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# SOUTH FORK SNOQUALMIE RIVER (TWIN FALLS) INSTREAM FLOW RESIDENT FISH HABITAT ANALYSIS

by

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Final Report
for
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Submitted ____________________

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# Summary

A run-of-river hydroelectric facility is proposed at Twin Falls on the South Fork of the Snoqualmie River which will divert from 60 to 89 percent of the river flow from a 1.2 mile reach of stream during periods of operation. An instream flow incremental analysis of the resident fish habitat requirements for rainbow and cutthroat trout and mountain whitefish was conducted. Utilizing the IFIM methodology annual minimum instream flow management curves were developed and compared to multiple post-project minimum flow alternatives to determine potential effects on instream fisheries habitat.

# ACKNOWLEDGMENTS

Our appreciation is extended to Jay Laughlin and Lin Wilson of Hosey and Associates Engineering Co. and Hal Beecher of the Washington Department of Game for the assistance they provided. Fred Winchell's help in the field is also appreciated.

Abbreviations appearing in the text are defined below:

| | |
|---|---|
| FRI | Fisheries Research Institute; University of Washington |
| IES | Independent Ecological Services; Olympia, Washington |
| IFG | Instream Flow Group; Fort Collins, Colorado |
| IFIM | Instream Flow Incremental Methodology |
| USGS | United States Geological Survey |
| WDG | Washington State Department of Game |
| WUA | Weighted Useable Area |

# INTRODUCTION

A run-of-river hydroelectric facility at Twin Falls on the South Fork of the Snoqualmie River has been proposed by South Fork Resources, Inc., to generate electrical energy. The South Fork originates in the Snoqualmie Pass area of the Cascade Mountains and flows generally northwest for 35 miles before converging with the Middle and North Forks of the Snoqualmie River near the town of North Bend, Washington (Fig. 1). Current project plans call for the diversion of 60 to 89 percent (approximately 120 to 600 cfs) from a 1.2 mile reach of the stream during periods of project operation. Although no significant changes in water quality parameters are anticipated, instream flows resulting from powerhouse operation are expected to affect existing fish populations associated habitat within the diversion reach. Following consultation with Federal, State, and Tribal fisheries agencies, studies were initiated to obtain information on the composition and temporal distribution of salmonid species within the affected river reach, and to determine the minimum instream flows necessary to protect the various life stages of salmonids present.

Results of snorkelling and electrofishing studies conducted by the Washington Department of Game, Hosey and Associates (1982), and the Fisheries Research Institute (Scott and Nakatani 1982a; 1982b) indicate that resident populations of rainbow trout (*Salmo gairdneri*), cutthroat trout (*Salmo clarki*), and mountain whitefish (*Prosopium williamsoni*) are found within the diversion reach. Access to the upper reaches of the Snoqualmie River is denied to anadromous fish due to an impassable waterfall located below the confluence of the tributary forks. Salmonid habitat within the length of the South Fork which will be affected by the Twin Falls project is generally poor in the middle and upper reaches, but moderately good in the lower 0.4 miles.

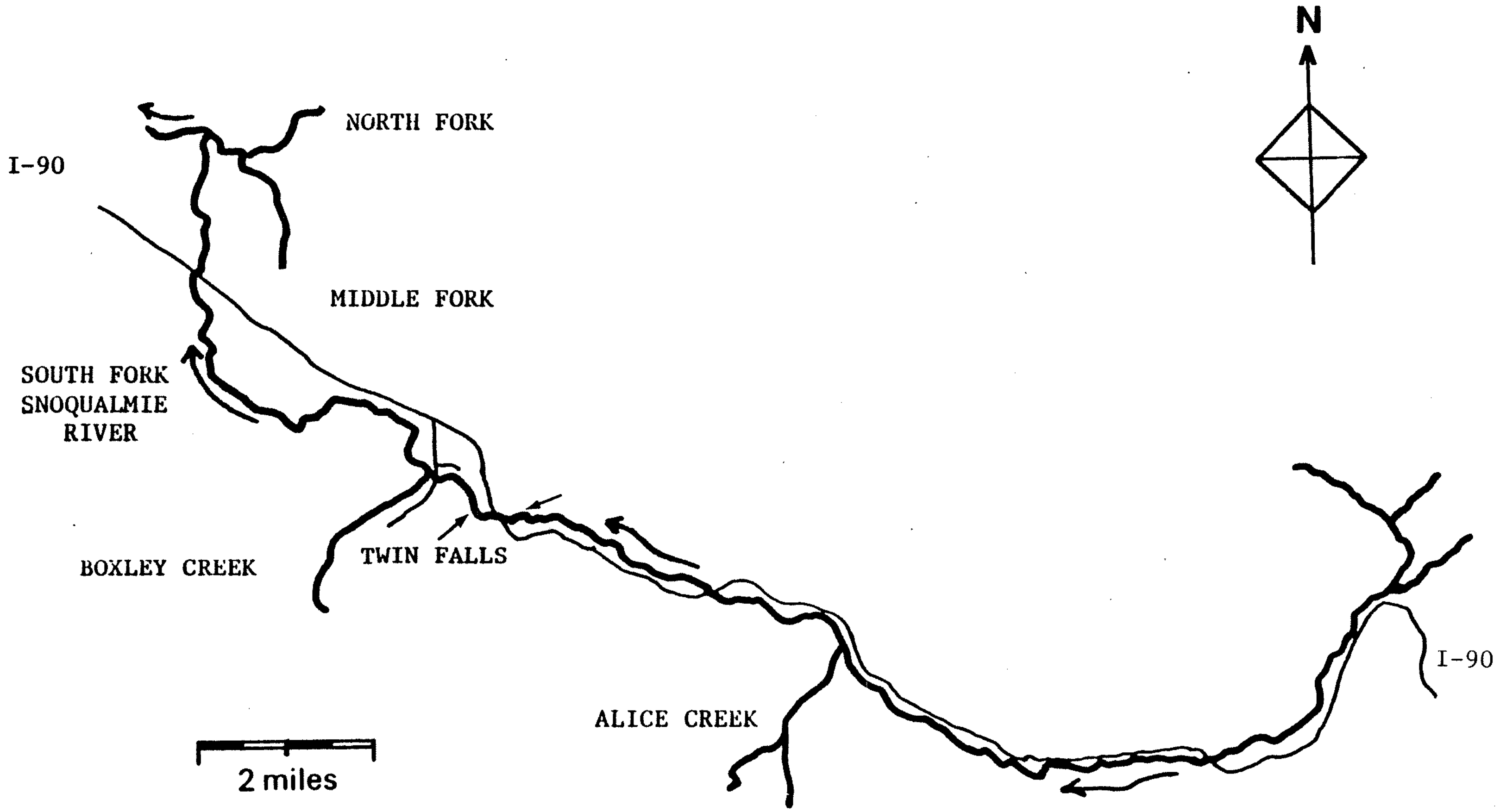


Fig. 1. South Fork Snoqualmie River and Twin Falls hydroelectric project location.

In the latter section, a series of riffles, runs and pools provides extensive cover and feeding areas for juvenile and adult salmonids. Spawning habitat, however, appears limited due to the patchy distribution of suitable sized substrate.

In regard to measures necessary to protect resident salmonid populations during project operation, the WDG recommended a post-project minimum rearing flow of 75 cfs based on toe-width measurements taken in the vicinity of the proposed intake structure (letter of November 2, 1981). It was subsequently decided to obtain additional information relating to instream flow needs of resident fish using the Instream Flow Incremental Methodology (IFIM) as applied to a study reach located near the proposed powerhouse discharge site. The IFIM is currently the most accepted method used to recommend minimum flows for fishes, and is specifically designed to quantify the impact of alternative flow regimes upon fishery habitat potential, expressing the effects through changes in a habitat index value for each species/life stage, and discharge of interest.

This study was conducted in two phases. Phase I included the IFIM field studies on the South Fork by Independent Ecological Services of Olympia, Washington (IES, 1982). The Fisheries Research Institute conducted Phase II which included an evaluation of the data, analysis, interpretation, and determination of minimum instream flow management curves. In addition, this report addresses multiple post-project minimum flow alternatives and the potential effect on instream habitat.

## METHODS

### Application of Instream Flow Incremental Methodology

The IFIM approach to instream flow analysis uses several computer programs, collectively called PHABSIM (Physical HABitat SIMulation system) to model various elements of open channel hydraulics and fish behavior. A discussion of the theory and applicability of PHABSIM is found in Milhous et al. (1981). The basic assessment process consists of several steps: 1) selection of study areas on the basis of the critical reach or representative reach concept; 2) field measurement of depth, velocity, and substrate composition along multiple transects within a study area; 3) hydraulic simulation of the spatial distribution of combinations of these parameters; 4) application of species-specific suitability functions (i.e., habitat suitability criteria) which give the likelihood of a given species/life stage being found in association with a particular flow or hydraulic condition; and 5) calculation of a Weighted Usable Area (WUA) value - an index of habitat availability, for each species/life stage and discharge of interest. The calculation of WUA roughly equates the area of suboptimal fish habitat within the study reach to an equivalent area of optimal habitat.

In applying the IFIM it is assumed that the stream channel remains unchanged while conveying the natural streamflows being simulated during the time intervals between field sampling sessions. Further assumptions are that the habitat parameters of depth, velocity, and substrate are the major determinants of fish distribution, that individuals of a species respond directly to changes in these parameters, and that the multivariate function used to calculate WUA correctly assumes that the effects of the parameters are independent of each other.

## IFG-4 Model Calibration

The IFG-4 program uses velocity, depth, and stage data collected under three distinctly different flow conditions to calibrate individual stage-discharge and velocity-discharge relationships at each vertical along the transects in a study reach. The results are extrapolated to an imaginary cell extending midway to the nearest verticals (or to the adjacent stream bank) and a variable distance up and downstream depending on the hydraulic conditions represented by adjacent transects. The study reach, therefore, may be viewed as a matrix of rectangular cells, each having a particular combination of depth, velocity and substrate characteristics. The program then calculates transect discharges for each set of calibration measurements, indicating various measures of the reliability of the model in the printed output. When the model has been calibrated to give velocity adjustment factors in the range of 0.9 to 1.1, and relatively few velocity prediction errors, it is suitable for use as a predictive tool (Milhous et al. 1981).

The original data set used to calibrate the hydraulic simulation model of the South Fork study reach appeared sufficiently accurate to use as model input. However, two errors were discovered in the transcription of field recorded data into the card image format required as input for the IFG-4 program. In the first case, water surface elevations measured at the low and high calibration discharges at one of the transects were entered in reverse order. The second error consisted of a series of velocity measurements which were incorrectly copied from the field notes. These corrections greatly increased the accuracy of the model, such that only minor adjustments to the remaining data, with the exception of a single transect, were required to obtain an acceptably calibrated model. The lowermost transect proved most difficult to calibrate and, following consultation with WDG and Hosey and Associates, was deleted from the data set. It was agreed that the four remaining transects adequately described the range of physical habitat present in the study area.

The original and revised IFG-4 model input data are presented for comparison in Appendix A. Water velocity and stage data which were corrected or altered during the calibration process are highlighted in the revised input data.

The primary value of the calibrated IFG-4 model lies in its ability to predict discharges and associated hydraulic parameters outside the range of observed (calibration) flows. Bovee and Milhous (1978) recommend extrapolating no further than 0.4 times the minimum discharge measured and 2.5 times the maximum calibration flow. These guidelines were adopted in the present study.

### Physical Habitat Criteria

A second computer program, HABTAT, computes the WUA values for each species/life stage over the range of discharges simulated using the depth, velocity, and substrate data predicted by the hydraulic model. The habitat simulation program accesses an information base in the form of habitat suitability functions (curves) for each of the physical parameters. The curves used in this study include several modifications to the species suitability criteria published by the Instream Flow Group (Bovee 1978). Revisions to the published curves, shown in Appendix Figures B1 - B12, were made following consultation with the WDG, Thomas R. Payne and Associates, and the project sponsors. The final criteria selected for application represent a consensus of fisheries biologists familiar with the habitat requirements of resident salmonid species/life stages found in streams similar to the South Fork Snoqualmie River.

An inspection of the substrate data and the WUA predictions obtained in Phase I suggested that the substrate index scale used to classify the streambed composition in the study area was not compatible with the published substrate suitability criteria which were incorporated in the habitat simulation process. This resulted in an upward bias of field recorded values, such that sandy substrate was interpreted by the HABTAT program as gravel size material, gravel substrate became cobbles, and so forth. Much of substratum in the study reach was dominated by boulder size materials. This size class was interpreted as bedrock, a substrate type with a comparatively low probability-of-use value for all salmonid life stages. As a result the predictions of WUA over the range of streamflows simulated were much lower than expected.

A second problem relating to substrate was the method used to characterize the substrate composition at each transect vertical. In the original study only the dominant particle size class observed was used to assign a substrate value to a given transect vertical. In high gradient streams like the South Fork it is advantageous to also account for the presence of subdominant particle size classes in order to better represent the heterogeneity of substrate types present.

It was decided that the best means of circumventing the problems described above was to return to the study site and obtain new substrate data. This was accomplished on January 30, 1983 by two FRI biologists familiar with the original data and the requirements of the IFIM. The permanent headpins marking the five transects used in the initial study were found and identified. Taped measurements of the longitudinal and horizontal distances between transect headpins indicated that the original measurements were sufficiently precise. The substrate composition along each transect was characterized by recording the three most prevalent particle sizes within each cell using the following substrate scale:

9 - Bedrock
8 - Boulder
7 - Cobble
6 - Large gravel
5 - Small gravel
4 - Sand
3 - Silt
2 - Mud
1 - Organic debris

For coding purposes the dominant particle size within a cell was multiplied by a factor of 0.67 and the second and third most prevalent size classes by 0.22 and 0.11, respectively. The final substrate value assigned to a vertical was the sum of the three products. It should be noted that the substrate values obtained in this manner are compatible with the revised habitat suitability criteria (Appendix B) used in the habitat simulation process.

Most evidence presented in the literature to date supports the validity of using the IFG-4 and HABTAT model combination to simulate habitat availability as a function of discharge. The WUA value, however, should not be interpreted as a direct measure of the carrying capacity of a stream since it does not incorporate other important environmental factors which influence aquatic productivity. Water quality and food limitations, in particular, may be more important than physical habitat in controlling population densities under moderate flow conditions. In regard to the analyses performed in this study, changes in WUA are considered an index of the availability of physical habitat at varying streamflows.

## Procedures Used To Derive Minimum Instream Flow Alternatives

The process used to develop instream flow alternatives for the South Fork of the Snoqualmie River consisted of the following steps:

1. Simulation of a range of discharges to determine WUA values for each species/life stage of interest;
2. Identification of discharges for the various species/life stages associated with the maximum WUA value ($Q_m$), the peak habitat efficiency value (i.e., the streamflow, $Q_E$, resulting in the maximum percentage of WUA within the wetted perimeter), and the WUA values representing 90, 80, 70, 60 and 50 percent of the maximum WUA available at $Q_m$. Discharges which provide for these percentages of the maximum WUA are designated as $Q_{90}$, $Q_{80}$, $Q_{70}$, $Q_{60}$, and $Q_{50}$, respectively;
3. Combination of the discharge data obtained in (2) above with stochastic projections of monthly discharge based on historical records to identify minimum flows for each species under normal (1 in 2 year) and critical (1 in 10 year) water year conditions;
4. Selection of salmonid life stages and species to be given preferential consideration in the determination of minimum flow alternatives; and
5. Derivation of alternative normal and critical water year minimum flow curves for the South Fork using the results of steps 1 through 4.

The final objective in this study was to predict the percentage change in physical habitat which will occur if any of several potential post-project instream flows are realized. Based on an evaluation of project operational constraints, Hosey and Associates suggested several instream flow regimes which might result from the diversion of water to the powerhouse. These monthly discharges were analyzed in relation to streamflows expected during median and critical water years in the South Fork. Median and critical water year streamflows were identified as the 50 and 90 percentile monthly mean discharge exceedance probabilities determined from Log-Pearson III analysis of 19 years (1961-1979) of discharge data recorded at USGS gage 12-143400 on the South Fork near Garcia, Washington. The stochastic discharges were adjusted to reflect streamflows at the project site using regression equations developed by Hosey and Associates. The regression equations were derived from correlation analysis between daily flows recorded at Garcia and Edgewick (gage 12-143600) during the two-year period (1963-65) when both gages were in operation. A graph of the relationship between the two sets of records may be found in IES (1982).

