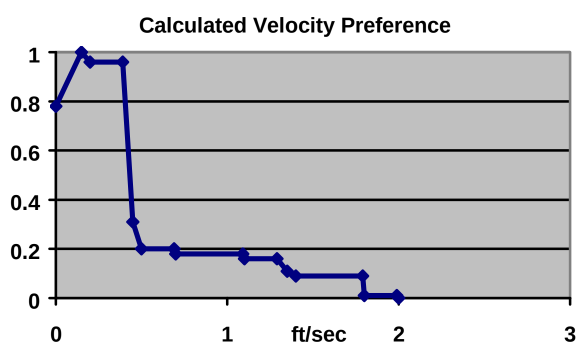
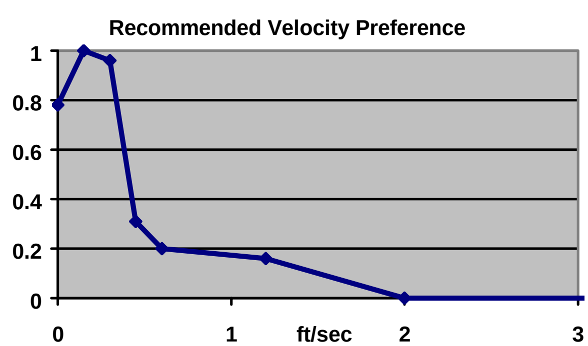


FIGURE 5b. Coho Salmon Juvenile Velocity Preference

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotting velocity (ft/sec)	Velocity preference
0.00-0.09	0.78	0.00	0.78
0.10-0.19	1.00	0.15	1.00
0.20-0.39	0.96	0.30	0.96
0.40-0.49	0.31	0.45	0.31
0.50-0.69	0.20	0.60	0.20
0.70-1.09	0.18	1.20	0.16
1.10-1.29	0.16	2.00	0.00
1.30-1.39	0.11	99	0.00
1.40-1.79	0.09		
1.80-1.99	0.01		
2.00+	0.00		

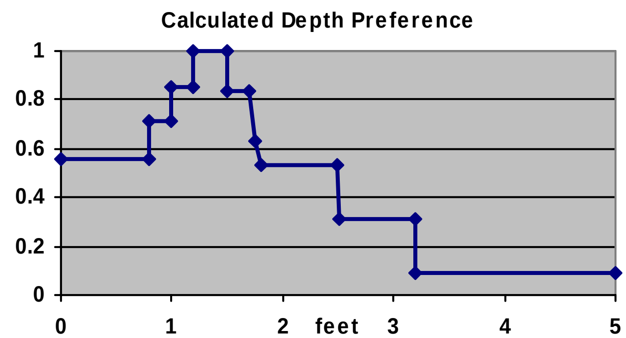




For Coho Salmon Rearing Substrate Preference, use Table 3.

FIGURE 6a. Fall Chum salmon (*O. keta*) Spawning Depth Preference
Kennedy Creek, Duckabush and Dosewallips Rivers (8 studies, 97 redds)

Fall chum (Nov-Jan)			
Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted Depth (feet)	Depth preference
0.00-0.79	0.56	0.00	0.00
0.80-0.99	0.71	0.30	0.00
1.00-1.19	0.85	0.60	0.55
1.20-1.49	1.00	1.20	1.00
1.50-1.69	0.84	1.50	1.00
1.70-1.79	0.63	1.75	0.63
1.80-2.49	0.53	3.90	0.10
2.5-3.19	0.31	5.00	0.05
3.2-5.00	0.09	99	0.05



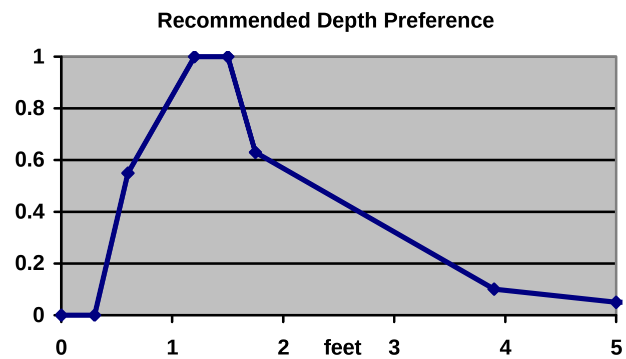
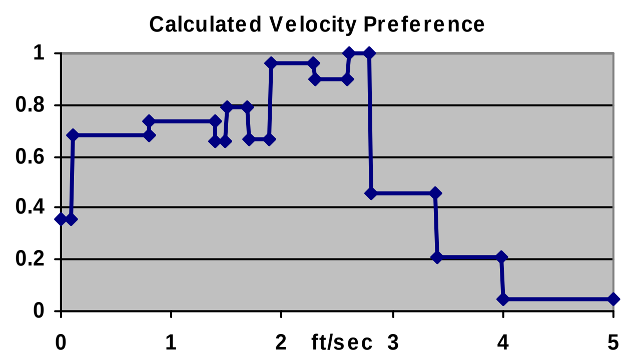
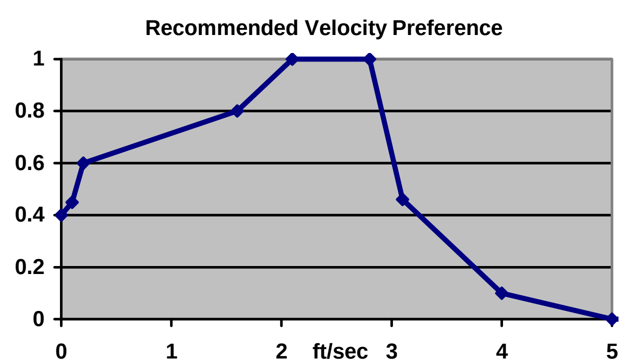


FIGURE 6b. Fall Chum Salmon Spawning Velocity Preference

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted Velocity (ft/sec)	Velocity preference
0.00-0.09	0.36	0.00	0.4
0.10-0.79	0.68	0.10	0.45
0.80-1.39	0.74	0.20	0.60
1.40-1.49	0.66	1.60	0.80
1.50-1.69	0.79	2.10	1.00
1.70-1.89	0.67	2.80	1.00
1.90-2.29	0.96	3.10	0.46
2.30-2.59	0.90	4.00	0.10
2.60-2.79	1.00	99	0.00
2.80-3.39	0.46		
3.40-3.99	0.21		
4.00-5.00	0.05		

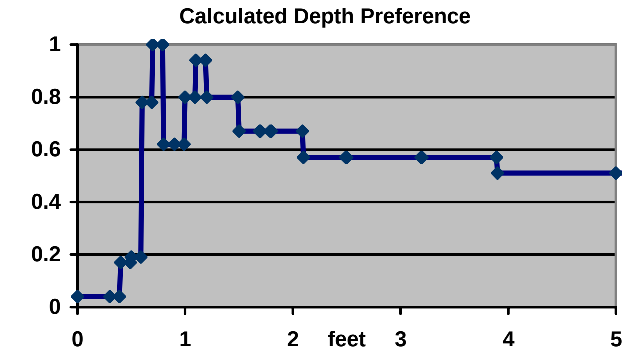




For Fall Chum Salmon Spawning Substrate Preference, use Table 2. Also see Table 8 for calculated preference information.