The percentage change in physical habitat expected for a given species/life stage during a particular month is calculated as

$$\%\ \text{change} = \frac{\text{WUA}_i - \text{WUA}_Q}{\text{WUA}_Q} \times 100$$

where $\text{WUA}_i$ = the physical habitat provided by the monthly discharge specified under post-project instream flow Regimes A,B,C, or D; and $\text{WUA}_Q$ is the index value predicted for the monthly median or critical flow.

A similar analysis was conducted using $Q_M$-based minimum monthly instream flows where $Q_M$ is the discharge associated with the maximum WUA identified for a given species.

# RESULTS AND DISCUSSION

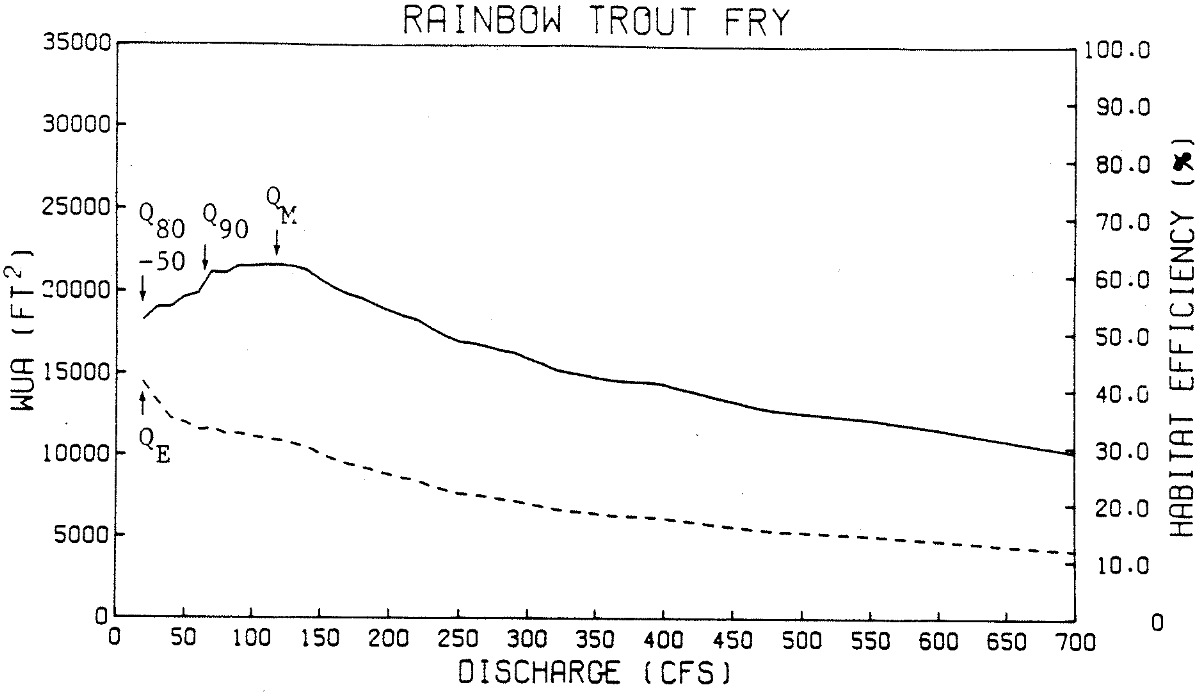
## IFG-4 Model Calibration

In addition to deleting the lowermost transect used in the original IFIM analysis, several corrections and minor adjustments of the water velocity and stage data were necessary to calibrate the South Fork IFG-4 model. The modifications required were not excessive, yet considerably enhanced the accuracy and reliability of the hydraulic simulation model. All changes in the original data are documented in Appendix Tables A1 and A2.

One measure of model performance is the correspondence between discharges predicted by the model for each transect ($Q_{CALC}$) and the input discharges ($Q_{QARD}$). The ratio of $Q_{QARD}$ to $Q_{CALC}$ is termed the Velocity Adjustment Factor (VAF) and is applied to each cell velocity to calculate the predicted velocities at a given discharge (Milhous et al. 1981). VAF's calculated using the original and revised data sets are presented in Appendix Table A3. The VAF's resulting from the revised model input vary between 0.82 and 1.09 for discharges simulated in the range of 20 to 1000 cfs, indicating that the IFG-4 model calibrated for the South Fork is suitable for predictive purposes.

## Weighted Usable Area (WUA) Predictions

The application of the suitability-of-use criteria illustrated in Appendix Figures B1 - B12 resulted in WUA indices of physical habitat for the various species/life stages of interest. WUA values are plotted (solid line) as a function of discharge for rainbow trout fry, juveniles (Figure 2), adults, and spawning (Figure 3). Habitat indices for the same life stages of cutthroat trout and mountain whitefish are depicted in Figures 4 and 5, and 6 and 7, respectively. The streamflow providing the maximum WUA for a given life stage, termed the $Q_M$ discharge, is indicated on each of the WUA versus



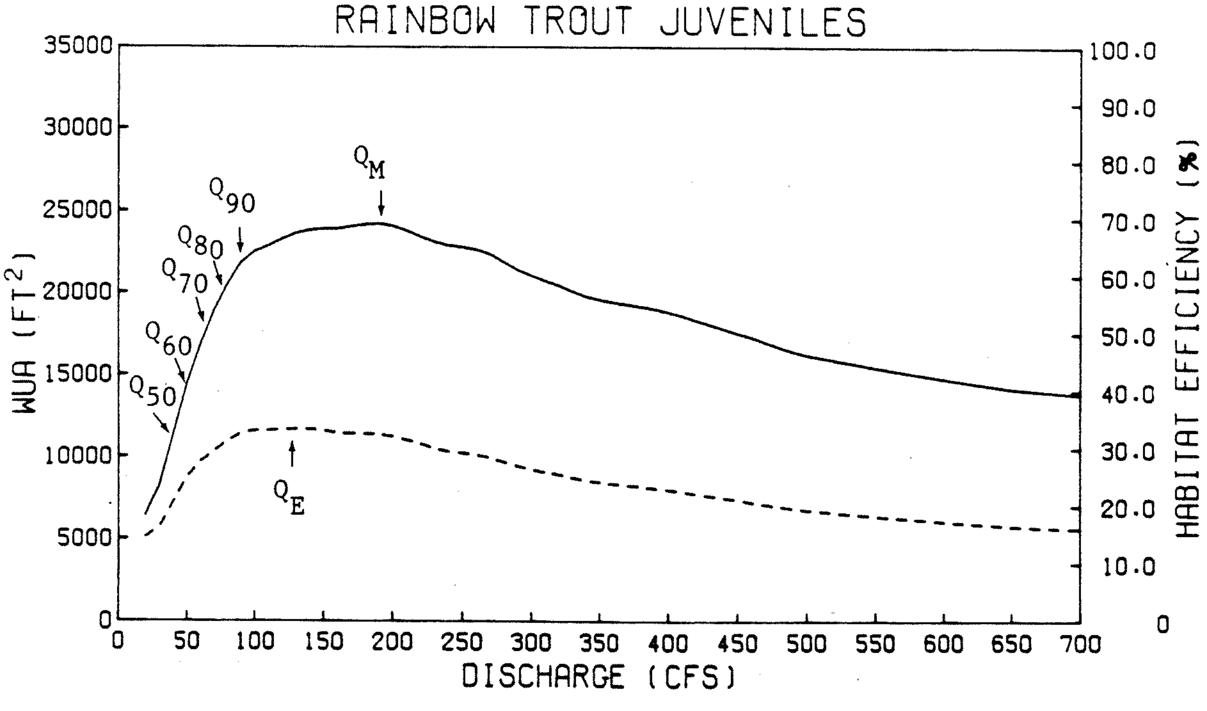


Figure 2. WUA (solid line) and habitat efficiency (dashed line) expressed as a function of discharge for rainbow trout fry and juveniles in the South Fork Snoqualmie River. $Q_*$ flows are indicated.

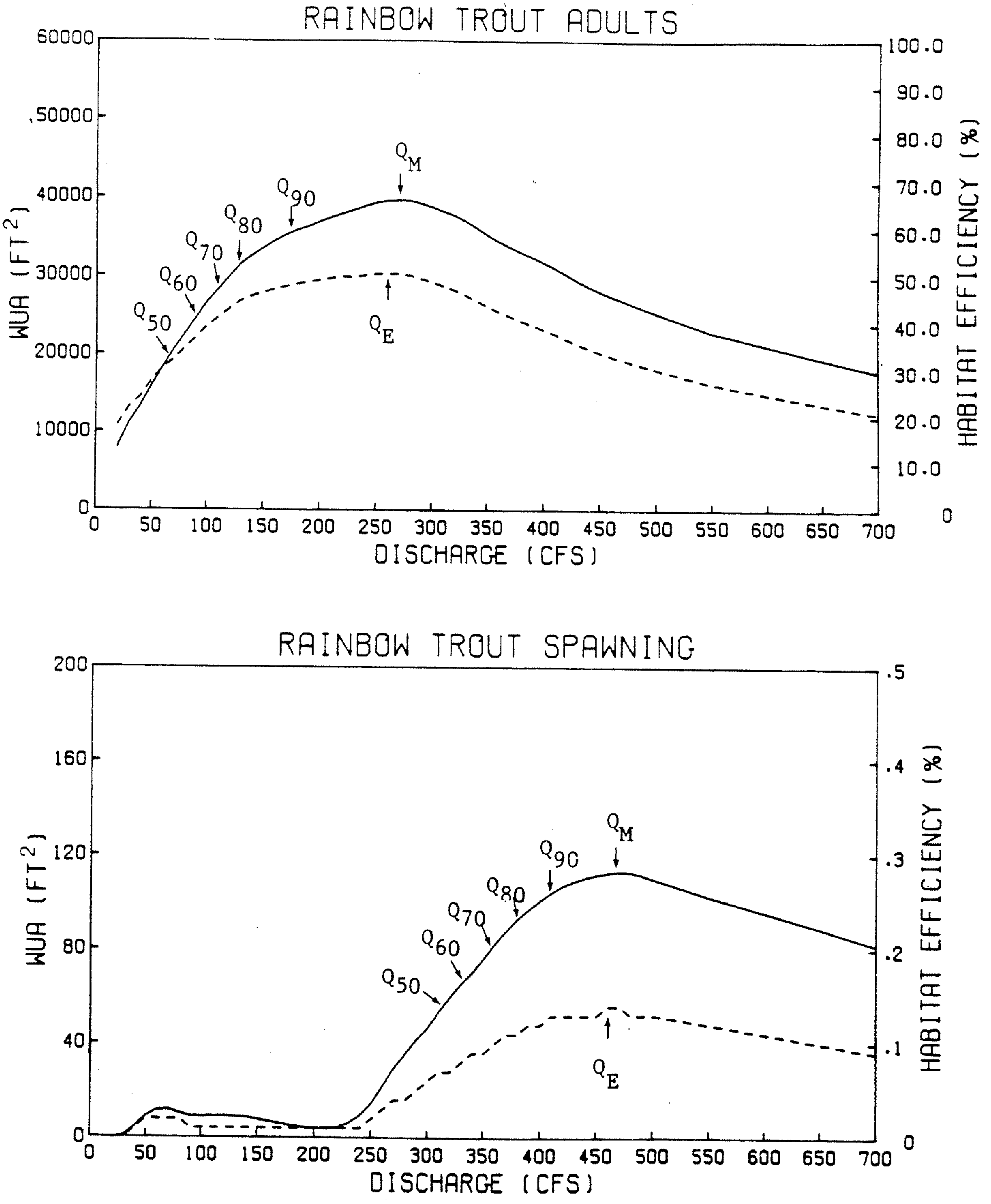


Figure 3. WUA (solid line) and habitat efficiency (dashed line) expressed as a function of discharge for rainbow trout adults and spawning in the South Fork Snoqualmie River. $Q_{*}$ flows are indicated.

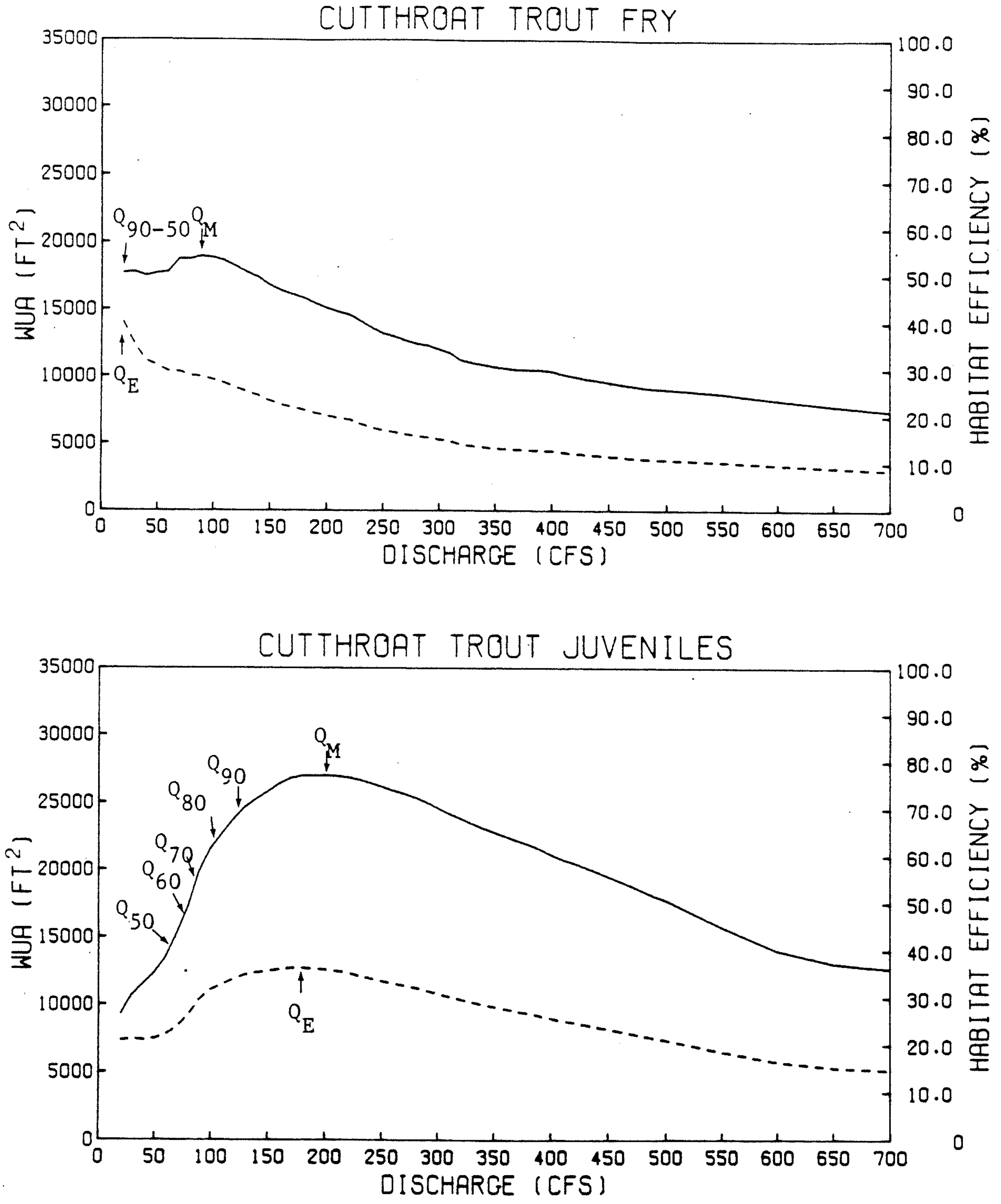
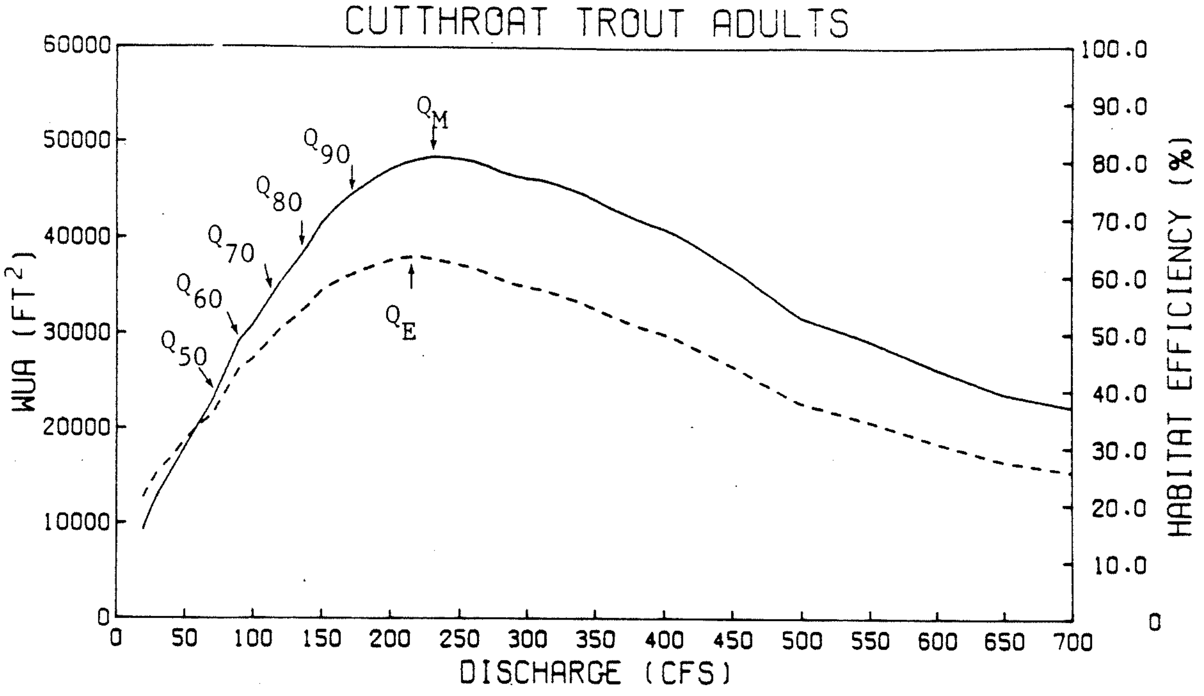


Figure 4. WUA (solid line) and habitat efficiency (dashed line) expressed as a function of discharge for cutthroat trout fry and juveniles in the South Fork Snoqualmie River. $Q_*$ flows are indicated.