FIGURE 7a. Summer Chum Salmon Spawning Depth Preference
Hood Canal (7 studies, 110 redds)

Summer chum (Sept-early Oct)			
Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.39	0.04	0.00	0.00
0.40-0.49	0.17	0.30	0.00
0.50-0.59	0.19	0.55	0.20
0.60-0.69	0.78	0.75	1.00
0.70-0.79	1.00	1.15	1.00
0.80-0.99	0.62	2.20	0.60
1.00-1.09	0.80	3.20	0.60
1.10-1.19	0.94	3.90	0.50
1.20-1.49	0.80	5.00	0.50
1.50-2.09	0.67	99	0.50
2.10-3.89	0.57		
3.90-5.00	0.51		



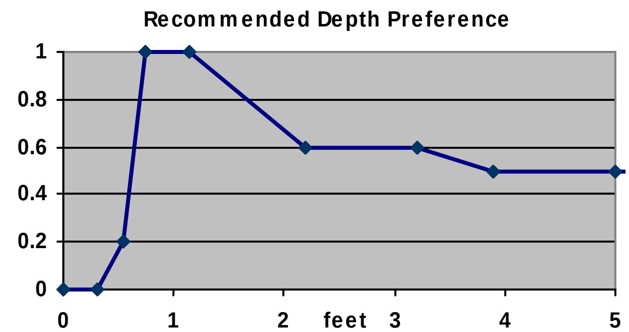
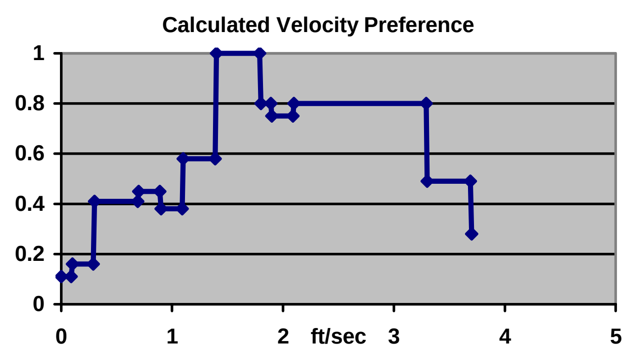
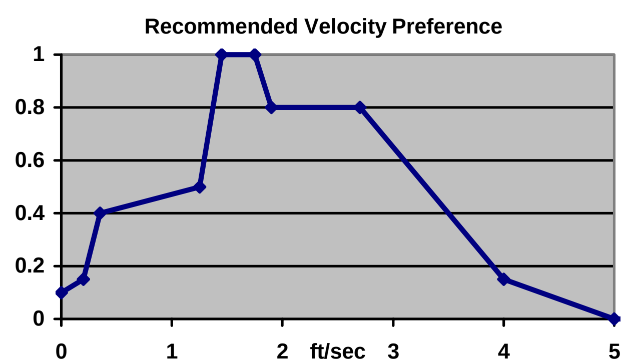


FIGURE 7b. Summer Chum Salmon Spawning Velocity Preference
Hood Canal (7 studies, 110 redds)

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted Velocity (ft/sec)	Velocity preference
0.00-0.09	0.11	0.00	0.10
0.10-0.29	0.16	0.20	0.15
0.30-0.69	0.41	0.35	0.40
0.70-0.89	0.45	1.25	0.50
0.90-1.09	0.38	1.45	1.00
1.10-1.39	0.58	1.75	1.00
1.40-1.79	1.00	1.90	0.80
1.80-1.89	0.74	2.70	0.80
1.90-2.09	0.75	4.00	0.15
2.10-3.29	0.80	5.00	0.00
3.30-3.69	0.49	99	0
3.70-5.00	0.28		



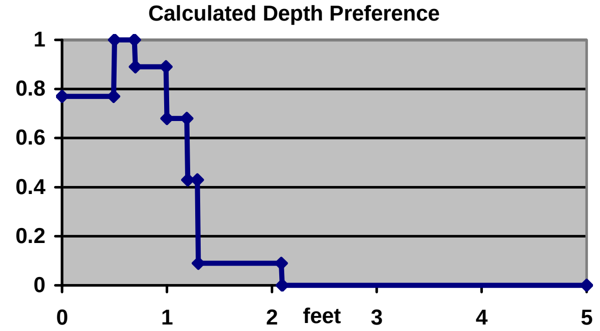


For Summer Chum Salmon Spawning Substrate Preference, use Table 2.

FIGURE 8a. Pink Salmon (*O. gorbuscha*) Spawning Depth Preference

Squire Creek, N. Fork Stillaguamish, Dosewallips, and Duckabush rivers (6 studies, 88 redds)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.49	0.77	0.00	0.00
0.50-0.69	1.00	0.55	1.00
0.70-0.99	0.89	0.65	1.00
1.00-1.19	0.68	1.10	0.68
1.20-1.29	0.43	1.40	0.20
1.30-2.09	0.09	2.10	0.05
2.10 +	0.00	5.00	0.00
		99	0.00



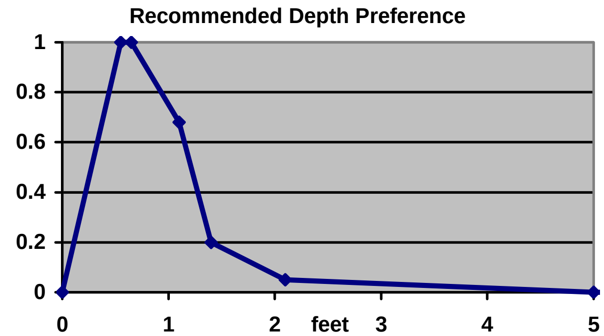
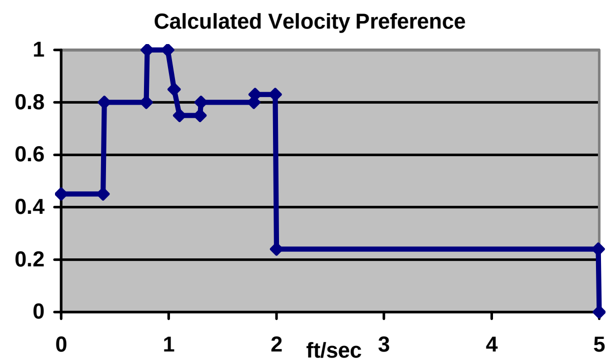


FIGURE 8b. Pink Salmon Spawning Velocity Preference

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.39	0.45	0.00	0.30
0.40-0.79	0.80	0.80	1.00
0.80-0.99	1.00	0.95	1.00
1.00-1.09	0.85	1.10	0.80
1.101.29	0.75	1.95	0.80
1.301.79	0.80	2.50	0.24
1.80-1.99	0.83	5.00	0.00
2.00-4.99	0.24	99	0.00
5.00 +	0.00		



For Pink Salmon Spawning Substrate Preference, use Table 2. Also see Table 10 for calculated preference information.

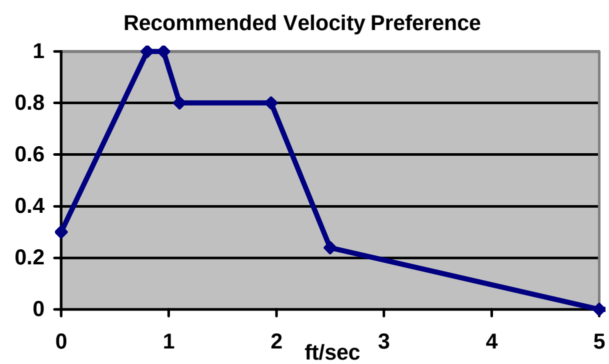
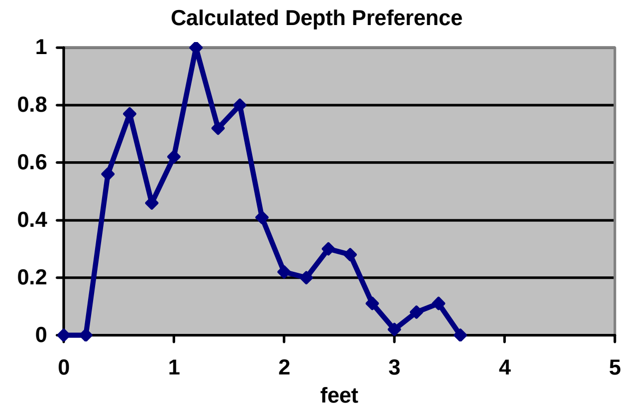


FIGURE 9a. Sockeye Salmon (*O. nerka*) Spawning Depth
Cedar River (3 studies, 1,037 redds) (Cascades Environmental 1990)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.0-0.09	0.00	0.00	0.00
0.1-0.29	0.00	0.25	0.00
0.3-0.49	0.56	0.60	0.77
0.5-0.69	0.77	1.15	1.00
0.7-0.89	0.46	1.25	1.00
0.9-1.09	0.62	1.60	0.80
1.1-1.29	1.00	2.00	0.22
1.3-1.49	0.72	3.50	0.00
1.5-1.69	0.80	99	0.00
1.7-1.89	0.41		
1.9-2.09	0.22		
2.1-2.29	0.20		
2.3-2.49	0.30		
2.5-2.69	0.28		
2.7-2.89	0.11		
2.9-3.09	0.02		
3.1-3.29	0.08		
3.3-3.49	0.11		
3.5+	0.00		