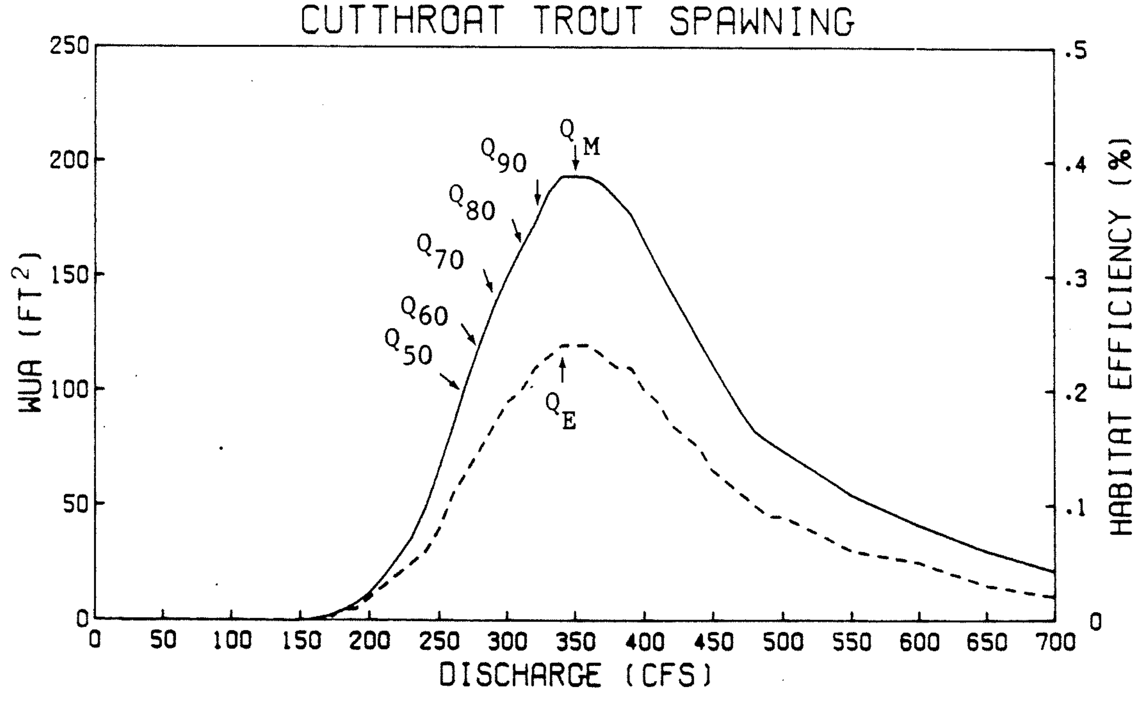


Figure 5. WUA (solid line) and habitat efficiency (dashed line) expressed as a function of discharge for cutthroat trout adults and spawning in the South Fork Snoqualmie River. $Q_*$ flows are indicated.

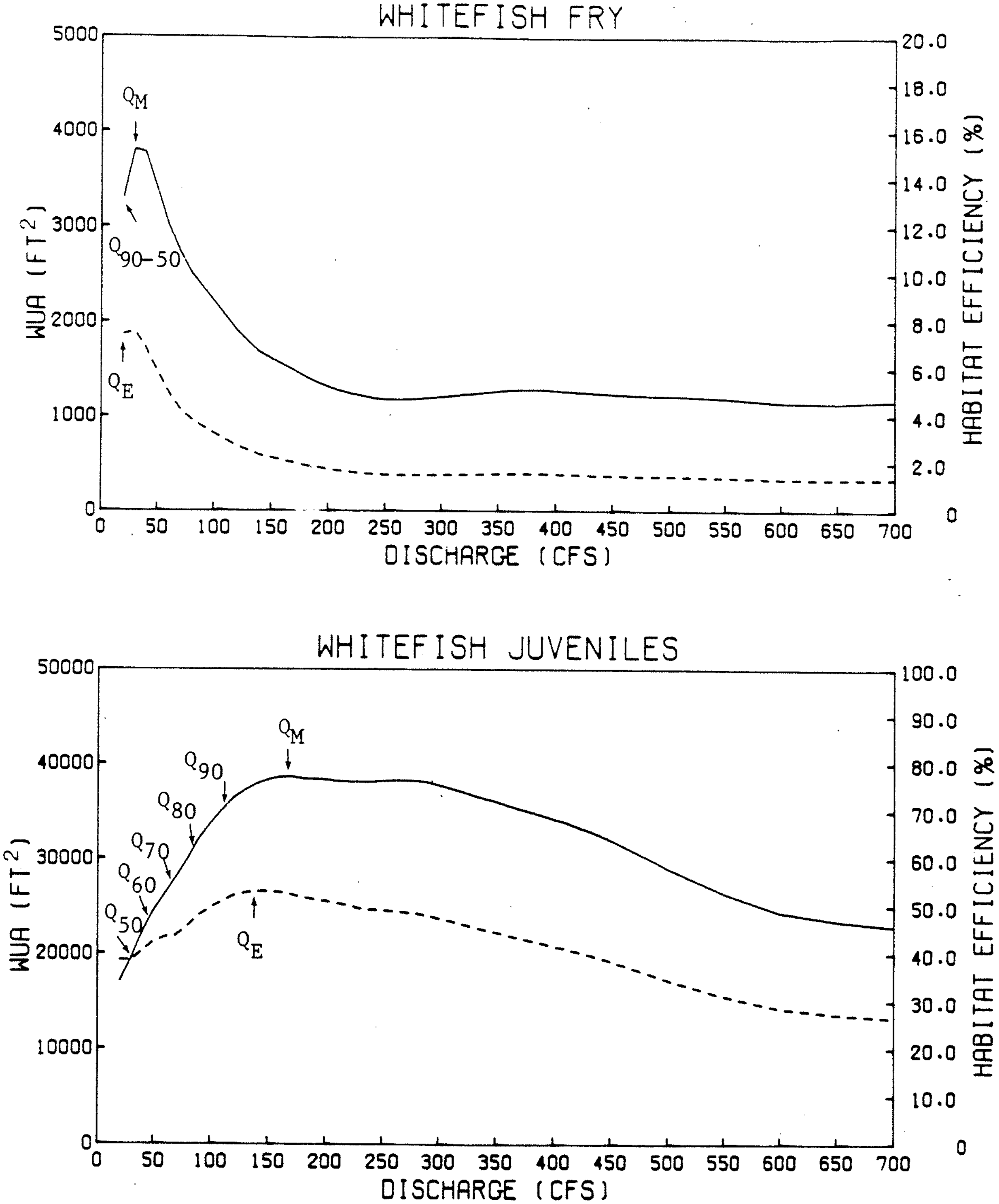


Figure 6. WUA (solid line) and habitat efficiency (dashed line) expressed as a function of discharge for Mountain whitefish fry and juveniles in the South Fork Snoqualmie River. $Q_*$ flows are indicated.

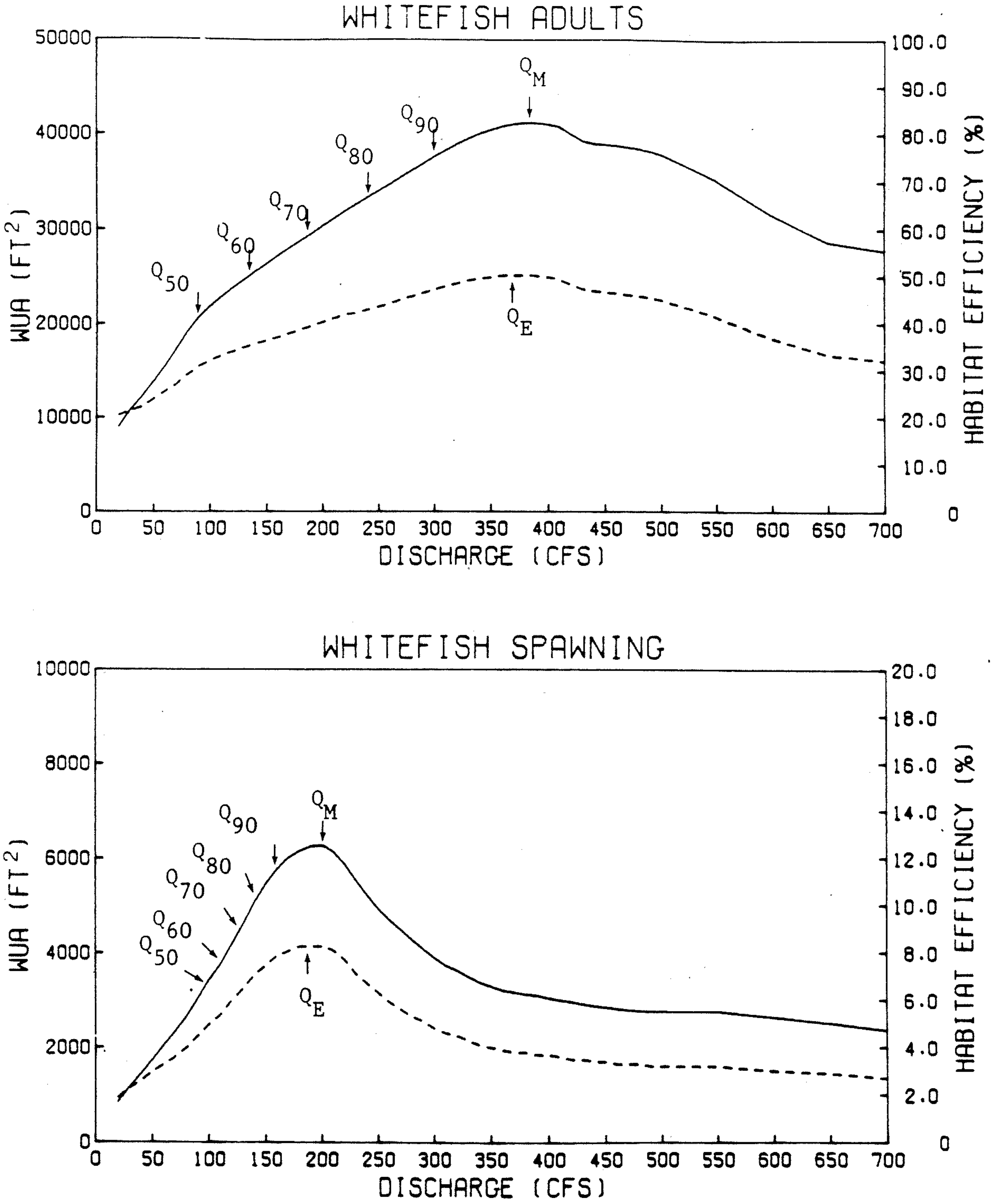


Figure 7. WUA (solid line) and habitat efficiency (dashed line) expressed as a function of discharge for Mountain whitefish adults and spawning in the South Fork Snoqualmie River. $Q_*$ flows are indicated.

discharge graphs. Also identified are the streamflows less than $Q_M$ which correspond to 10, 20, 30, 40 and 50 percent reductions in the maximum WUA value for each life stage. These discharges are designated as $Q_{90}$, $Q_{80}$, $Q_{70}$, $Q_{60}$, and $Q_{50}$, respectively.

A final parameter of interest is the $Q_E$ discharge, defined as the streamflow associated with the peak habitat efficiency. $Q_E$ is determined from the relation between WUA and gross stream surface area provided by the simulated discharges, which is portrayed in Figures 2 through 7 as a dashed line. The $Q_E$ value for a given life stage is identified as the streamflow which provides the highest WUA to gross stream surface area ratio within the range of 20 to 1000 cfs.

$Q_M$, $Q_E$, and $Q_{90}$ through $Q_{50}$ discharges and associated WUA values are summarized for each species/life stage in Table 1. $Q_M$ streamflow requirements for the four life stages of all species may be generally ranked in the following order of magnitude: fry < juveniles < adults < spawning. The spawning $Q_M$ values for mountain whitefish, however, are less than the adult life stage $Q_M$ discharge. $Q_E$ streamflows were generally lower, particularly for the rainbow and cutthroat trout fry life stages, than associated $Q_M$ flows. Selection of discharges on the basis of peak habitat efficiency values rather than maximum WUA values (i.e., $Q_E$ instead of $Q_M$ flows) resulted in an average reduction of 12.6% in discharge with a corresponding loss in WUA of only 2.4%, as shown in Table 2.

A major reason for the substantial differences observed between discharges indicated by the peak habitat efficiency and maximal WUA methods is the tendency for WUA curves, notably those for the fry life stage, to exhibit an inflection point at discharge levels below the WUA maxima. The $Q_E$ value for a given life stage generally coincided with the inflection point exhibited

Table 1. $Q_M$, $Q_E$, and $Q_{90}$ through $Q_{50}$ streamflow requirements and associated WUA values for trout and whitefish life stages known to occur in the South Fork Snoqualmie River.

| Species | Life stage | $Q_M$ | WUA | $Q_E$ | WUA | $Q_{90}$ | WUA | $Q_{80}$ | WUA | $Q_{70}$ | WUA | $Q_{60}$ | WUA | $Q_{50}$ | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | Fry | 120 | 21569 | <20 | 18239 | 46 | 19412 | <20 | 17255 | <20 | 15098 | <20 | 12941 | <20 | 10784 |
| | Juveniles | 190 | 24238 | 130 | 23650 | 90 | 21814 | 74 | 19391 | 61 | 16967 | 51 | 14543 | 43 | 12119 |
| | Adults | 270 | 39714 | 260 | 39632 | 177 | 35742 | 132 | 31771 | 107 | 27800 | 86 | 23828 | 67 | 19857 |
| | Spawning | 470 | 113 | 460 | 113 | 403 | 102 | 376 | 91 | 355 | 79 | 335 | 68 | 315 | 57 |
| Cutthroat trout | Fry | 90 | 18945 | <20 | 17744 | <20 | 17050 | <20 | 15156 | <20 | 13261 | <20 | 11367 | <20 | 9472 |
| | Juveniles | 200 | 27013 | 180 | 27001 | 126 | 24312 | 100 | 21610 | 86 | 18909 | 75 | 16208 | 61 | 13507 |
| | Adults | 230 | 48486 | 220 | 48197 | 165 | 43638 | 139 | 38789 | 114 | 33941 | 90 | 29092 | 75 | 24243 |
| | Spawning | 350 | 194 | 340 | 193 | 321 | 174 | 304 | 155 | 289 | 135 | 277 | 116 | 266 | 97 |
| Mountain whitefish | Fry | 30 | 3811 | 30 | 3811 | 22 | 3430 | <20 | 3049 | <20 | 2668 | <20 | 2287 | <20 | 1906 |
| | Juveniles | 170 | 38702 | 140 | 37947 | 108 | 34832 | 85 | 30962 | 65 | 27092 | 44 | 23221 | 30 | 19351 |
| | Adults | 380 | 41185 | 370 | 41066 | 292 | 37067 | 234 | 32948 | 180 | 28830 | 130 | 24711 | 89 | 20593 |
| | Spawning | 200 | 6281 | 190 | 6266 | 156 | 5653 | 140 | 5025 | 125 | 4397 | 110 | 3769 | 93 | 3140 |

Table 2. Average percent reduction in species streamflow requirements and WUA relative to $Q_M$ and associated WUA maxima under $Q_E$, and $Q_{90}$ through $Q_{50}$ discharges.

| Species | % reduction in WUA | % reduction in discharge |
|---|---|---|
| | $Q_E$ | |
| Rainbow trout | 4.7 | 17.1 |
| Cutthroat trout | 1.6 | 12.6 |
| Mountain whitefish | 1.0 | 6.4 |
| TOTAL | 2.4 | 12.6 |
| | $Q_{90}$ | |
| Rainbow trout | 10.0 | 31.8 |
| Cutthroat trout | 10.0 | 33.6 |
| Mountain whitefish | 10.0 | 25.9 |
| TOTAL | 10.0 | 30.4 |
| | $Q_{80}$ | |
| Rainbow trout | 20.0 | 42.7 |
| Cutthroat trout | 20.0 | 35.3 |
| Mountain whitefish | 20.0 | 39.9 |
| TOTAL | 20.0 | 39.3 |
| | $Q_{70}$ | |
| Rainbow trout | 30.0 | 48.3 |
| Cutthroat trout | 30.0 | 42.6 |
| Mountain whitefish | 30.0 | 50.0 |
| TOTAL | 30.0 | 47.0 |
| | $Q_{60}$ | |
| Rainbow trout | 40.0 | 53.1 |
| Cutthroat trout | 40.0 | 46.9 |
| Mountain whitefish | 40.0 | 61.0 |
| TOTAL | 40.0 | 53.7 |
| | $Q_{50}$ | |
| Rainbow trout | 50.0 | 57.6 |
| Cutthroat trout | 50.0 | 51.5 |
| Mountain whitefish | 50.0 | 70.2 |
| TOTAL | 50.0 | 59.8 |

by the associated WUA versus discharge curve. In other cases, the discharge associated with the peak habitat efficiency value was equivalent to or slightly less than the discharge at which WUA was highest.

Reductions in streamflow requirements resulting from 10 to 50 percent decreases in the $Q_M$-associated WUA are summarized by species in Table 2. It should be pointed out that average discharge requirements decrease less rapidly with successive 10 percent reductions in WUA. For example, an initial 10 percent reduction in WUA from 100 to 90 percent results in an average reduction of 30 percent in discharge, whereas decreasing WUA from 60 to 50 percent represents only a 6 percent reduction in discharge.

Mention should be made of the relative paucity of rainbow and cutthroat trout spawning habitat predicted by the HABTAT model, even at optimal ($Q_M$) flows. Approximately 113 square feet of rainbow spawning WUA per 1000 linear feet of stream is provided by a $Q_M$ flow of 470 cfs, representing less than 0.14% of the gross stream surface area present at this discharge. Similarly, cutthroat spawning habitat is estimated to be 194 square feet/1000 feet of stream at a $Q_M$ of 350 cfs, or roughly 0.24% of the total wetted perimeter.

Two additional points to be made are that 1) $Q_M$ flows occur infrequently in the South Fork during the spawning period, such that rainbow and cutthroat trout spawning habitat under normal water year conditions is rarely maximized, and 2) the gross habitat features of the reach of stream selected for the IFIM analysis are not representative of the majority of the diversion reach. An inventory of the morphological characteristics of the South Fork by South Fork Resources, Inc. (1982) indicates that the IFIM study area is only representative of the lower 0.4 miles of the diversion reach. The remaining 0.8 miles is characterized either by high gradient cascades and falls or by channelized sections of stream resulting from the construction of Interstate

90. In light of the diminished availability of suitable spawning habitat expected under these circumstances, it is reasonable to assume that the diversion reach does not currently provide significant amounts of resident trout spawning habitat. Nevertheless, this assumption should be considered speculative until further documentation of spawner utilization within the affected reach is provided.

## Alternative Minimum Instream Flows

Instream flow requirements for a given species/life stage are important only for the time interval that the life stage is present in the proposed diversion reach. The temporal distribution and relative abundance of salmonids utilizing the South Fork was ascertained from published sources (Scott and Nakatani 1982a and b; Scott and Crossman 1973) and from consultation with the WDG. On the basis of this information, it was agreed that rainbow and cutthroat trout are equally abundant in the affected reach of stream, each species comprising approximately 40 percent of the total salmonid population. For purposes of analysis, mountain whitefish were assumed to account for the remaining 20 percent of salmonids present. Brook trout (*Salvelinus fontinalis*) and brown trout (*Salmo trutta*) were included in the original IFIM study conducted by IES (1982); however, electrofishing and snorkelling surveys have not documented the presence of these species in the study reach and the habitat requirements for these species were not included in the following analysis.

A general phenology chart defining the timing of trout and whitefish life stages known to occur in the South Fork is presented in Figure 8. Information provided by Scott and Nakatani (1982a,b) suggests that the timing of rainbow and cutthroat trout life stages in the South Fork is identical. As opposed to the spring and early summer spawning trout species, mountain whitefish spawn

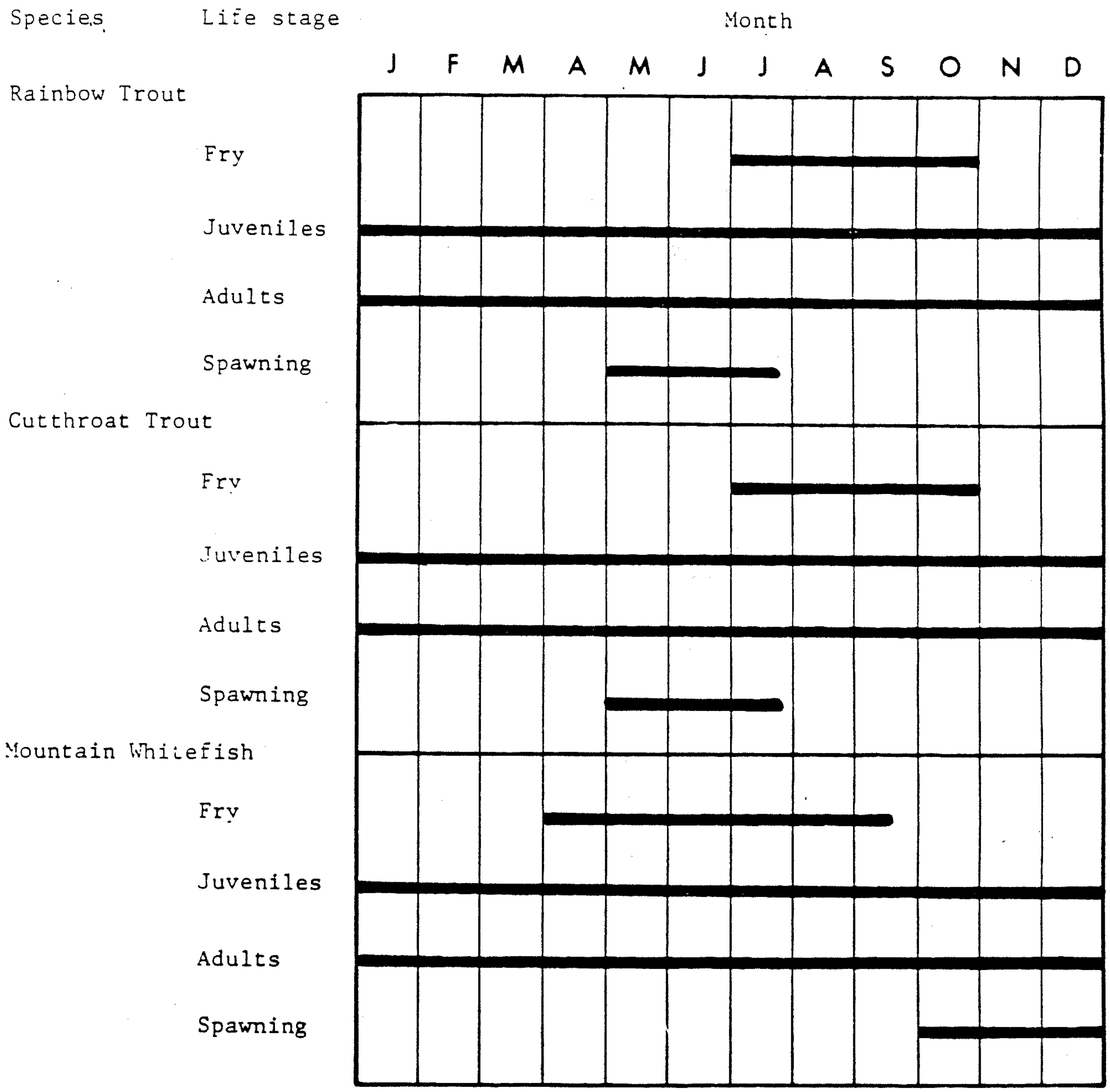


Figure 8. Phenology chart for salmonid species/life stages utilizing the South Fork Snoqualmie River.

during the late fall and winter months. The incubation phase for whitefish eggs is therefore longer than it is for rainbow and cutthroat eggs, due primarily to seasonal differences in intragravel water temperatures.

A prerequisite to establishing minimum monthly instream flows for the South Fork which account for all species/life stages present in the river is determining streamflows which can be expected to occur during "normal" and "critical" water years. Normal and critical monthly flows are utilized in the negotiating process to provide additional operating flexibility and to minimize a consistent fish habitat loss. This usually results in two minimum instream flow regimes. How to determine when to apply the normal or critical curve must also be negotiated and may be more difficult for a run-of-river than a storage project. Summary statistics of USGS discharge data recorded at the Garcia gage on the South Fork include flow exceedence probability values at the 50th and 90th percentiles, corresponding to flows which are <u>not</u> exceeded on a stochastic basis in 1 out of 2 years (normal) and 1 out of 10 years (critical), respectively. Normal and critical water year mean monthly flows at the Twin Falls Project sites, derived using Hosey and Associates regression equations are presented in Table 3.

Alternative instream minimum flows for the life stages of the various salmonid species were calculated for normal and critical water years using a combination of the hydrologic data described above and the $Q_*$ flows specific to the life stages. The symbol $Q_*$ refers to the particular set of streamflow requirements under consideration, i.e., $Q_M$, $Q_E$, $Q_{90}$, $Q_{80}$, $Q_{70}$, $Q_{60}$, or $Q_{50}$. It should be emphasized that each of these $Q_*$ values are analyzed in the same manner in the derivation of final minimum flow curves, as will be discussed below. Because of their relative differences in magnitude, however, each set of $Q_*$ flows will result in a unique minimum instream flow alternative.

Table 3. Median and critical (90 percentile flow exceedance) monthly discharges and alternative post-project instream flows for the South Fork Snoqualmie River.

| | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | J | F | M | A | M | J | J | A | S | O | N | D |
| Median | 550 | 375 | 320 | 470 | 750 | 638 | 239 | 104 | 113 | 227 | 423 | 485 |
| Critical | 257 | 160 | 215 | 295 | 512 | 362 | 112 | 63 | 64 | 100 | 271 | 260 |
| Regime A | 150 | 150 | 150 | 150 | 150 | 150 | 100 | 75 | 75 | 100 | 150 | 150 |
| Regime B | 100 | 100 | 100 | 100 | 100 | 100 | 75 | 50 | 50 | 75 | 100 | 100 |
| Regime C | 75 | 75 | 75 | 75 | 75 | 75 | 50 | 50 | 50 | 50 | 75 | 75 |
| Regime D | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |

Table 4. Streamflow requirements for a normal water year based on $Q_M$ values identified for salmonid life stages occurring in the South Fork Snoqualmie River. The monthly median flow is indicated at the head of each column.

| Species | Life stage | $Q_M$ | 550 | 375 | 320 | 470 | 750 | 638 | 239 | 104 | 113 | 227 | 423 | 485 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 120 |  |  |  |  |  |  | 120 | 104 | 113 | 120 |  |  |
|  | Juvenile | 190 | 190 | 190 | 190 | 190 | 190 | 190 | 190 | 104 | 113 | 190 | 190 | 190 |
|  | Adult | 270 | 270 | 270 | 270 | 270 | 270 | 270 | 239 | 104 | 113 | 227 | 270 | 270 |
|  | Spawning | 470 |  |  |  |  | 470 | 470 | 70 |  |  |  |  |  |
| Cutthroat trout | Fry | 90 |  |  |  |  |  |  | 90 | 90 | 90 | 90 |  |  |
|  | Juvenile | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 200 | 104 | 113 | 200 | 200 | 200 |
|  | Adult | 230 | 230 | 230 | 230 | 230 | 230 | 230 | 230 | 104 | 113 | 227 | 230 | 230 |
|  | Spawning | 350 |  |  |  |  | 350 | 350 | 239 |  |  |  |  |  |
| Mountain whitefish | Fry | 30 |  |  |  | 30 | 30 | 30 | 30 | 30 | 30 |  |  |  |
|  | Juvenile | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 170 | 104 | 113 | 170 | 170 | 170 |
|  | Adult | 380 | 380 | 375 | 320 | 380 | 380 | 380 | 239 | 104 | 113 | 227 | 380 | 380 |
|  | Spawning | 200 |  |  |  |  |  |  |  |  |  | 200 | 200 | 200 |

Table 5. Streamflow requirements for a critical water year based on $Q_M$ values identified for salmonid life stages occurring in the South Fork Snoqualmie River. The monthly 1 in 10 year flow is indicated at the head of each column.

| Species | Life stage | $Q_M$ | 257 | 160 | 215 | 295 | 512 | 362 | 112 | 63 | 64 | 100 | 271 | 260 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 120 |  |  |  |  |  |  | 112 | 63 | 64 | 100 |  |  |
|  | Juvenile | 190 | 190 | 160 | 190 | 190 | 190 | 190 | 112 | 63 | 64 | 100 | 190 | 190 |
|  | Adult | 270 | 257 | 160 | 215 | 270 | 270 | 270 | 112 | 63 | 64 | 100 | 270 | 260 |
|  | Spawning | 470 |  |  |  |  | 470 | 362 | 70 |  |  |  |  |  |
| Cutthroat trout | Fry | 90 |  |  |  |  |  |  | 90 | 63 | 64 | 90 |  |  |
|  | Juvenile | 200 | 200 | 160 | 200 | 200 | 200 | 200 | 112 | 63 | 64 | 100 | 200 | 200 |
|  | Adult | 230 | 230 | 160 | 215 | 230 | 230 | 230 | 112 | 63 | 64 | 100 | 230 | 230 |
|  | Spawning | 350 |  |  |  |  | 350 | 350 | 112 |  |  |  |  |  |
| Mountain whitefish | Fry | 30 |  |  |  | 30 | 30 | 30 | 30 | 30 | 30 |  |  |  |
|  | Juvenile | 170 | 170 | 160 | 170 | 170 | 170 | 170 | 112 | 63 | 64 | 100 | 170 | 170 |
|  | Adult | 380 | 257 | 160 | 215 | 295 | 380 | 362 | 112 | 63 | 64 | 100 | 271 | 260 |
|  | Spawning | 200 |  |  |  |  |  |  |  |  |  | 100 | 200 | 200 |

Using $Q_M$ flows as an example, the discharge required for a given life stage during a particular month of a normal water year is defined as the streamflow less than or equal to the median monthly flow which results in the smallest reduction in habitat relative to the WUA available at $Q_M$. Table 4 identifies the normal water year $Q_M$-based streamflow requirements for each species/life stage during the months of the year they are known to occur in the South Fork. To illustrate the constraining effect that median monthly discharges have on streamflow requirements Table 4 indicates that adult rainbow trout habitat, which is maximized at a $Q_M$ of 270 cfs, is normally reduced during the summer months when monthly discharges average from 73 to 171 cfs. As a consequence, the monthly streamflow requirements for this life stage during July through September are set equal to the corresponding median monthly flow. In the case of rainbow trout spawning flow requirements in July, note that the discharge specified, 70 cfs, is less than both the $Q_M$ and median monthly flow value. From an inspection of the spawning WUA versus Q for this species shown curve in Figure 3, it can be seen that the spawning WUA provided by 70 cfs is actually greater than that available at 171 cfs, the median flow for the month of July.