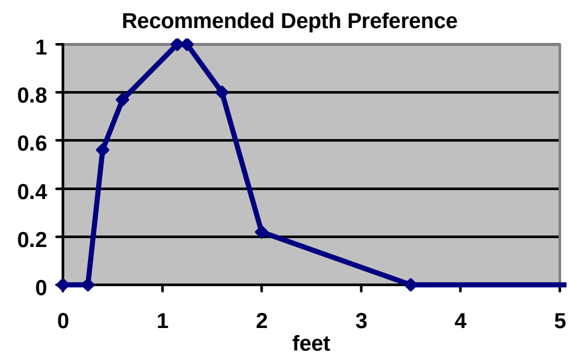
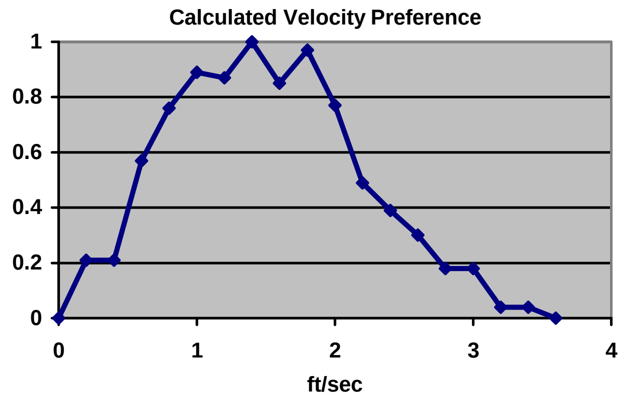
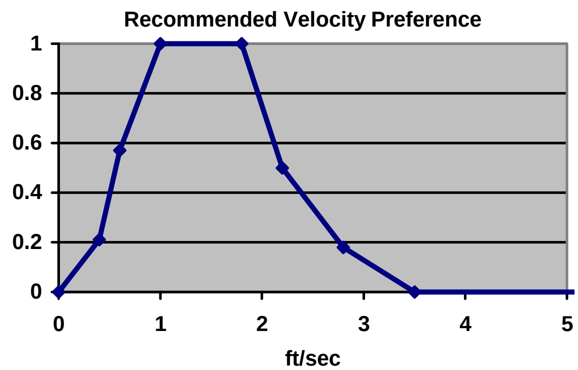


FIGURE 9b. Sockeye Salmon Spawning Velocity Preference
Cedar River (3 studies, 1,037 redds) (Cascades Environmental 1990)

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.0-0.09	0.00	0.00	0.00
0.1-0.29	0.21	0.40	0.21
0.3-0.49	0.21	0.60	0.57
0.5-0.69	0.57	1.00	1.00
0.7-0.89	0.76	1.80	1.00
0.9-1.09	0.89	2.20	0.50
1.1-1.29	0.87	2.80	0.18
1.3-1.49	1.00	3.50	0.00
1.5-1.69	0.85	99	0.00
1.7-1.89	0.97		
1.9-2.09	0.77		
2.1-2.29	0.49		
2.3-2.49	0.39		
2.5-2.69	0.30		
2.7-2.89	0.18		
2.9-3.09	0.18		
3.1-3.29	0.04		
3.3-3.49	0.04		
3.5+	0.00		

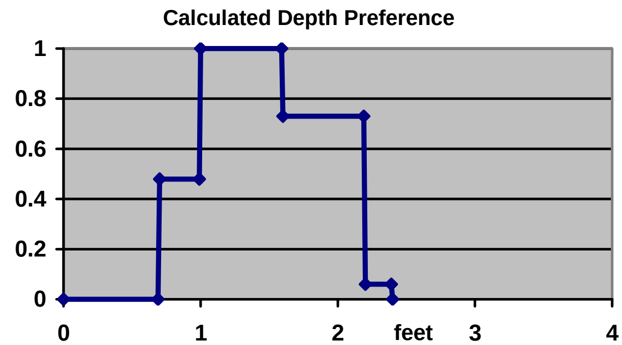




For Sockeye Salmon Spawning Substrate Preference, use Table 2.
Also see Table 11 for calculated substrate preference information.

FIGURE 10a. Steelhead (*O. mykiss*) Spawning Depth Preference
Cedar River (2 studies, 25 redds)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.59	0.00	0.00	0.00
0.60-0.69	0.00	0.65	0.00
0.70-0.99	0.48	1.25	1.00
1.00-1.49	1.00	1.55	1.00
1.50-1.59	1.00	2.40	0.50
1.60-2.19	0.73	99	0.50
2.20-2.39	0.58		
2.40+	0.06		



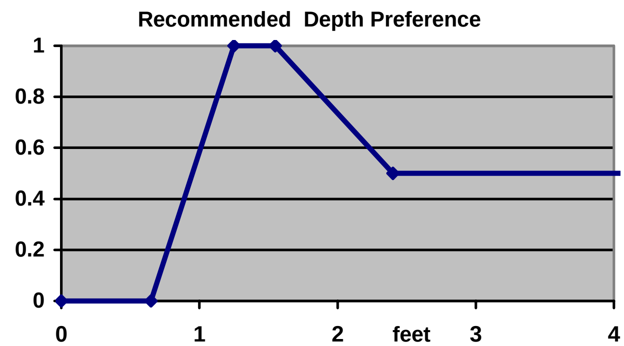
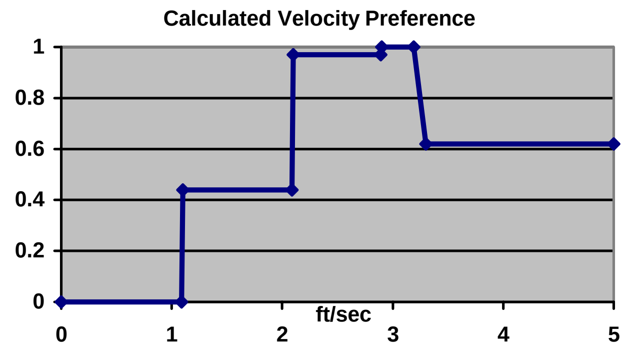
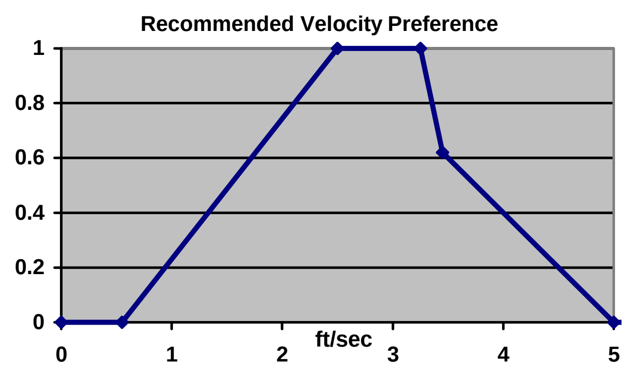


FIGURE 10b. Steelhead Spawning Velocity Preference

Calculated velocity preference curve		Recommended velocity preference curve	
velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00 1.09	0.00	0.00	0.00
1.10 2.09	0.44	0.55	0.00
2.10 2.89	0.97	2.50	1.00
2.90 3.19	1.00	3.25	1.00
3.20-3.29	1.00	3.45	0.62
3.30-3.59	0.62	5.00	0.00
3.60-3.99	0.62	99	0.00
4.00-4.49	0.62		
4.50-4.99	0.62		
5.00+	0.62		





For Steelhead Spawning Substrate Preference, use Table 5.

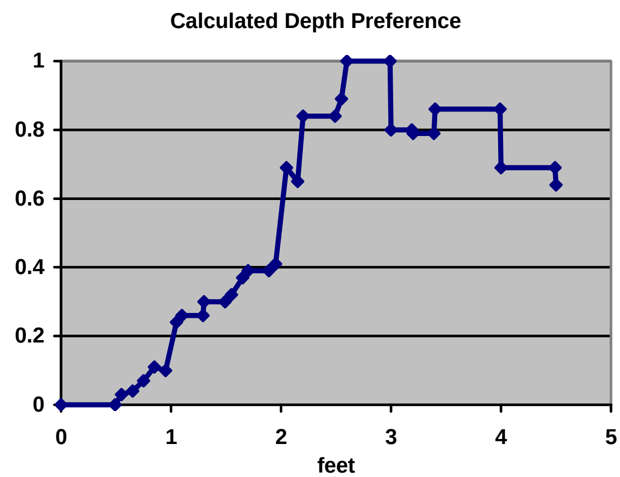
For Juvenile Steelhead Winter Rearing Depth Preference, use Figure 14a.
For Juvenile Steelhead Winter Rearing Velocity Preference, use Figure 14b.
For Juvenile Steelhead Winter Rearing Substrate Preference, use Table 3.

FIGURE 11a. Steelhead Juvenile Depth Preference

Multiple WA rivers (10 studies, 913 fish). For methods and one study, see Beecher et al. (1993)

Calculated depth preference curve	
Depth interval (feet)	Depth preference
0.00-0.49	0.00
0.50-0.59	0.03
0.60-0.69	0.04
0.70-0.79	0.07
0.80-0.89	0.11
0.90-0.99	0.10
1.00-1.09	0.24
1.10-1.29	0.26
1.30-1.49	0.30
1.50-1.59	0.32
1.60-1.69	0.37
1.70-1.89	0.39
1.90-1.99	0.41
2.00-2.09	0.69
2.10-2.19	0.65
2.20-2.49	0.84
2.50-2.59	0.89
2.60-2.99	1.00
3.00-3.19	0.80
3.20-3.39	0.79
3.40-3.99	0.86
4.00-4.49	0.69
4.50+	0.64

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.25	0.00
1.8	0.39
2.65	1.00
2.95	1.00
4.50	0.64
99	0.64



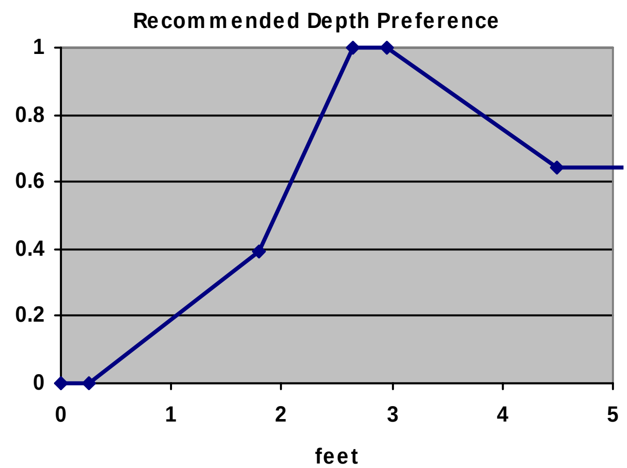
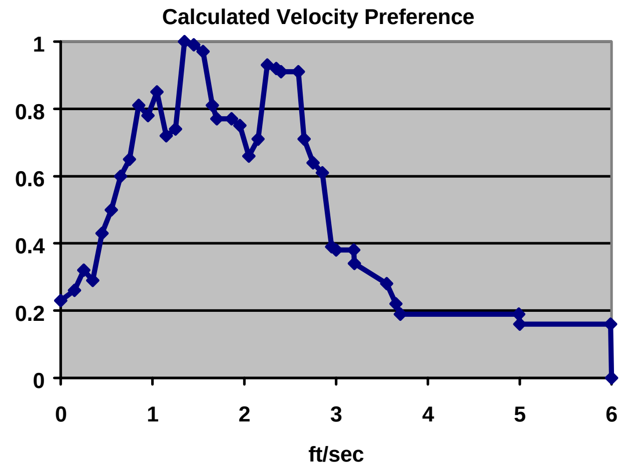
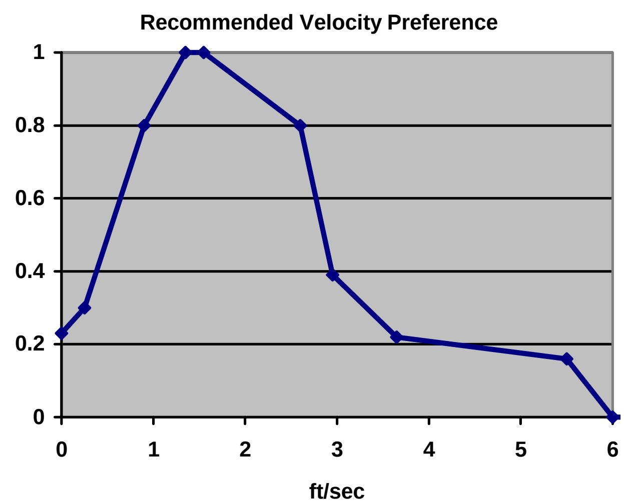


FIGURE 11b. Steelhead Juvenile Velocity Preference

Multiple WA rivers (12 studies, 962 fish). For methods and one study, see Beecher et al. (1993)

Calculated depth preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.09	0.23	0.00	0.23
0.10-0.19	0.26	0.25	0.3
0.20-0.29	0.32	0.90	0.8
0.30-0.39	0.29	1.35	1.00
0.40-0.49	0.43	1.55	1.00
0.50-0.59	0.50	2.60	0.80
0.60-0.69	0.60	2.95	0.39
0.70-0.79	0.65	3.65	0.22
0.80-0.89	0.81	5.50	0.16
0.90-0.99	0.78	6.00	0.00
1.00-1.09	0.85	99	0.00
1.10-1.19	0.72		
1.20-1.29	0.74		
1.30-1.39	1.00		
1.40-1.49	0.99		
1.50-1.59	0.97		
1.60-1.69	0.81		
1.70-1.89	0.77		
1.90-1.99	0.75		
2.00-2.09	0.66		
2.10-2.19	0.71		
2.20-2.29	0.93		
2.30-2.39	0.92		
2.40-2.59	0.91		
2.60-2.69	0.71		
2.70-2.79	0.64		
2.80-2.89	0.61		
2.90-2.99	0.39		
3.00-3.19	0.38		
3.20-3.49	0.34		
3.50-3.59	0.28		
3.60-3.69	0.22		
3.70-4.99	0.19		
5.00-5.99	0.16		
6.00+	0.00		

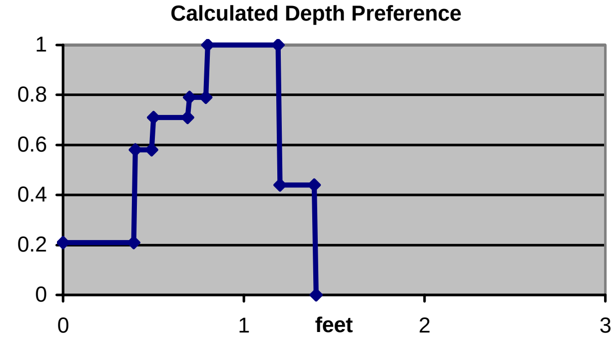


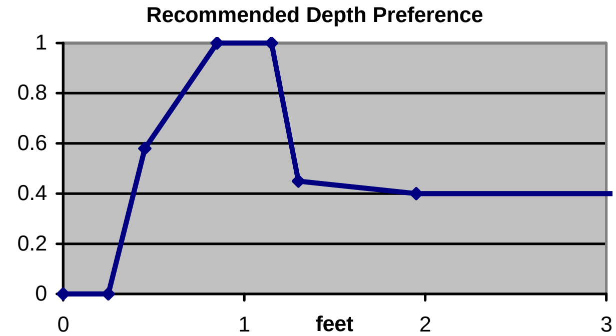


For Steelhead Juvenile Substrate Preference, use Table 3.

FIGURE 12a. Resident Rainbow Trout (*O. mykiss*) Spawning Depth Preference
Tributaries to Packwood Lake, Lewis County (2 studies, 27 redds)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.29	0.21	0.00	0.00
0.30-0.39	0.21	0.25	0.00
0.40-0.49	0.58	0.45	0.58
0.50-0.69	0.71	0.85	1.00
0.70-0.79	0.79	1.15	1.00
0.80-1.09	1.00	1.30	0.45
1.10-1.19	1.00	1.95	0.40
1.20-1.39	0.44	2.50*	0.40
1.40-2.49	0.00	99.00	0.40
2.50+	NA*		

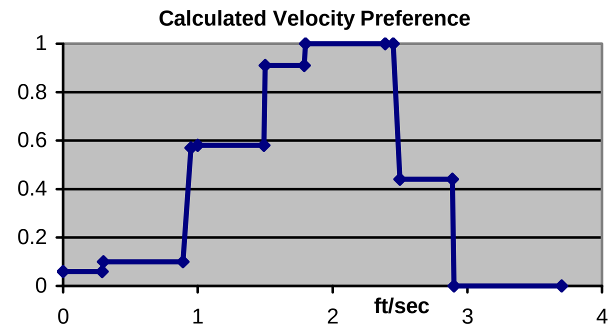


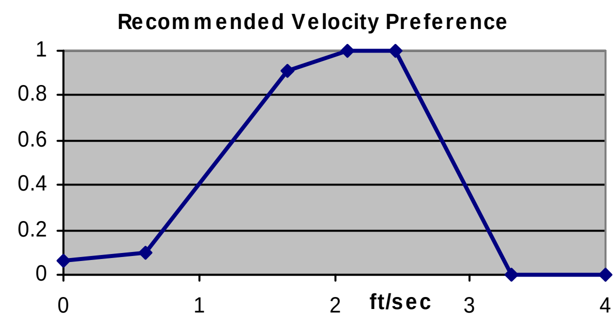


* Study sites were small stream with shallow depths (< 2.5 ft.). Other site observations show rainbow trout spawning in excess of 4 ft.