In order to calculate $Q_M$-based streamflow requirements during critical water years, 1 in 10 year monthly flows were used instead of median discharges. The limiting effect of critical water year discharges on streamflow requirements identified for the various life stages is more pronounced, as evidenced by the discharges tabulated in Table 5.

Similar normal and critical water year tables were constructed using $Q_E$, $Q_{90}$, $Q_{80}$, $Q_{70}$, $Q_{60}$, and $Q_{50}$ discharges to calculate streamflow requirements for the various species/life stages. With the exception of those based on $Q_M$ values, $Q_*$ tables of the streamflows required to preserve habitat values under normal and critical water year conditions are presented in Appendix C.

The process of deriving a single flow recommendation for each species required that weighting coefficients be assigned to the trout and whitefish life stages for the months each is known to inhabit the South Fork. The weight ascribed to each life stage is the average of three independent evaluations by FRI biologists of the relative importance of the various habitat types which are utilized in the South Fork during successive months of the year. Month-specific weighting coefficients are shown in Table 6. Note that the sum of the weighting coefficients equals 1.0 for each species for any given month.

Monthly flow requirements for each species were determined by multiplying the life stage flow requirements by their respective weighting coefficients and adding the products. The same procedure was followed for both normal and critical water year $Q_*$ based flows. Species flow requirements for normal and critical water years under the various $Q_*$ options are listed by month in Tables 7 and 8, respectively. The $Q_*$-based monthly flow requirements calculated for each species were multiplied by their estimated numerical proportions to derive composite normal and critical water year minimum instream flow curves. Rainbow and cutthroat trout each comprised an estimated 40 percent of the salmonid population inhabiting the South Fork. Whitefish were assumed to constitute the remaining 20 percent of the population. Normal water year monthly instream flow minima based on $Q_m$, $Q_E$, and $Q_{90}$ through $Q_{50}$ summarized in Table 7 are illustrated in Figure 9. The corresponding critical water year instream flow curves listed in Table 8 are plotted in Figure 10.

Hosey and Associates provided several potential annual flow regimes which may be expected to occur in the diversion reach due to powerhouse operation. The potential post-project flows, summarized in Table 3, have been graphed on

Table 6. Month-specific weighting factors (mean of three independent evaluations) derived for trout and whitefish life stages known to inhabit the South Fork Snoqualmie River.

| | | Month | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life stage | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout and cutthroat trout | Fry | | | | | | | 0.22 | 0.47 | 0.53 | 0.47 | | |
| | Juveniles | 0.6 | 0.6 | 0.6 | 0.6 | 0.13 | 0.13 | 0.12 | 0.25 | 0.27 | 0.33 | 0.60 | 0.60 |
| | Adults | 0.4 | 0.4 | 0.4 | 0.4 | 0.23 | 0.17 | 0.09 | 0.28 | 0.20 | 0.20 | 0.40 | 0.40 |
| | Spawning | | | | | 0.64 | 0.70 | 0.57 | | | | | |
| Mountain whitefish | Fry | | | | 0.30 | 0.40 | 0.47 | 0.47 | 0.47 | 0.33 | | | |
| | Juveniles | 0.57 | 0.57 | 0.57 | 0.40 | 0.30 | 0.30 | 0.30 | 0.30 | 0.37 | 0.30 | 0.27 | 0.30 |
| | Adults | 0.43 | 0.43 | 0.43 | 0.30 | 0.30 | 0.23 | 0.23 | 0.23 | 0.30 | 0.30 | 0.23 | 0.27 |
| | Spawning | | | | | | | | | | 0.40 | 0.50 | 0.43 |

Table 7. Monthly minimum instream flows for a <u>normal</u> water year derived for each salmonid species for all species combined based on $Q_M$, $Q_E$, and $Q_{90}$ through $Q_{50}$ streamflow requirements.

$Q_M$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 222.0 | 222.0 | 222.0 | 222.0 | 387.6 | 399.6 | 110.6 | 104.0 | 113.0 | 164.5 | 222.0 | 222.0 |
| CUTTHROAT TROUT | 212.0 | 212.0 | 212.0 | 212.0 | 302.9 | 310.1 | 200.7 | 97.4 | 100.8 | 153.7 | 212.0 | 212.0 |
| MOUNTAIN WHITEFISH | 260.3 | 258.1 | 234.5 | 191.0 | 177.0 | 152.5 | 120.1 | 69.2 | 85.6 | 199.1 | 233.3 | 239.6 |
| MINIMUM INSTREAM FLOW | 226. | 225. | 221. | 212. | 312. | 314. | 149. | 94. | 103. | 167. | 220. | 222. |

$Q_E$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 182.0 | 182.0 | 182.0 | 182.0 | 371.1 | 383.1 | 81.4 | 64.5 | 63.7 | 97.7 | 182.0 | 182.0 |
| CUTTTHROAT TROUT | 196.0 | 196.0 | 196.0 | 196.0 | 291.6 | 298.8 | 182.0 | 64.5 | 63.7 | 112.8 | 196.0 | 196.0 |
| MOUNTAIN WHITEFISH | 238.9 | 238.9 | 238.9 | 176.0 | 165.0 | 141.2 | 111.1 | 69.2 | 85.6 | 186.1 | 217.9 | 223.6 |
| MINIMUM INSTREAM FLOW | 199. | 199. | 199. | 186. | 298. | 301. | 128. | 65. | 68. | 121. | 195. | 196. |

$Q_{90}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 124.8 | 124.8 | 124.8 | 124.8 | 310.3 | 323.9 | 76.8 | 73.2 | 71.3 | 86.7 | 124.8 | 124.8 |
| CUTTHROAT TROUT | 141.6 | 141.6 | 141.6 | 141.6 | 259.8 | 269.1 | 170.6 | 64.5 | 63.7 | 84.0 | 141.6 | 141.6 |
| MOUNTAIN WHITEFISH | 187.1 | 187.1 | 187.1 | 137.4 | 128.8 | 109.9 | 97.7 | 65.5 | 83.0 | 162.9 | 174.3 | 178.3 |
| MINIMUM INSTREAM FLOW | 144. | 144. | 144. | 134. | 254. | 259. | 118. | 68. | 71. | 101. | 141. | 142. |

Table 7 (continued)

$Q_{80}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 97.2 | 97.2 | 97.2 | 97.2 | 280.6 | 295.3 | 65.1 | 57.0 | 53.2 | 60.2 | 97.2 | 97.2 |
| CUTTHROAT TROUT | 115.6 | 115.6 | 115.6 | 115.6 | 239.5 | 249.4 | 165.1 | 63.5 | 60.2 | 70.2 | 115.6 | 115.6 |
| MOUNTAIN WHITEFISH | 149.1 | 149.1 | 149.1 | 110.2 | 103.7 | 88.7 | 88.7 | 58.8 | 72.0 | 149.6 | 146.8 | 148.9 |
| MINIMUM INSTREAM FLOW | 115. | 115. | 115. | 107. | 229. | 236. | 110. | 60. | 60. | 82. | 114. | 115. |

$Q_{70}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 79.4 | 79.4 | 79.4 | 79.4 | 259.7 | 274.6 | 61.3 | 53.8 | 48.5 | 50.9 | 79.4 | 79.4 |
| CUTTHROAT TROUT | 97.2 | 97.2 | 97.2 | 97.2 | 222.4 | 232.9 | 161.2 | 60.0 | 56.4 | 60.6 | 97.2 | 97.2 |
| MOUNTAIN WHITEFISH | 114.4 | 114.4 | 114.4 | 86.0 | 81.5 | 70.3 | 70.3 | 52.8 | 64.6 | 123.5 | 121.5 | 121.8 |
| MINIMUM INSTREAM FLOW | 94. | 94. | 94. | 88. | 209. | 217. | 103. | 56. | 55. | 69. | 95. | 95. |

$Q_{60}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 65.0 | 65.0 | 65.0 | 65.0 | 240.8 | 255.7 | 58.2 | 46.2 | 41.6 | 43.4 | 65.0 | 65.0 |
| CUTTHROAT TROUT | 81.0 | 81.0 | 81.0 | 81.0 | 207.7 | 218.9 | 157.7 | 53.3 | 48.9 | 52.1 | 81.0 | 81.0 |
| MOUNTAIN WHITEFISH | 81.0 | 81.0 | 81.0 | 62.6 | 60.2 | 52.5 | 52.5 | 46.5 | 56.8 | 96.2 | 96.8 | 95.6 |
| MINIMUM INSTREAM FLOW | 75. | 75. | 75. | 71. | 191. | 200. | 97. | 49. | 48. | 57. | 78. | 78. |

$Q_{50}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 52.6 | 52.6 | 52.6 | 52.6 | 222.6 | 237.5 | 55.5 | 38.9 | 35.6 | 37.0 | 52.6 | 52.6 |
| CUTTHROAT TROUT | 66.6 | 66.6 | 66.6 | 66.6 | 195.4 | 206.9 | 154.7 | 45.7 | 42.1 | 44.5 | 66.6 | 66.6 |
| MOUNTAIN WHITEFISH | 55.4 | 55.4 | 55.4 | 44.7 | 43.7 | 38.9 | 38.9 | 38.9 | 44.4 | 72.9 | 75.1 | 73.0 |
| MINIMUM INSTREAM FLOW | 59. | 59. | 59. | 57. | 176. | 186. | 92. | 42. | 40. | 47. | 63. | 62. |

Table 8. Monthly minimum instream flows for a <u>critical</u> water year derived for each salmonid species and for all species combined based on $Q_M$, $Q_E$, and $Q_{90}$ through $Q_{50}$ streamflow requirements.

$Q_M$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 216.8 | 160.0 | 200.0 | 222.0 | 387.6 | 324.0 | 88.1 | 63.0 | 64.0 | 100.0 | 222.0 | 218.0 |
| CUTTHROAT TROUT | 212.0 | 160.0 | 206.0 | 212.0 | 302.9 | 310.1 | 107.2 | 63.0 | 64.0 | 95.3 | 212.0 | 212.0 |
| MOUNTAIN WHITEFISH | 207.4 | 160.0 | 189.4 | 165.5 | 177.0 | 152.5 | 73.5 | 47.5 | 52.8 | 100.0 | 208.2 | 207.2 |
| MINIMUM INSTREAM FLOW | 213. | 160. | 200. | 207. | 312. | 284. | 93. | 60. | 62. | 98. | 215. | 213. |

$Q_E$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 180.8 | 142.0 | 164.0 | 182.0 | 371.1 | 314.5 | 67.8 | 42.8 | 40.7 | 62.4 | 182.0 | 182.0 |
| CUTTHROAT TROUT | 196.0 | 160.0 | 194.0 | 196.0 | 291.6 | 298.8 | 91.8 | 42.8 | 40.7 | 62.4 | 196.0 | 196.0 |
| MOUNTAIN WHITEFISH | 190.3 | 148.6 | 172.3 | 153.5 | 165.0 | 139.4 | 73.5 | 47.5 | 52.8 | 100.0 | 195.1 | 193.9 |
| MINIMUM INSTREAM FLOW | 189. | 151. | 178. | 182. | 298. | 273. | 79. | 44. | 43. | 70. | 190. | 190. |

$Q_{90}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 124.8 | 118.0 | 124.8 | 124.8 | 310.3 | 295.2 | 70.9 | 53.1 | 52.9 | 71.3 | 124.8 | 124.8 |
| CUTTHROAT TROUT | 141.6 | 139.6 | 141.6 | 141.6 | 259.8 | 269.1 | 91.8 | 42.9 | 40.7 | 62.4 | 141.6 | 141.6 |
| MOUNTAIN WHITEFISH | 172.1 | 130.4 | 154.0 | 137.4 | 128.8 | 109.9 | 68.5 | 43.7 | 50.1 | 100.0 | 169.5 | 169.7 |
| MINIMUM INSTREAM FLOW | 141. | 129. | 137. | 134. | 254. | 248. | 79. | 47. | 47. | 73. | 140. | 140. |

Table 8 (continued)

$Q_{80}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 97.2 | 97.2 | 97.2 | 97.2 | 280.6 | 285.5 | 80.4 | 42.8 | 40.7 | 53.8 | 97.2 | 97.2 |
| CUTTHROAT TROUT | 115.6 | 115.6 | 115.6 | 115.6 | 239.5 | 249.4 | 90.3 | 42.8 | 40.7 | 62.4 | 115.6 | 115.6 |
| MOUNTAIN WHITEFISH | 149.1 | 117.3 | 140.9 | 110.2 | 103.7 | 98.7 | 60.7 | 42.8 | 49.5 | 95.5 | 146.8 | 148.9 |
| MINIMUM INSTREAM FLOW | 115. | 109. | 113. | 107. | 229. | 232. | 80. | 43. | 42. | 66. | 114. | 115. |

$Q_{70}$

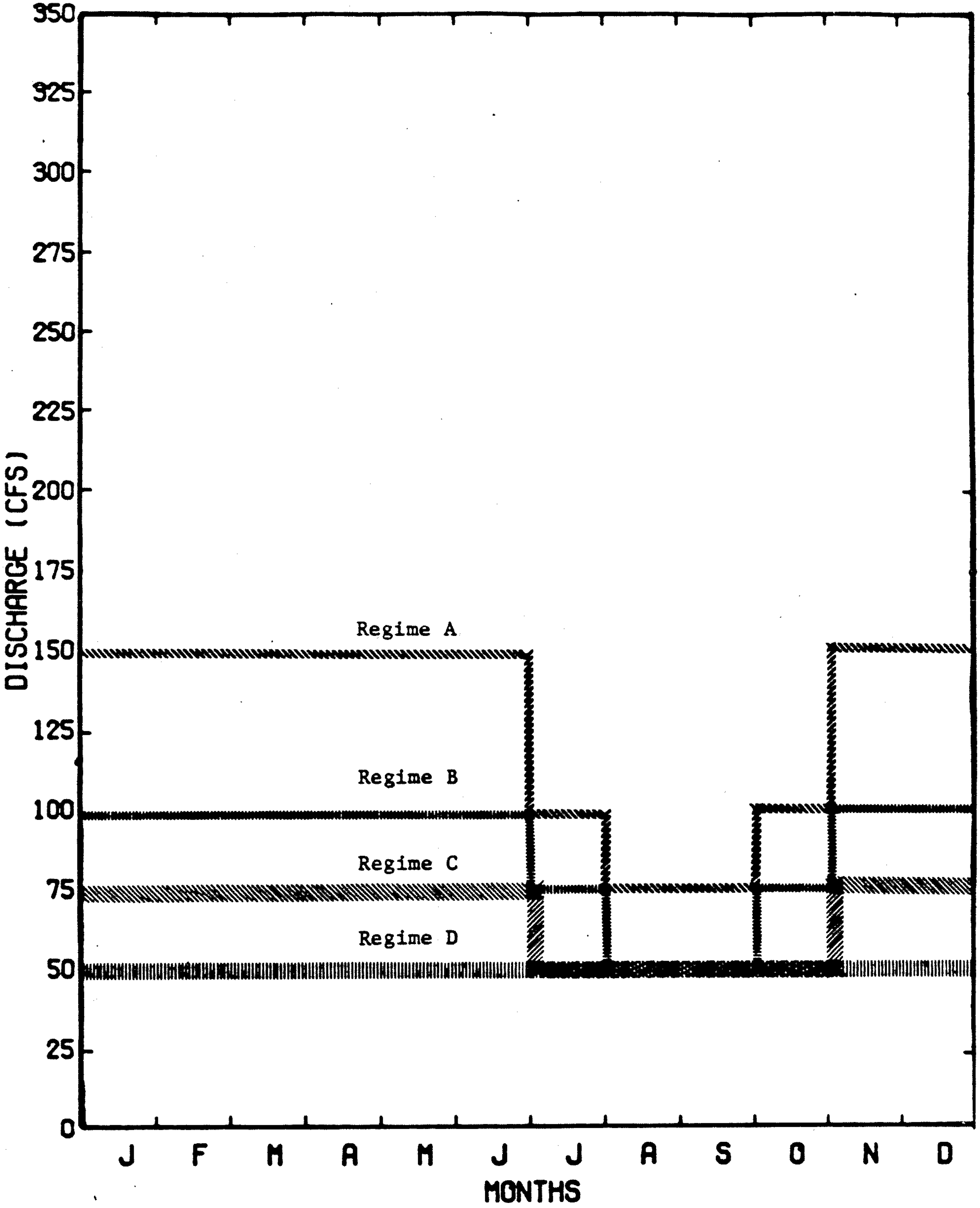
| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 79.4 | 79.4 | 79.4 | 79.4 | 259.7 | 274.6 | 61.3 | 42.3 | 39.9 | 49.5 | 79.4 | 79.4 |
| CUTTHROAT TROUT | 97.2 | 97.2 | 97.2 | 97.2 | 222.4 | 232.9 | 88.6 | 42.8 | 40.7 | 57.8 | 97.2 | 97.2 |
| MOUNTAIN WHITEFISH | 114.4 | 105.8 | 114.4 | 86.0 | 81.5 | 70.3 | 54.7 | 42.8 | 49.5 | 89.5 | 121.5 | 121.8 |
| MINIMUM INSTREAM FLOW | 94. | 92. | 94. | 88. | 209. | 217. | 71. | 43. | 42. | 61. | 95. | 95. |