FIGURE 12b. Resident Rainbow Trout Spawning Velocity Preference

Calculated depth preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.29	0.06	0.00	0.06
0.30-0.89	0.10	0.60	0.10
0.90-0.99	0.57	1.65	0.91
1.00-1.49	0.58	2.10	1.00
1.50-1.79	0.91	2.45	1.00
1.80-2.39	1.00	3.30	0.00
2.40-2.49	1.00	99	0.00
2.50-2.89	0.44		
2.90-3.69	0.00		
3.70+	0.00		

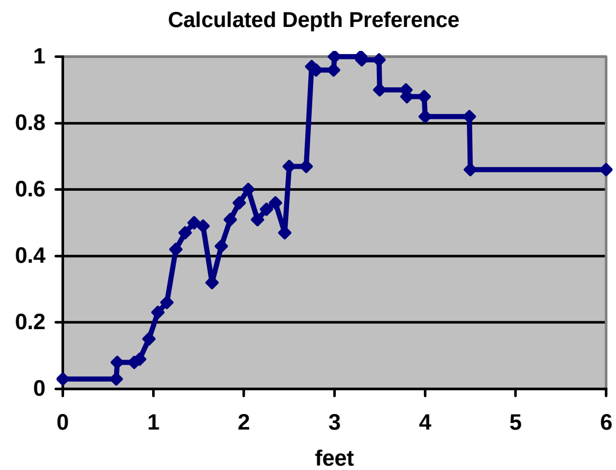




For Resident Rainbow Trout Spawning Substrate Preference, use Table 6.

FIGURE 13a. Resident Rainbow Trout Juvenile and Adult Rearing Depth Preference
Multiple WA rivers (11 studies, 765 fish)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.59	0.03	0.00	0.00
0.60-0.79	0.08	0.55	0.00
0.80-0.89	0.09	1.55	0.45
0.90-0.99	0.15	2.25	0.50
1.00-1.09	0.23	2.60	0.65
1.10-1.19	0.26	2.75	1.00
1.20-1.29	0.42	3.40	1.00
1.30-1.39	0.47	4.75	0.66
1.40-1.49	0.50	99	0.66
1.50-1.59	0.49		
1.60-1.69	0.32		
1.70-1.79	0.43		
1.80-1.89	0.51		
1.90-1.99	0.56		
2.00-2.09	0.60		
2.10-2.19	0.51		
2.20-2.29	0.54		
2.30-2.39	0.56		
2.40-2.49	0.47		
2.50-2.69	0.67		
2.70-2.79	0.97		
2.80-2.99	0.96		
3.00-3.29	1.00		
3.30-3.49	0.99		
3.50-3.79	0.90		
3.80-3.99	0.88		
4.00-4.49	0.82		
4.50+	0.66		



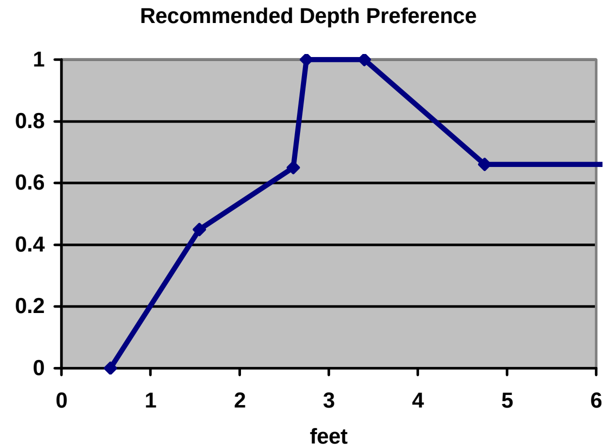
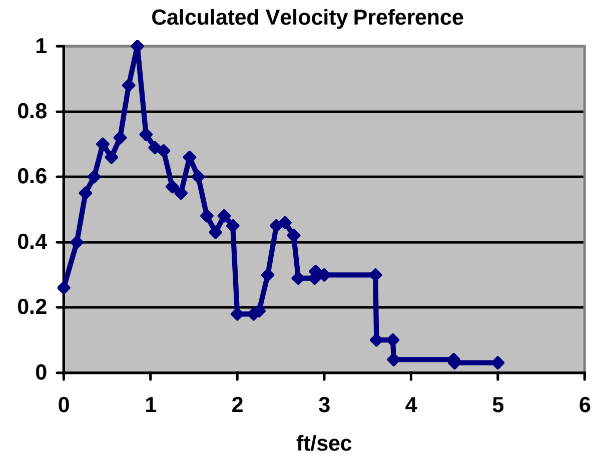
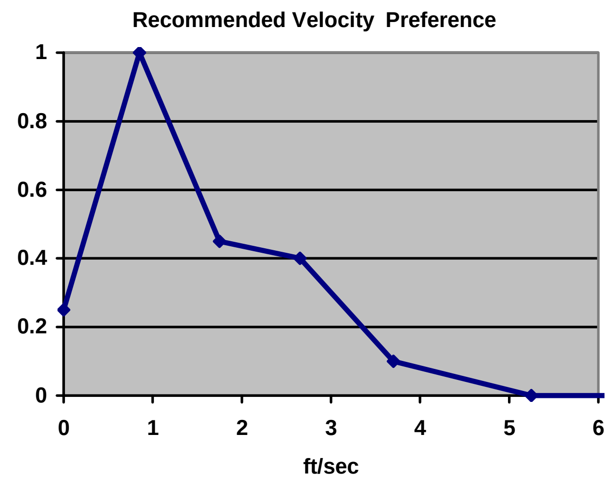


FIGURE 13b. Resident Rainbow Trout Juvenile and Adult Rearing Velocity Preference
Multiple WA rivers (11 studies, 765 fish)

Calculated depth preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity suitability
0.00 0.09	0.26	0.00	0.25
0.10 0.19	0.40	0.85	1.00
0.20 0.29	0.55	1.75	0.45
0.30 0.39	0.60	2.65	0.4
0.40 0.49	0.70	3.70	0.10
0.50 0.59	0.66	5.25	0.00
0.60 0.69	0.72	99	0.00
0.70 0.79	0.88		
0.80 0.89	1.00		
0.90 0.99	0.73		
1.00 1.09	0.69		
1.10 1.19	0.68		
1.20 1.29	0.57		
1.30 1.39	0.55		
1.40-1.49	0.66		
1.50-1.59	0.60		
1.60 1.69	0.48		
1.70 1.79	0.43		
1.80 1.89	0.48		
1.90-1.99	0.45		
2.00 2.19	0.18		
2.20-2.29	0.19		
2.30 2.39	0.30		
2.40 2.49	0.45		
2.50-2.59	0.46		
2.60 2.69	0.42		
2.70 2.89	0.29		
2.90-2.99	0.31		
3.00 3.59	0.30		
3.60 3.79	0.10		
3.80 4.49	0.04		
4.50-4.99	0.03		
5.00+	0.03		





For Resident Rainbow Trout Juvenile Substrate Preference, use Table 3.

FIGURE 14a. Resident Rainbow Trout Winter Depth Preference
Campbell and Neuner (1985)[1]

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

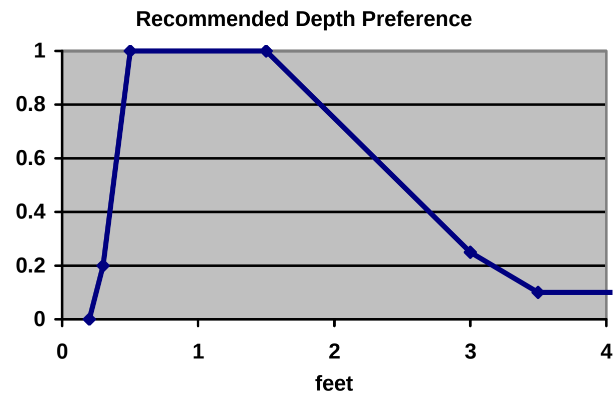
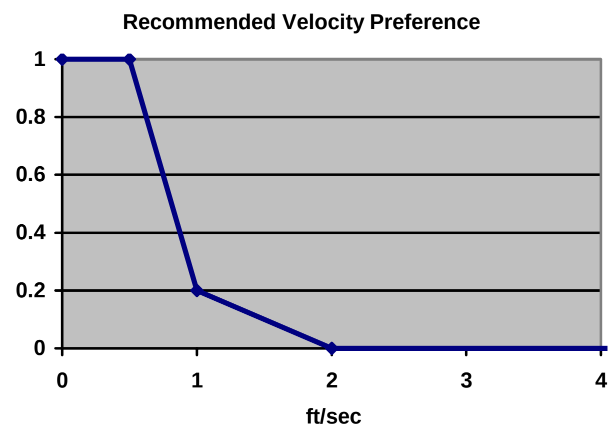


FIGURE 14b. Resident Rainbow Trout Winter Velocity Preference
Campbell and Neuner (1985)

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

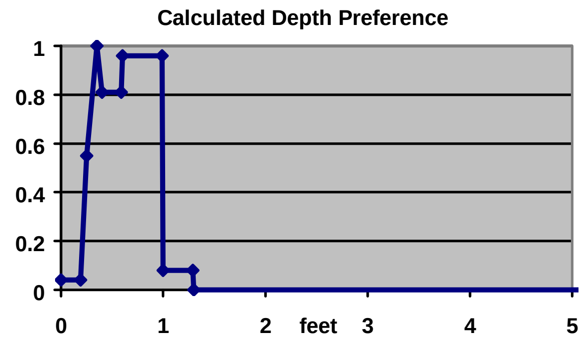


For Winter Substrate Preference, use Table 3.

[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, cobble and boulders) for refuge. During the nighttime, the fish were always observed resting on the bottom in quiet areas with sandy to silty substrates. (Campbell pers. comm.).

FIGURE 15a. Cutthroat Trout (*O. clarki*) Spawning Depth Preference
Irely Creek (6 studies, 69 redds)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.19	0.04	0.00	0.00
0.20-0.29	0..55	0.15	0.04
0.3-0.39	1.00	0.35	0.90
0.40-0.59	0.81	0.45	1.00
0.60-0.99	0.96	0.75	1.00
1.00-1.29	0.08	0.95	0.10
1.30+	0.00	1.30	0.07
		5.00	0.00
		99	0.00



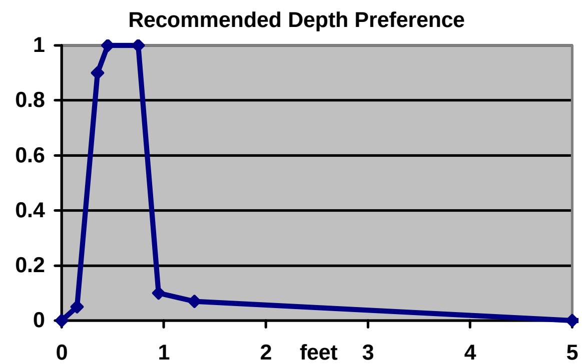
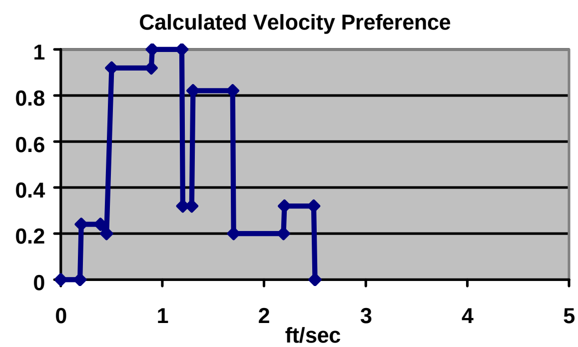
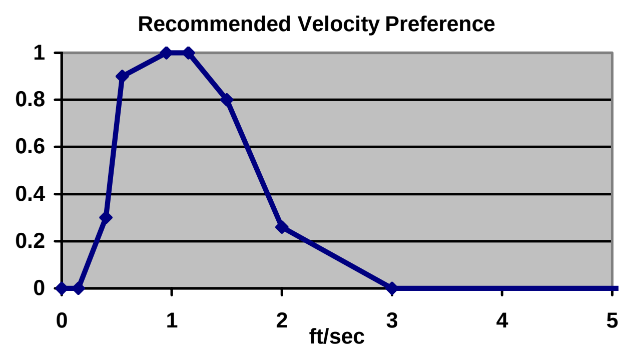


FIGURE 15b. Cutthroat Spawning Velocity Preference
Irely Creek (6 studies, 69 redds)

Calculated velocity preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00 0.19	0.00	0.00	0.00
0.20-0.39	0.24	0.15	0.00
0.40-0.49	0.20	0.4	0.30
0.50-0.89	0.92	0.55	0.90
0.90-1.19	1.00	0.95	1.00
1.20-1.29	0.32	1.15	1.00
1.30-1.69	0.82	1.5	0.80
1.70-2.19	0.26	2.00	0.26
2.20-2.49	0.14	3.00	0.00
2.5-+	0.00	99	0





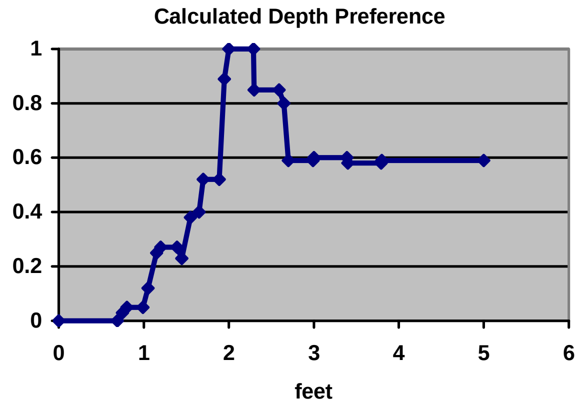
For Cutthroat Trout Spawning Substrate Preference, use Table 6

FIGURE 16a. Cutthroat Trout Juvenile and Adult Rearing Depth Preference

Ohanapecosh River & Early Winters Creek (5 studies, 251 fish)

Calculated depth preference curve	
Depth interval (feet)	Depth preference
0.00-0.59	0.00
0.60-0.69	0.00
0.70-0.79	0.03
0.80-0.99	0.05
1.00-1.09	0.12
1.10-1.19	0.25
1.20-1.39	0.27
1.40-1.49	0.23
1.50-1.59	0.38
1.60-1.69	0.40
1.70-1.89	0.52
1.90-1.99	0.89
2.00-2.19	1.00
2.20-2.29	1.00
2.30-2.59	0.85
2.60-2.69	0.80
2.70-2.99	0.59
3.00-3.39	0.60
3.40-3.79	0.58
3.80-4.99	0.59
5.00+	0.59

Recommended depth preference curve	
Plotted depth (feet)	Depth preference
0.00	0.00
0.65	0.00
1.80	0.50
1.95	0.90
2.05	1.00
2.25	1.00
2.65	0.80
2.80	0.60
99	0.60



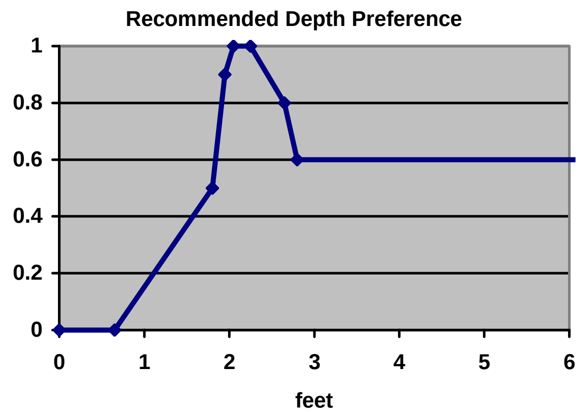
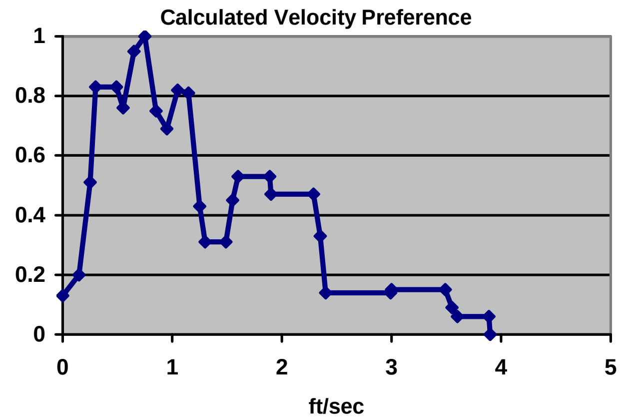
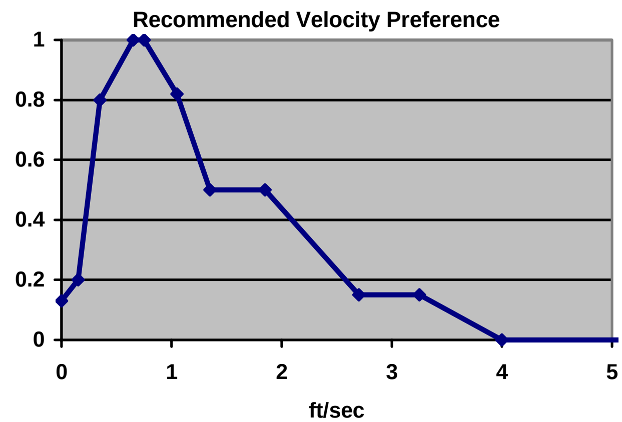