$Q_{60}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 65.0 | 65.0 | 65.0 | 65.0 | 240.8 | 255.7 | 58.2 | 39.8 | 37.2 | 43.4 | 65.0 | 65.0 |
| CUTTHROAT TROUT | 81.0 | 81.0 | 81.0 | 81.0 | 207.7 | 218.9 | 85.3 | 42.8 | 40.7 | 52.1 | 81.0 | 81.0 |
| MOUNTAIN WHITEFISH | 81.0 | 81.0 | 81.0 | 62.6 | 60.2 | 52.5 | 48.4 | 37.1 | 42.1 | 83.2 | 96.8 | 95.6 |
| MINIMUM INSTREAM FLOW | 75. | 75. | 75. | 71. | 191. | 200. | 67. | 40. | 40. | 55. | 78. | 78. |

$Q_{50}$

| | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | 52.6 | 52.6 | 52.6 | 52.6 | 222.6 | 237.5 | 55.5 | 35.3 | 35.0 | 37.0 | 52.6 | 52.6 |
| CUTTHROAT TROUT | 66.6 | 66.6 | 66.6 | 66.6 | 195.4 | 206.9 | 82.3 | 42.3 | 39.9 | 44.5 | 66.6 | 66.6 |
| MOUNTAIN WHITEFISH | 55.4 | 55.4 | 55.4 | 44.7 | 43.7 | 39.9 | 38.9 | 32.9 | 36.9 | 72.9 | 75.1 | 73.0 |
| MINIMUM INSTREAM FLOW | 59. | 59. | 59. | 57. | 176. | 186. | 63. | 38. | 37. | 47. | 63. | 62. |



350
325
300
275
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225
200
175
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125
100
75
50
25
0
DISCHARGE (CFS)
Regime A
Regime B
Regime C
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MONTHS

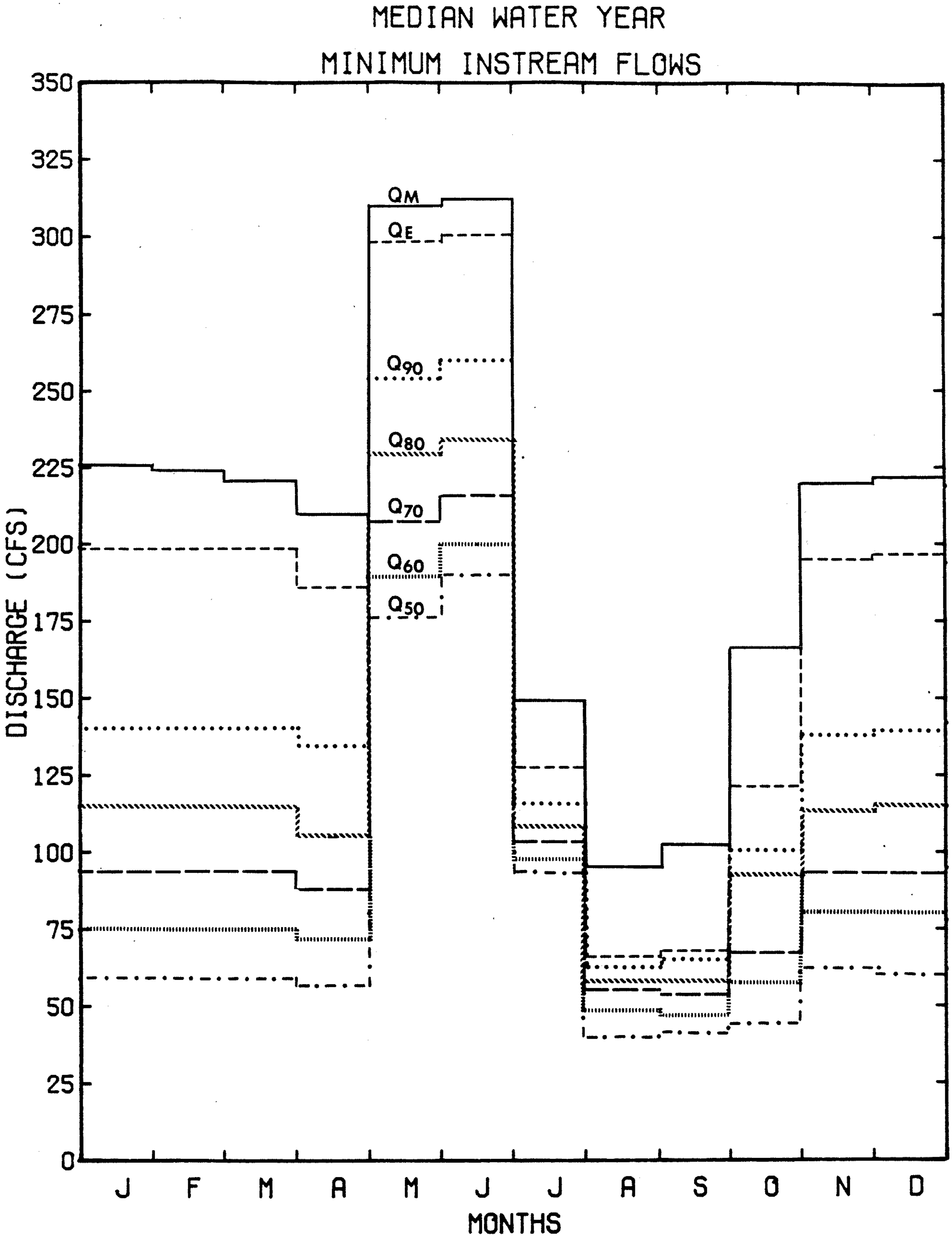
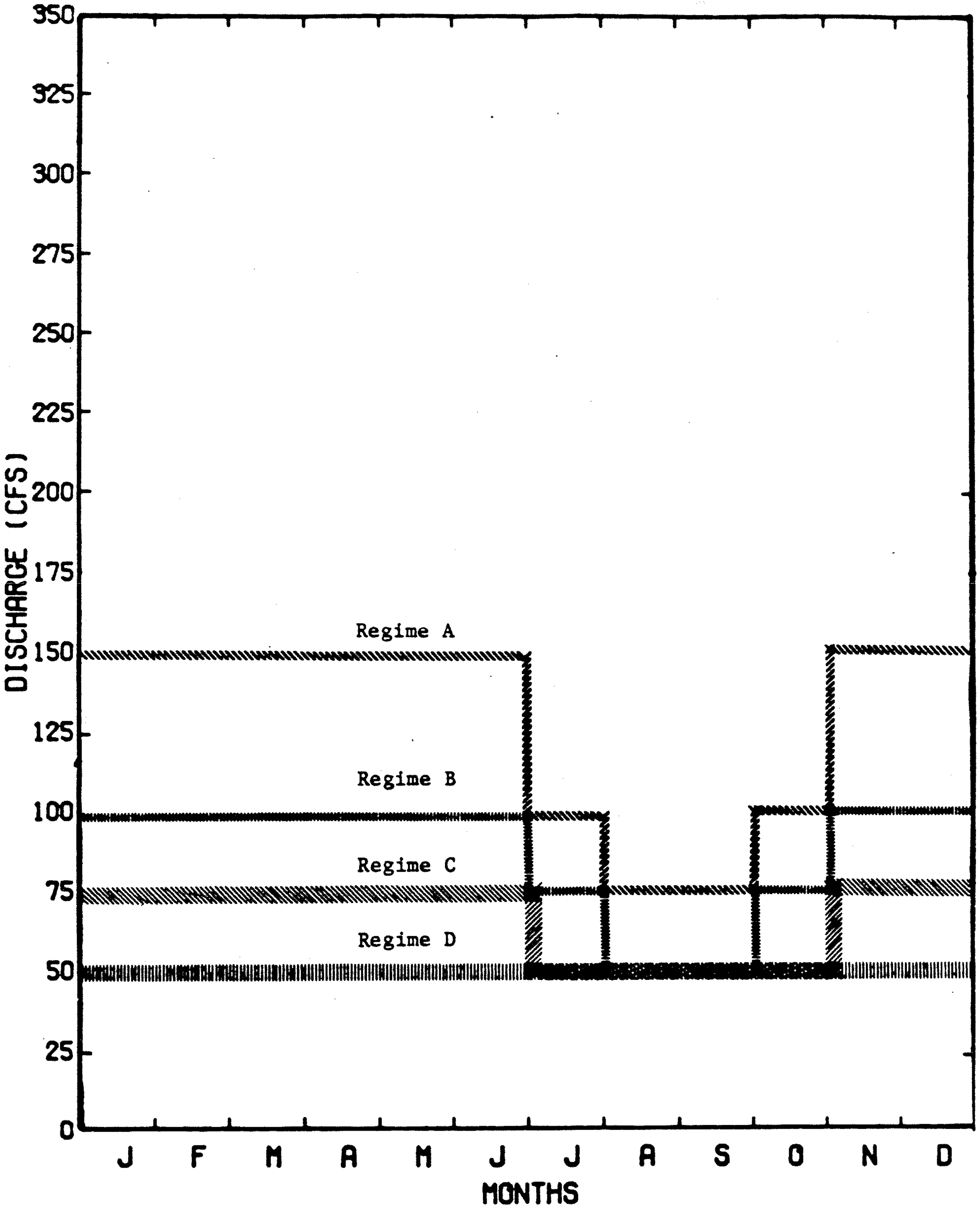


Figure 9. Alternative minimum instream flow curves for the South Fork Snoqualmie River during a normal water year based on $Q_M$, $Q_E$, and $Q_{90}$ through $Q_{50}$ streamflow requirements. Overlay: Potential post-project flow regimes identified for the diversion reach.


DISCHARGE (CFS)
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325
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275
250
225
200
175
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125
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75
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Regime A
Regime B
Regime C
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S
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MONTHS

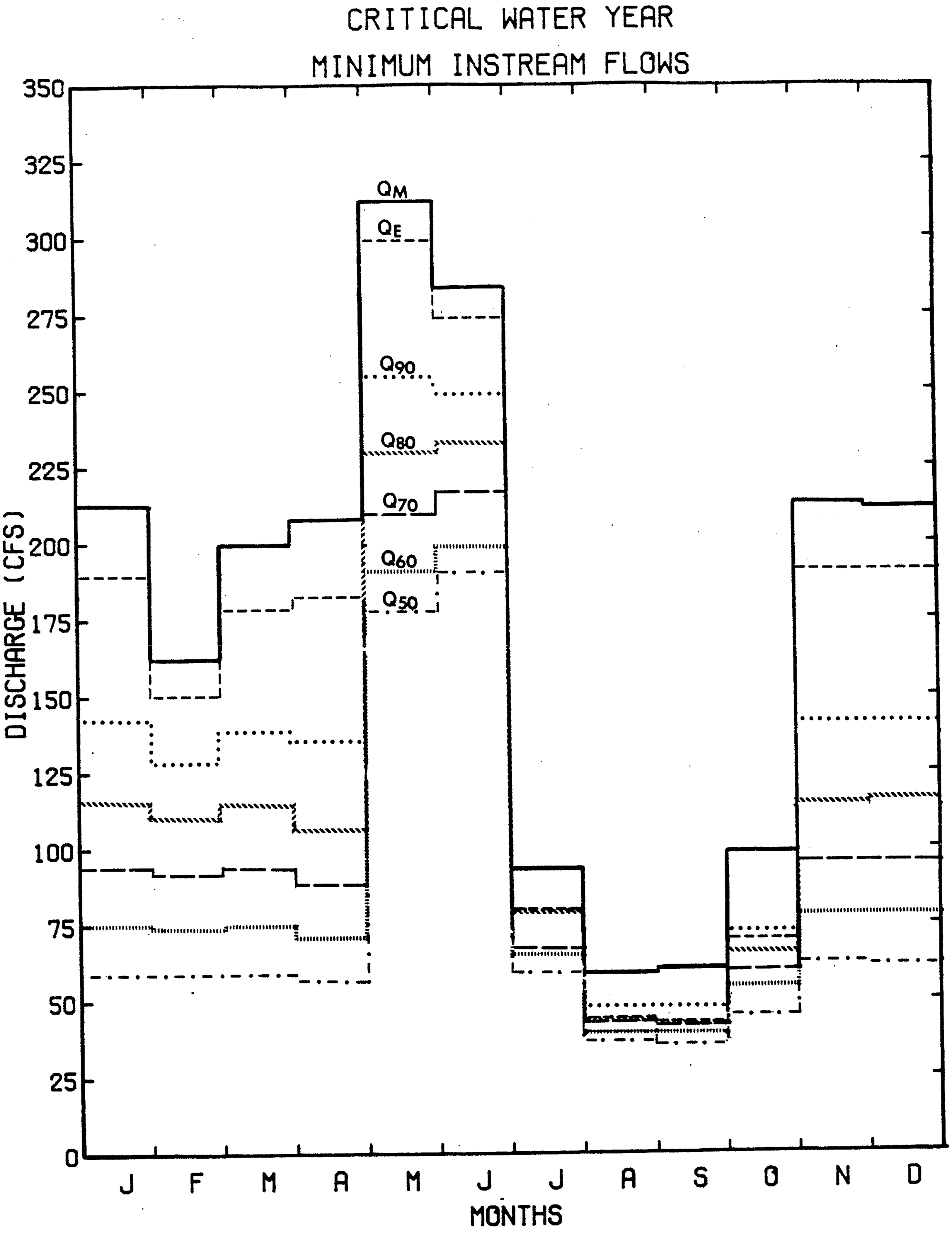

Figure 10. Alternative minimum instream flow curves for the South Fork Snoqualmie River during a critical water year based on $Q_M$, $Q_E$, and $Q_{90}$ through $Q_{50}$ streamflow requirements. Overlay: Potential post-project flow regimes identified for the diversion reach.

transparencies designed to overlay on Figures 9 and 10 in order to facilitate comparison with the various minimum instream flow curves derived from the IFIM analysis.

The validity of the method used in this study to generate alternative instream flow curves from the application of the IFIM is discussed in Stober et al. (1982). The overall method takes into account 1) biological information in the form of habitat suitability criteria, timing of occurrence, and relative abundance estimates for the salmonid species/life stages known to inhabit the South Fork Snoqualmie River; 2) hydraulic information consisting of field measurements of depth and velocity distributions within several study reaches, and the application of these data to predict physical habitat indices for a range of simulated discharges; and 3) hydrologic information characterizing the variability in streamflow which occurs naturally both within and between annual cycles.

## Post-project Effects

The objective of this portion of the study was to quantitatively describe the percent change in WUA for the various species/life stages which can be expected to result from the various post-project instream flow scenarios presented shown in the overlays for Figures 9 and 10. The WUA provided by discharges specified under Regimes A, B, C, and D were analyzed in relation to the habitat available under normal and critical water year monthly flows. A similar analysis was performed for $Q_M$-based minimum instream flows. Table 9 indicates the percentage change in WUA for each species/life stage using median monthly discharges as a basis for comparison. Table 10 summarizes the expected change in habitat availability with respect to critical monthly flows.