FIGURE 16b. Cutthroat Trout Juvenile and Adult Rearing Velocity Preference
Ohanapecosh River & Early Winters Creek (6 studies, 261 fish)

Calculated velocity preference curve	
Velocity interval (ft/sec)	Velocity preference
0.00 0.09	0.13
0.10-0.19	0.20
0.20-0.29	0.51
0.30-0.49	0.83
0.50 0.59	0.76
0.60-0.69	0.95
0.70-0.79	1.00
0.80 0.89	0.75
0.90-0.99	0.69
1.00 1.09	0.82
1.10-1.19	0.81
1.20-1.29	0.43
1.30-1.49	0.31
1.50 1.59	0.45
1.60-1.89	0.53
1.90 2.29	0.47
2.30-2.39	0.33
2.40 2.99	0.14
3.00-3.49	0.15
3.50-3.59	0.09
3.60-3.89	0.06
3.90+	0.00

Recommended velocity preference curve	
Plotted velocity (ft/sec)	Velocity preference
0.00	0.13
0.15	0.20
0.35	0.80
0.65	1.00
0.75	1.00
1.05	0.82
1.35	0.50
1.85	0.50
2.70	0.15
3.25	0.15
4.00	0.00
99	0.00

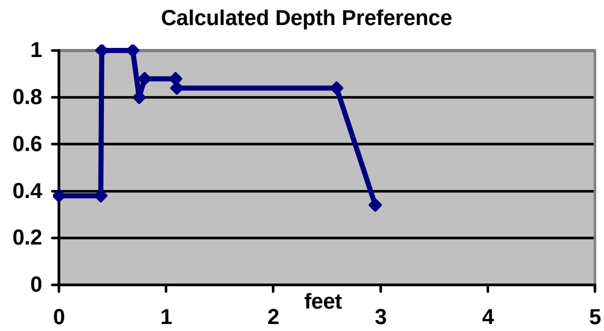




For Cutthroat Trout Winter Depth Preference, use Figure 14a
For Cutthroat Trout Winter Velocity Preference, use Figure 14b
For Cutthroat Trout Winter Substrate Preference, use Table 3

FIGURE 17a. Bull Trout and Dolly Varden Spawning Depth Preference
2 undisclosed streams (2 studies, 34 redds)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.39	0.38	0.00	0.00
0.40-0.69	1.00	0.35	0.38
0.70-0.79	0.80	0.45	1.00
0.80-1.09	0.88	0.65	1.00
1.10-2.59	0.84	0.95	0.88
2.60-3.29	0.34	1.85	0.84
3.30+	NA	2.95	0.34
		99	0.34



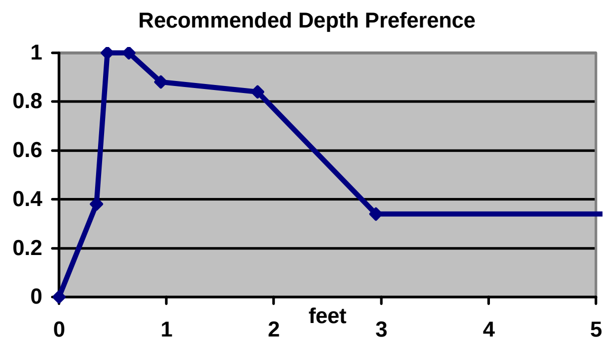
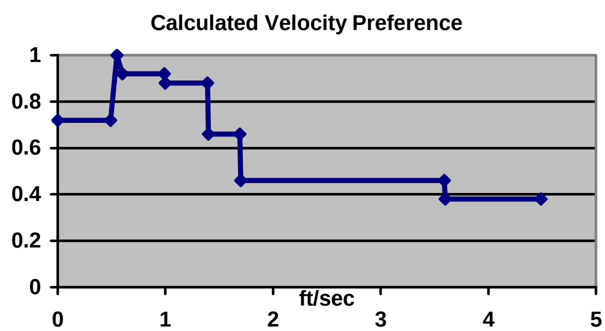
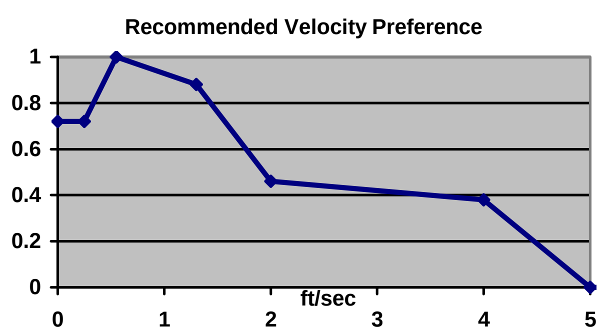


FIGURE 17b. Bull Trout and Dolly Varden Spawning Velocity Preference

Calculated depth preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00-0.49	0.72	0.00	0.72
0.50-0.59	1.00	0.25	0.72
0.60-0.99	0.92	0.55	1.00
1.00-1.39	0.88	1.25	0.88
1.40-1.69	0.66	2.00	0.46
1.70-3.59	0.46	4.00	0.38
3.60-4.49	0.38	5.00	0.00
4.50+	NA	99	0.00

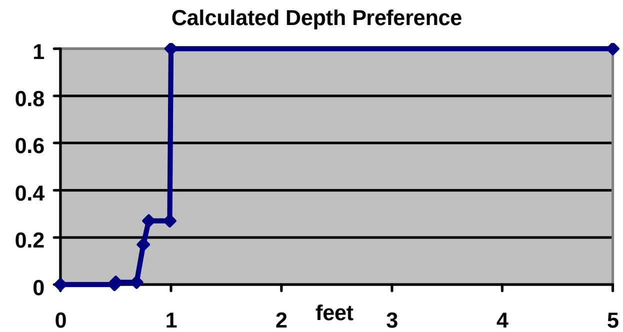




For Bull Trout and Dolly Varden Juvenile Spawning Substrate Preference, use Table 7.

FIGURE 18a. Bull Trout and Dolly Varden Juvenile and Adult Depth Preference
Dungeness, Tucannon and Mad Rivers and Early Winters Creek (4 studies, 39 fish)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00-0.49	0.00	0.0	0.00
0.50-0.69	0.01	0.55	0.01
0.70-0.79	0.17	0.85	0.27
0.80-0.99	0.27	1.00	1.00
1.00+	1.00	99	1.00



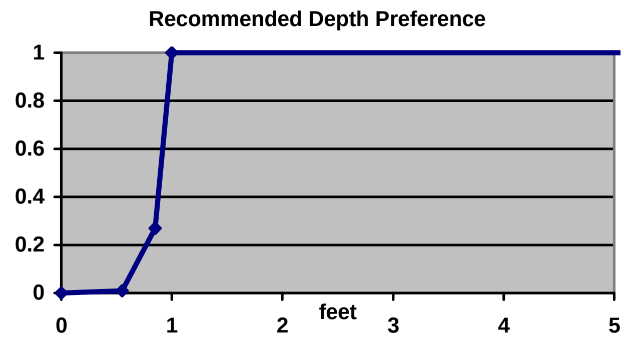
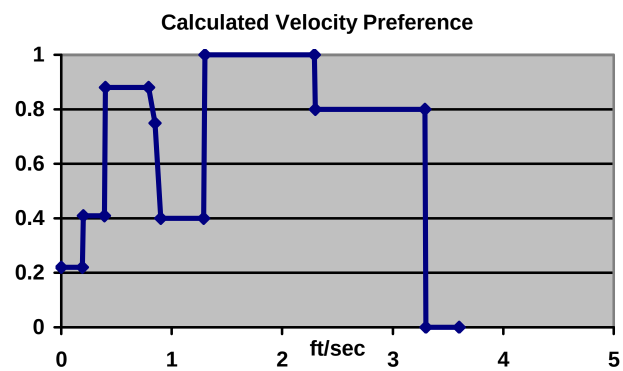
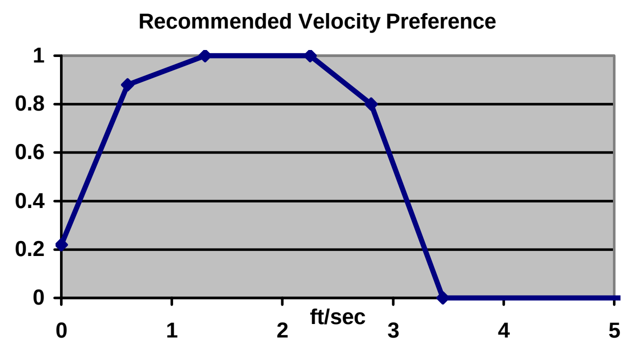