The primary benefit of the foregoing analysis is to identify periods of salmonid life history which are susceptible to reduction of instream habitat caused either by drought conditions or by water diversion.

Table 9. Percentage change in WUA for different life stages of salmonids when comparing post-project flow Regimes A-D with median monthly discharges. $Q_M$-based minimum instream flows for a normal water year are also compared.

| SPECIES | LIFE STAGE | MONTH | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
| RAINBOW TROUT | FRY | | | | | | | 24.5 | -1.9 | -1.9 | 20.5 | | |
| | JUVENILES | 55.2 | 24.7 | 17.4 | 41.1 | 75.3 | 67.8 | -1.4 | -12.8 | -14.0 | -2.6 | 31.5 | 44.8 |
| | ADULTS | 46.6 | .7 | -10.9 | 24.9 | 106.2 | 68.5 | -31.4 | -21.5 | -25.2 | -30.3 | 12.0 | 28.7 |
| | SPAWNING | | | | | -89.8 | -91.6 | -2.0 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | 37.7 | .3 | 1.9 | 32.1 | | |
| | JUVENILES | 63.7 | 17.2 | 8.4 | 37.3 | 103.0 | 94.7 | -18.4 | -26.7 | -29.7 | -19.2 | 26.5 | 41.5 |
| | ADULTS | 14.9 | -20.5 | -26.3 | -3.3 | 67.3 | 39.4 | -36.2 | -24.1 | -29.0 | -36.2 | -14.4 | 1.1 |
| | SPAWNING | | | | | -100.0 | -100.0 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 31.4 | 33.9 | 41.2 | 86.0 | 21.7 | 30.4 | | | |
| | JUVENILES | 45.6 | 9.3 | 3.5 | 24.5 | 71.4 | 62.2 | -11.6 | -15.5 | -18.6 | -11.5 | 15.3 | 28.2 |
| | ADULTS | -25.0 | -35.8 | -32.3 | -31.6 | -2.8 | -9.2 | -34.4 | -18.1 | -21.2 | -32.6 | -33.3 | -31.0 |
| | SPAWNING | | | | | | | | | | -39.0 | 16.6 | 24.3 |
| MONTHLY DISCHARGE: | | | | | | | | | | | | | |
| MEDIAN | | 550. | 375. | 320. | 470. | 750. | 638. | 239. | 104. | 113. | 227. | 423. | 485. |
| REGIME A | | 150. | 150. | 150. | 150. | 150. | 150. | 100. | 75. | 75. | 100. | 150. | 150. |

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY | | | | | | | 22.2 | -8.7 | -8.8 | 18.4 | | |
| | JUVENILES | 46.1 | 17.4 | 10.5 | 32.9 | 65.0 | 57.9 | -13.5 | -36.7 | -37.5 | -14.7 | 23.8 | 36.3 |
| | ADULTS | 16.4 | -20.1 | -29.2 | -.8 | 63.8 | 33.8 | -44.7 | -42.2 | -44.9 | -43.8 | -11.0 | 2.2 |
| | SPAWNING | | | | | -88.0 | -90.1 | 21.2 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | 37.5 | -5.4 | -3.8 | 32.0 | | |
| | JUVENILES | 36.9 | -2.0 | -9.4 | 14.9 | 69.8 | 62.9 | -38.9 | -44.0 | -46.2 | -39.5 | 5.8 | 16.4 |
| | ADULTS | 5.6 | -27.0 | -32.3 | -11.1 | 53.7 | 29.1 | -50.3 | -43.4 | -47.1 | -50.4 | -21.4 | -7.0 |
| | SPAWNING | | | | | -100.0 | -100.0 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 80.8 | 84.3 | 94.3 | 120.3 | 58.0 | 69.3 | | | |
| | JUVENILES | 28.0 | -3.9 | -9.0 | 9.5 | 50.7 | 47.6 | -24.0 | -28.6 | -31.2 | -24.0 | 1.4 | 12.7 |
| | ADULTS | -37.9 | -46.9 | -43.9 | -43.3 | -19.5 | -24.8 | -45.2 | -38.0 | -40.3 | -43.8 | -44.8 | -42.9 |
| | SPAWNING | | | | | | | | | | -55.8 | 16.6 | 24.3 |
| MONTHLY DISCHARGE: | | | | | | | | | | | | | |
| MEDIAN | | 550. | 375. | 320. | 470. | 750. | 638. | 239. | 104. | 113. | 227. | 423. | 485. |
| REGIME B | | 100. | 100. | 100. | 100. | 100. | 100. | 75. | 50. | 50. | 75. | 100. | 100. |

Table 9 (continued)

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY | | | | | | | 13.7 | -8.7 | -8.8 | 10.1 | | |
| | JUVENILES | 28.3 | 3.0 | -3.0 | 16.6 | 44.0 | 38.7 | -37.1 | -36.7 | -37.5 | -38.0 | 8.7 | 19.7 |
| | ADULTS | -6.0 | -35.5 | -42.9 | -20.0 | 32.2 | 8.0 | -59.2 | -42.2 | -44.9 | -58.6 | -28.2 | -17.5 |
| | SPAWNING | | | | | -85.2 | -97.8 | -.5 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | 29.7 | -5.4 | -3.8 | 24.5 | | |
| | JUVENILES | 2.6 | -26.6 | -32.1 | -14.0 | 27.2 | 22.0 | -53.3 | -44.0 | -46.2 | -53.7 | -20.7 | -11.3 |
| | ADULTS | -17.8 | -43.1 | -47.3 | -30.8 | 19.7 | -.3 | -63.0 | -43.4 | -47.1 | -63.0 | -38.8 | -27.6 |
| | SPAWNING | | | | | -100.0 | -100.0 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 114.0 | 118.2 | 130.1 | 186.0 | 58.0 | 69.3 | | | |
| | JUVENILES | 10.0 | -17.4 | -21.8 | -6.0 | 29.4 | 22.5 | -35.8 | -28.6 | -31.2 | -35.7 | -12.9 | -3.2 |
| | ADULTS | -48.2 | -55.7 | -53.2 | -52.7 | -32.8 | -37.2 | -58.5 | -38.0 | -40.3 | -57.4 | -53.9 | -52.3 |
| | SPAWNING | | | | | | | | | | -69.2 | -15.5 | -9.9 |
| MONTHLY DISCHARGE: | | | | | | | | | | | | | |
| MEDIAN | | 550. | 375. | 320. | 470. | 750. | 638. | 239. | 104. | 113. | 227. | 423. | 485. |
| REGIME C | | 75. | 75. | 75. | 75. | 75. | 75. | 50. | 50. | 50. | 50. | 75. | 75. |

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY | | | | | | | 13.7 | -8.7 | -8.8 | 10.1 | | |
| | JUVENILES | -6.8 | -25.1 | -29.5 | -15.3 | 5.3 | .7 | -37.1 | -36.7 | -37.5 | -38.0 | -21.0 | -13.1 |
| | ADULTS | -30.8 | -52.5 | -57.9 | -41.1 | -2.7 | -20.5 | -59.2 | -42.2 | -44.9 | -58.6 | -47.1 | -39.3 |
| | SPAWNING | | | | | -87.9 | -90.0 | -.5 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | 29.7 | -5.4 | -3.8 | 24.5 | | |
| | JUVENILES | -21.6 | -43.9 | -48.1 | -34.2 | -2.8 | -6.7 | -53.3 | -44.0 | -46.2 | -53.7 | -39.4 | -32.2 |
| | ADULTS | -38.7 | -57.6 | -60.7 | -48.4 | -10.7 | -25.6 | -63.0 | -43.4 | -47.1 | -63.0 | -54.3 | -46.0 |
| | SPAWNING | | | | | -100.0 | -100.0 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 177.9 | 183.4 | 198.7 | 186.0 | 58.0 | 69.3 | | | |
| | JUVENILES | -7.1 | -30.2 | -33.9 | -20.5 | 9.4 | 3.5 | -35.8 | -28.6 | -31.2 | -35.7 | -26.4 | -18.2 |
| | ADULTS | -60.7 | -66.4 | -64.5 | -64.2 | -49.1 | -52.5 | -58.5 | -38.0 | -40.3 | -57.4 | -65.1 | -63.9 |
| | SPAWNING | | | | | | | | | | -69.2 | -41.1 | -37.1 |
| MONTHLY DISCHARGE: | | | | | | | | | | | | | |
| MEDIAN | | 550. | 375. | 320. | 470. | 750. | 638. | 239. | 104. | 113. | 227. | 423. | 485. |
| REGIME D | | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. |

Table 9 (continued)

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY | | | | | | | 19.7 | .8 | -.1 | 11.2 | | |
| | JUVENILES | 50.5 | 21.1 | 14.6 | 39.7 | 51.0 | 44.1 | 4.8 | -2.7 | -1.5 | 3.6 | 28.5 | 41.1 |
| | ADULTS | 66.9 | 14.5 | .9 | 39.8 | 133.9 | 90.4 | -13.9 | -7.3 | -5.3 | -8.3 | 26.7 | 45.9 |
| | SPAWNING | | | | | -27.1 | -38.3 | -15.4 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | 23.0 | 1.7 | 1.8 | 13.6 | | |
| | JUVENILES | 69.5 | 21.4 | 12.7 | 43.3 | 89.4 | 81.1 | -2.6 | -6.5 | -4.6 | .2 | 31.6 | 47.0 |
| | ADULTS | 65.5 | 14.4 | 5.8 | 37.9 | 128.7 | 90.2 | -14.6 | -5.6 | -7.2 | -9.2 | 22.8 | 45.3 |
| | SPAWNING | | | | | 1039.2 | 413.6 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 3.1 | 1.8 | 7.6 | 35.7 | 7.1 | 7.9 | | | |
| | JUVENILES | 44.6 | 8.6 | 2.8 | 23.8 | 66.8 | 57.5 | .5 | -4.4 | -4.0 | 1.6 | 14.5 | 27.2 |
| | ADULTS | -8.0 | -21.5 | -17.9 | -18.8 | 41.6 | 32.8 | -21.0 | -4.7 | -4.2 | -14.4 | -19.4 | -16.2 |
| | SPAWNING | | | | | | | | | | 5.7 | 98.8 | 109.9 |
| MONTHLY DISCHARGE: | | | | | | | | | | | | | |
| MEDIAN | | 550. | 375. | 320. | 470. | 750. | 638. | 239. | 104. | 113. | 227. | 423. | 485. |
| QM-NORMAL | | 226. | 225. | 221. | 212. | 312. | 314. | 149. | 94. | 103. | 167. | 220. | 222. |

Table 10. Percentage change in WUA for different life stages of salmonids when comparing post-project flow Regimes A-D with 90 percentile monthly discharges. $Q_M$-based minimum instream flows for a critical water year are also compared.

| SPECIES | LIFE STAGE | MONTH |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
| RAINBOW TROUT | FRY |  |  |  |  |  |  | -.2 | 4.2 | 3.2 | 0 |  |  |
|  | JUVENILES | 5.7 | .1 | 1.5 | 13.0 | 49.7 | 23.6 | -1.9 | 13.3 | 12.1 | 0 | 7.5 | 5.9 |
|  | ADULTS | -15.2 | -2.6 | -11.0 | -13.8 | 36.0 | -1.9 | -6.8 | 13.7 | 12.2 | 0 | -15.4 | -15.2 |
|  | SPAWNING |  |  |  |  | -92.9 | -90.9 | -1.4 |  |  |  |  |  |
| CUTTHROAT TROUT | FRY |  |  |  |  |  |  | 1.8 | 4.5 | 3.5 | 0 |  |  |
|  | JUVENILES | -.5 | -2.2 | -4.1 | 4.1 | 48.9 | 15.2 | -5.7 | 15.7 | 14.2 | 0 | .8 | -.2 |
|  | ADULTS | -30.1 | -22.0 | -30.1 | -27.4 | 8.6 | -22.1 | -8.2 | 14.8 | 13.6 | 0 | -29.2 | -30.0 |
|  | SPAWNING |  |  |  |  | -100.0 | -100.0 | -100.0 |  |  |  |  |  |
| MOUNTAIN WHITEFISH | FRY |  |  |  | 33.6 | 32.4 | 25.1 | 9.2 | -10.9 | -9.9 |  |  |  |
|  | JUVENILES | .2 | -.7 | .7 | 1.3 | 35.7 | 7.9 | -4.8 | 8.2 | 7.5 | 0 | .3 | .2 |
|  | ADULTS | -23.6 | -3.0 | -16.3 | -29.2 | -28.6 | -35.4 | -5.2 | 14.2 | 12.9 | 0 | -25.9 | -24.1 |
|  | SPAWNING |  |  |  |  |  |  |  |  |  | 0 | -22.9 | -26.5 |
| MONTHLY DISCHARGE: |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CRITICAL |  | 257. | 160. | 215. | 295. | 512. | 362. | 112. | 63. | 64. | 100. | 271. | 260. |
| REGIME A |  | 150. | 150. | 150. | 150. | 150. | 150. | 100. | 75. | 75. | 100. | 150. | 150. |

|  |  | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY |  |  |  |  |  |  | -2.0 | -3.1 | -4.0 | -1.8 |  |  |
|  | JUVENILES | -.5 | -5.8 | -4.5 | 6.4 | 40.9 | 16.4 | -13.8 | -17.7 | -18.6 | -12.2 | 1.2 | -.3 |
|  | ADULTS | -32.6 | -22.7 | -29.3 | -31.5 | 8.0 | -22.1 | -24.7 | -16.3 | -17.4 | -19.3 | -32.8 | -32.7 |
|  | SPAWNING |  |  |  |  | -91.7 | -89.3 | 21.9 |  |  |  |  |  |
| CUTTHROAT TROUT | FRY |  |  |  |  |  |  | 1.6 | -1.5 | -2.4 | -.1 |  |  |
|  | JUVENILES | -16.8 | -18.2 | -19.8 | -12.9 | 24.5 | -3.7 | -29.4 | -11.6 | -12.7 | -25.1 | -15.7 | -16.5 |
|  | ADULTS | -35.8 | -28.3 | -35.7 | -33.3 | -.2 | -28.4 | -28.5 | -14.4 | -15.2 | -22.2 | -34.9 | -35.6 |
|  | SPAWNING |  |  |  |  | -100.0 | -100.0 | -100.0 |  |  |  |  |  |
| MOUNTAIN WHITEFISH | FRY |  |  |  | 83.9 | 82.1 | 72.2 | 29.3 | 15.7 | 17.0 |  |  |  |
|  | JUVENILES | -11.9 | -12.7 | -11.5 | -11.0 | 19.3 | -5.1 | -18.3 | -8.6 | -9.2 | -14.1 | -11.9 | -11.9 |
|  | ADULTS | -36.8 | -19.7 | -30.7 | -41.4 | -40.9 | -46.5 | -20.9 | -13.5 | -14.5 | -16.5 | -38.6 | -37.2 |
|  | SPAWNING |  |  |  |  |  |  |  |  |  | -27.5 | -22.9 | -26.5 |
| MONTHLY DISCHARGE: |  |  |  |  |  |  |  |  |  |  |  |  |  |
| CRITICAL |  | 257. | 160. | 215. | 295. | 512. | 362. | 112. | 63. | 64. | 100. | 271. | 260. |
| REGIME B |  | 100. | 100. | 100. | 100. | 100. | 100. | 75. | 50. | 50. | 75. | 100. | 100. |

Table 10 (continued)

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY | | | | | | | -8.8 | -3.1 | -4.0 | -8.7 | | |
| | JUVENILES | -12.6 | -17.3 | -16.2 | -6.6 | 23.7 | 2.2 | -37.4 | -17.7 | -18.6 | -36.2 | -11.2 | -12.5 |
| | ADULTS | -45.6 | -37.6 | -43.0 | -44.8 | -12.8 | -37.1 | -44.6 | -16.3 | -17.4 | -40.6 | -45.8 | -45.7 |
| | SPAWNING | | | | | -89.7 | -86.7 | 0 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | -4.1 | -1.5 | -2.4 | -5.8 | | |
| | JUVENILES | -37.7 | -38.8 | -39.9 | -34.8 | -6.7 | -27.8 | -46.0 | -11.6 | -12.7 | -42.7 | -36.8 | -37.5 |
| | ADULTS | -50.0 | -44.2 | -50.0 | -48.1 | -22.3 | -44.2 | -46.7 | -14.4 | -15.2 | -41.9 | -49.3 | -49.9 |
| | SPAWNING | | | | | -100.0 | -100.0 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 117.7 | 115.6 | 103.9 | 67.8 | 15.7 | 17.0 | | | |
| | JUVENILES | -24.3 | -25.0 | -24.0 | -23.5 | 2.5 | -18.5 | -30.9 | -8.6 | -9.2 | -27.4 | -24.3 | -24.3 |
| | ADULTS | -47.2 | -33.0 | -42.2 | -51.1 | -50.6 | -55.4 | -40.1 | -13.5 | -14.5 | -36.8 | -48.8 | -47.6 |
| | SPAWNING | | | | | | | | | | -49.4 | -44.1 | -46.7 |
| MONTHLY DISCHARGE: CRITICAL | | 257. | 160. | 215. | 295. | 512. | 362. | 112. | 63. | 64. | 100. | 271. | 260. |
| REGIME C | | 75. | 75. | 75. | 75. | 75. | 75. | 50. | 50. | 50. | 50. | 75. | 75. |