FIGURE 18b. Bull Trout and Dolly Varden Juvenile and Adult Velocity Preference

Calculated depth preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity suitability
0.00 0.19	0.22	0.00	0.22
0.20 0.39	0.41	0.60	0.88
0.40 0.79	0.88	1.30	1.00
0.80 0.89	0.75	2.25	1.00
0.90 1.29	0.40	2.80	0.80
1.30 2.29	1.00	3.45	0.00
2.30 3.29	0.80	99.0	0.00
3.30-3.59	0.00		
3.60			

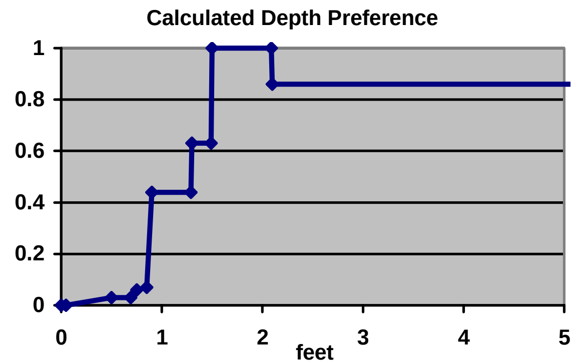




For Bull Trout and Dolly Varden Juvenile Substrate Preference, use Table 3.

FIGURE 19a. Brook Trout Juvenile and Adult Rearing Depth Preference
Ohanapecosh River and Leech Creek (4 studies, 39 fish)

Calculated depth preference curve		Recommended depth preference curve	
Depth interval (feet)	Depth preference	Plotted depth (feet)	Depth preference
0.00 0.39	0.00	0.00	0.00
0.40 0.49	0.00	0.85	0.07
0.50 0.69	0.03	1.00	0.45
0.70 0.79	0.06	1.60	1.00
0.80 0.89	0.07	2.00	1.00
0.90 1.29	0.44	2.20	0.86
1.30 1.49	0.63	99	0.86
1.50 2.09	1.00		
2.10+	0.86		



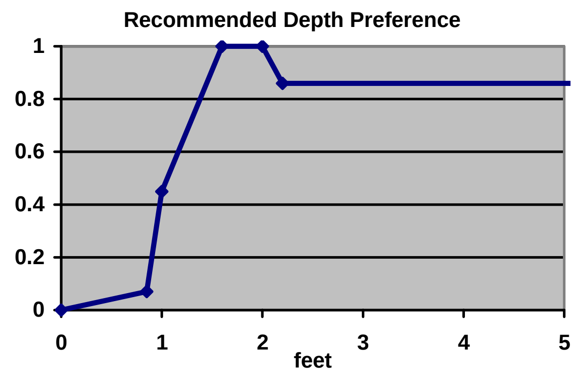
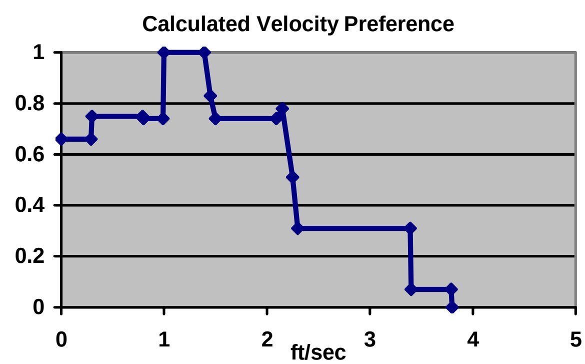
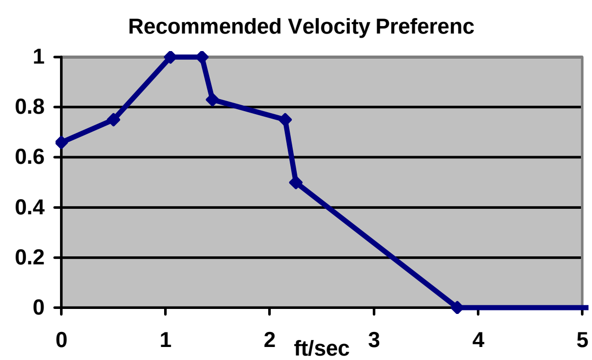


FIGURE 19b. Brook Trout Juvenile and AdultRearing Velocity Preference

Calculated depth preference curve		Recommended velocity preference curve	
Velocity interval (ft/sec)	Velocity preference	Plotted velocity (ft/sec)	Velocity preference
0.00 0.29	0.66	0.00	0.66
0.30 0.79	0.75	0.50	0.75
0.80 0.99	0.74	1.05	1.00
1.00 1.39	1.00	1.35	1.00
1.40 1.49	0.83	1.45	0.83
1.50 2.09	0.74	2.15	0.75
2.10 2.19	0.78	2.25	0.50
2.20 2.29	0.51	3.80	0.00
2.30 3.39	0.31	99	0.00
3.40 3.79	0.07		
3.80+	0.00		





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

FIGURE 20a. Mountain Whitefish Juvenile Depth Preference
Locke 2002

Depth (ft)	Recommended depth preference
0.0	0.0
0.5	0.0
1.0	0.1
1.5	0.4
2.0	0.8
3.0	1.0
4.5	1.0
5.0	0.5
6.0	0.5

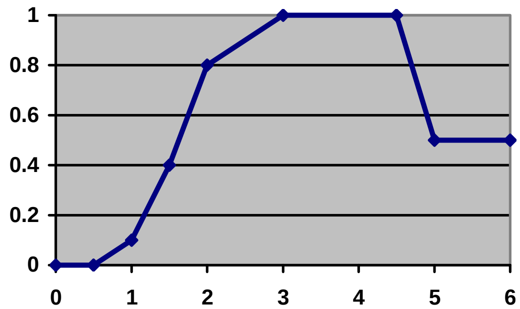


FIGURE 20b. Mountain Whitefish Juvenile Velocity Preference
Locke 2002

Velocity (ft/sec)	Recommended velocity preference
C	0.2
1.0	0.4
1.5	1.0
2.5	1.0
3.0	0.5
4.0	0.0
6.0	0.0

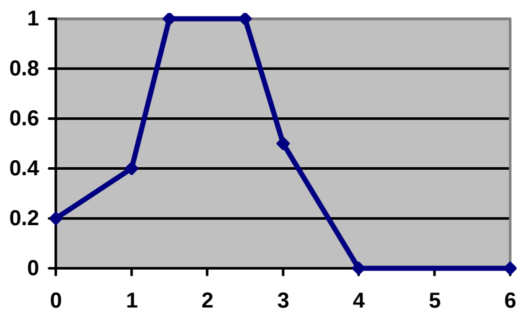


FIGURE 21a. Mountain Whitefish Adult Depth Preference
Locke 2002

Depth (feet)	Recommended depth preference
0.0	0.0
1.0	0.0
2.0	0.4
3.0	1.0
6.0	1.0

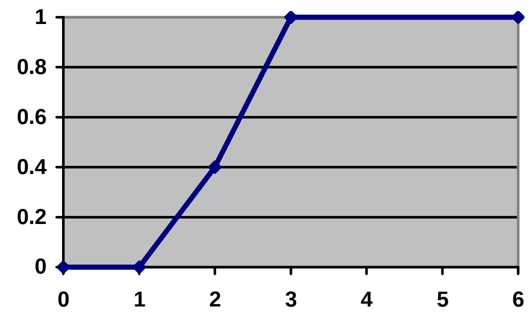


FIGURE 21b. Mountain Whitefish Adult Velocity Preference
Locke 2002

Velocity (ft/sec)	Recommended velocity preference
0.0	0.10
1.0	0.25
1.8	1.00
3.0	1.00
3.5	0.40
4.0	0.20
4.5	0.10
5.0	0.00
6.0	0.00