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY | | | | | | | -8.8 | -3.1 | -4.0 | -8.7 | | |
| | JUVENILES | -36.5 | -39.9 | -39.1 | -32.2 | -10.1 | -25.8 | -37.4 | -17.7 | -18.6 | -36.2 | -35.5 | -36.4 |
| | ADULTS | -60.0 | -54.0 | -58.0 | -59.3 | -35.8 | -53.7 | -44.6 | -16.3 | -17.4 | -40.6 | -60.1 | -60.0 |
| | SPAWNING | | | | | -91.6 | -89.1 | 0 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | -4.1 | -1.5 | -2.4 | -5.8 | | |
| | JUVENILES | -52.4 | -53.2 | -54.1 | -50.1 | -28.7 | -44.8 | -46.0 | -11.6 | -12.7 | -42.7 | -51.7 | -52.2 |
| | ADULTS | -62.7 | -58.4 | -62.7 | -61.3 | -42.0 | -58.4 | -46.7 | -14.4 | -15.2 | -41.9 | -62.2 | -62.6 |
| | SPAWNING | | | | | -100.0 | -100.0 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 182.6 | 180.0 | 164.7 | 67.8 | 15.7 | 17.0 | | | |
| | JUVENILES | -36.0 | -36.6 | -35.8 | -35.4 | -13.4 | -31.2 | -30.9 | -8.6 | -9.2 | -27.4 | -36.0 | -36.1 |
| | ADULTS | -60.0 | -49.2 | -56.2 | -63.0 | -62.6 | -66.2 | -40.1 | -13.5 | -14.5 | -36.8 | -61.2 | -60.3 |
| | SPAWNING | | | | | | | | | | -49.4 | -61.0 | -62.9 |
| MONTHLY DISCHARGE: CRITICAL | | 257. | 160. | 215. | 295. | 512. | 362. | 112. | 63. | 64. | 100. | 271. | 260. |
| REGIME D | | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. | 50. |

Table 10 (continued)

| | | JAN | FEB | MAR | APR | MAY | JUN | JUL | AUG | SEP | OCT | NOV | DEC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| RAINBOW TROUT | FRY | | | | | | | .5 | -2.1 | -1.8 | .0 | | |
| | JUVENILES | 4.5 | 0 | 2.0 | 12.6 | 28.9 | 11.7 | -4.0 | -4.0 | -2.5 | -.3 | 5.9 | 4.7 |
| | ADULTS | -4.9 | 0 | -2.0 | -4.1 | 54.3 | 15.3 | -11.9 | -3.8 | -2.6 | -1.5 | -5.0 | -5.0 |
| | SPAWNING | | | | | -49.4 | -54.4 | -2.1 | | | | | |
| CUTTHROAT TROUT | FRY | | | | | | | 2.9 | -1.0 | -1.6 | .2 | | |
| | JUVENILES | 3.8 | 0 | .4 | 8.8 | 38.9 | 12.6 | -10.7 | -3.5 | -2.6 | -1.2 | 5.1 | 4.1 |
| | ADULTS | -.2 | 0 | -1.9 | 2.8 | 48.5 | 8.2 | -11.6 | -2.9 | -2.0 | -1.0 | 1.3 | -.0 |
| | SPAWNING | | | | | 138.0 | -33.7 | -100.0 | | | | | |
| MOUNTAIN WHITEFISH | FRY | | | | 6.4 | .6 | -7.1 | 14.5 | 2.8 | 2.3 | | | |
| | JUVENILES | -.4 | 0 | .5 | .9 | 32.0 | 7.4 | -8.0 | -1.9 | -1.4 | -.9 | -.4 | -.4 |
| | ADULTS | -9.2 | 0 | -3.7 | -17.1 | 4.0 | -10.7 | -8.5 | -3.4 | -2.2 | -1.0 | -11.4 | -9.8 |
| | SPAWNING | | | | | | | | | | -2.0 | 34.6 | 29.6 |
| MONTHLY DISCHARGE: | | | | | | | | | | | | | |
| | CRITICAL | 257. | 160. | 215. | 295. | 512. | 362. | 112. | 63. | 64. | 100. | 271. | 260. |
| | QM-CRITICAL | 213. | 160. | 200. | 207. | 312. | 284. | 93. | 60. | 62. | 98. | 215. | 213. |

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# APPENDIX A

Appendix Table A1. Original input data for IFG-4 model; provided by Independent Ecological Services (1982).

```
SOUTH FORK SNOQUALMIE INSTREAM FLOW ANALYSIS - ORIGINAL DATA
THREE FLOWS:  7/3/82  7/24/82  8/28/82
IOC          1111000201001
XSEC         0        0.  .00        94.30
             0   0.0 99.4  5.0 98.8 10.0 98.4 13.0 98.8 15.5 97.9 30.0 97.1
             0 34.0 96.8 40.0 95.7 47.0 96.4 55.0 97.6 59.0 94.3 64.0 95.6
             0 67.5 98.5 70.0 95.6 76.0 95.3 81.5 96.1 87.5 97.3 91.0 96.7
             0 94.5 97.0 97.0 97.6104.0 95.5109.0 96.4113.0 96.7116.0 97.7
             0117.5 96.1121.0 95.9124.0 96.3127.0 96.5128.0 97.6133.0 96.3
             0135.5 96.6138.0 98.8139.0 97.9140.0 97.9
NS           0         0.0         4.0         6.0         6.0         6.0         7.0
NS           0         7.0         7.0         8.0         8.0         8.0         8.0
NS           0         8.0         8.0         7.0         7.0         8.0         8.0
NS           0         8.0         6.0         8.0         8.0         8.0         8.0
NS           0         5.0         8.0         7.0         8.0         8.0         8.0
NS           0         6.0         8.0         5.0         5.0
CAL1         0      97.93        376.
VEL1         0 0.00 0.00 0.00 0.00 0.00 0.80 1.80 1.00 1.50 3.50 2.90 2.70
VEL1         0 0.00 3.70 2.70 2.20 1.30 1.70 1.30 1.50 1.40 1.30 1.10 3.40
VEL1         0 0.80 2.60 0.30 2.10 1.70 1.90 0.30 0.00 0.00 0.00
CAL2         0      97.27        213.
VEL2         0 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.80 2.40 0.00 2.40 1.60
VEL2         0 0.00 0.20 1.80 1.50 0.00 1.90 0.80 0.00 0.80 1.20 1.90 0.00
VEL2         0 0.70 2.20 0.50 1.60 0.00 2.60 0.50 0.00 0.00 0.00
CAL3         0      96.88         47.
VEL3         0 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.10 1.90 0.40 1.10 0.00
VEL3         0 0.00 0.00 1.10 0.80 0.00 0.00 0.00 0.00 0.20 1.20 0.30 0.00
VEL3         0 0.50 0.40 0.00 0.00 0.00 0.20 0.20 0.00 0.00 0.00
XSEC         1        84.  .65       96.40
             1   0.0103.6  3.0103.5  7.0102.3  9.6100.4 13.0100.2 15.0100.2
             1 18.0 99.3 21.0 98.9 24.0 98.6 28.0 97.6 33.0 97.4 37.0100.2
             1 40.0100.6 42.0 98.6 46.0 96.1 51.0 98.4 54.0 98.0 60.0 98.4
             1 62.5 97.3 64.0 97.2 66.0 97.0 72.0 97.2 77.0 97.0 84.0 97.4
             1 87.0100.0 90.0101.6 94.0 99.6 97.0100.3100.0 98.0104.0 97.1
             1107.5 96.4111.0 99.5113.0 98.1120.0 97.6125.0 97.8129.0 99.6
             1135.0 99.0138.6100.4141.1102.2
NS           1         8.0         7.0         8.0         8.0         8.0         8.0
NS           1         8.0         8.0         8.0         6.0         8.0         8.0
NS           1         8.0         8.0         8.0         8.0         8.0         8.0
NS           1         8.0         8.0         8.0         8.0         8.0         8.0
NS           1         8.0         8.0         8.0         9.0         8.0         8.0
NS           1         8.0         6.0         8.0         8.0         7.0         7.0
NS           1         8.0         8.0         9.0
CAL1         1     100.35        467.
VEL1         1 0.00 0.00 0.00 0.00 0.40 0.00 0.00 0.30 2.40 3.00 4.30 0.00
VEL1         1 0.00 3.20 0.30 0.20 3.50 4.80 1.00 0.40 3.00 1.70 1.80 2.00
VEL1         1 4.20 0.00 1.00 0.00 0.10 1.10 2.00 2.70 3.30 1.00 2.50 1.10
VEL2         1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 1.20 0.60 4.90 3.30 0.00
VEL2         1 0.00 4.40 0.00 2.20 3.90 2.40 0.00 1.00 2.80 0.00 2.10 2.40
VEL2         1 4.80 0.00 0.00 0.00 0.40 0.30 0.60 0.00 1.00 0.00 0.70 0.70
VEL2         1 0.00 0.00 0.00
CAL3         1      96.56        102.
VEL3         1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 6.00 1.10 0.00
VEL3         1 0.00 0.00 3.10 0.70 5.00 0.20 0.00 1.00 1.00 0.20 2.00 1.80
VEL3         1 0.00 0.00 0.00 0.00 0.90 0.00 0.00 0.00 1.00 0.60 0.00 0.00
VEL3         1 0.00 0.00 0.00
XSEC         2       244.  .50        99.4
             2   0.0105.6  2.0105.8  6.5103.4 13.0102.8 14.5104.9 17.2103.3
             2 21.0103.4 22.3104.2 25.0102.0 26.5102.0 27.4102.9 29.0101.7
             2 32.0102.4 36.0101.4 39.0102.7 49.5100.6 59.0 99.4 65.0 99.5
             2 71.5101.6 77.0103.0 80.0103.0 83.0103.5 89.0103.8 92.0103.9
             2 94.0105.0 96.5104.1101.0105.9104.5107.1
NS           2         9.0         9.0         8.0         8.0         8.0         8.0
NS           2         8.0         8.0         8.0         8.0         8.0         8.0
NS           2         8.0         8.0         8.0         8.0         7.0         8.0
NS           2         6.0         7.0         8.0         8.0         8.0         7.0
NS           2         7.0         7.0         8.0         8.0
CAL1         2     103.40        378.
VEL1         2 0.00 0.00 0.00 0.30 0.00 0.30 0.40 1.10 1.70 1.10 1.80 1.20
VEL1         2 2.10 1.40 1.50 2.80 3.00 1.80 2.00 1.50 0.30 1.50 0.40 1.10
VEL1         2 0.00 1.30 0.00 0.00
```

Appendix Table A1 (continued)

```
CAL2      2    103.83        200.
VEL2      2 0.00 0.00 0.00 0.10 0.00 0.10 0.50 0.00 1.00 0.90 1.00 1.20
VEL2      2 0.80 0.90 0.40 1.60 2.20 1.20 0.60 0.70 0.20 0.00 0.00 0.00
VEL2      2 0.00 0.00 0.00 0.00
CAL3      2    104.52        59.
VEL3      2 0.00 0.0 0.00 0.00 0.00 0.00 0.00 0.00 0.30 0.30 0.50 0.30
VEL3      2 0.40 1.10 0.20 0.10 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
VEL3      2 0.00 0.00 0.00 0.00
XSEC      3     174.  .35     102.7
          3  0.0110.9  5.0107.5  6.0106.3  8.0106.3 17.0103.5 29.0102.7
          3 31.0103.0 36.5103.5 41.0105.6 44.0104.4 46.0105.5 47.5104.8
          3 51.9104.7 54.6103.9 57.0104.6 61.0104.0 67.0105.0 71.0104.5
          3 74.0105.1 79.0106.3 81.0106.9 82.2107.8
NS        3       9.0       9.0       9.0       9.0       9.0       8.0
NS        3       8.0       7.0       7.0       7.0       8.0       8.0
NS        3       8.0       8.0       8.0       5.0       5.0       5.0
NS        3       8.0       8.0       8.0       8.0
CAL1      3    106.87        445.
VEL1      3 0.00 0.00 0.00 0.10 2.00 4.90 3.10 2.60 2.60 1.90 3.20 2.80
VEL1      3 1.10 1.80 2.20 1.10 1.20 0.70 0.50 0.00 0.00 0.00
CAL2      3    105.98        113.
VEL2      3 0.00 0.00 0.00 0.00 0.60 1.00 0.90 0.70 0.80 0.50 1.00 1.30
VEL2      3 0.30 3.10 2.80 1.10 1.00 1.00 0.30 0.00 0.00 0.00
CAL3      3    105.39        85.
VEL3      3 0.00 0.00 0.00 0.00 0.80 1.20 1.20 1.70 0.00 0.20 0.00 2.20
VEL3      3 0.10 1.50 0.80 0.50 0.10 0.60 0.00 0.00 0.00 0.00
XSEC      4     200.  .50     106.8
          4  0.0112.7  8.5112.5 11.0111.6 15.2110.6 16.5111.5 21.0110.8
          4 23.0110.4 26.0109.5 27.2110.5 29.2109.5 32.5110.2 36.0109.8
          4 38.7111.7 41.0111.2 45.0110.1 49.0109.0 53.0107.9 57.0107.9
          4 63.0107.7 66.0107.9 76.0107.3 81.5106.8 84.0107.1 87.7111.6
          4 89.2113.1 91.2114.5
NS        4       8.0       8.0       8.0       6.0       8.0       8.0
NS        4       8.0       8.0       8.0       6.0       8.0       8.0
NS        4       8.0       8.0       8.0       8.0       8.0       7.0
NS        4       6.0       5.0       8.0       9.0       9.0       9.0
NS        4       9.0       9.0
VEL1      4 0.20 1.50 0.80 2.30 2.00 2.90 2.60 2.80 2.10 1.80 1.50 0.00
VEL1      4 0.00 0.00
CAL2      4    110.67        89.
VEL2      4 0.00 0.00 0.00 0.00 0.00 0.00 0.30 0.10 0.00 0.10 0.10 0.10
VEL2      4 0.00 0.00 0.50 0.90 0.70 1.30 0.80 0.70 0.60 0.60 0.50 0.00
VEL2      4 0.00 0.00
CAL3      4    109.93        61.
VEL3      4 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
VEL3      4 0.00 0.00 0.00 1.00 0.80 0.90 0.80 0.90 0.70 0.50 0.30 0.00
VEL3      4 0.00 0.00
ENDJ
```

Appendix Table A2. Calibrated input data for IFG-4 model. Changes to original data are either underlined or indicated by a ⬋.

```
SOUTH FORK SNOQUALMIE INSTREAM FLOW ANALYSIS - CALIBRATED MODEL
THREE FLOWS:  7/3/82  7/24/82  8/28/82          CLEVE STEWARD
IOC            0000000201001
XSEC       1       82.   .25         96.4
           1  0.0103.6  3.0103.5  7.0102.3  9.6100.4 13.0100.2 15.0100.2
           1 18.0 99.3 21.0 98.9 24.0 98.6 28.0 97.6 33.0 97.4 37.0100.2
           1 40.0100.6 42.0 98.6 46.0 98.1 51.0 98.4 54.0 98.0 60.0 98.4
           1 62.5 97.3 64.0 97.2 66.0 97.0 72.0 97.2 77.0 97.0 84.0 97.4
           1 87.0100.0 90.0101.6 94.0 99.6 97.0100.3100.0 98.0104.0 97.1
           1107.5 96.4111.0 99.5115.0 98.1120.0 97.6125.0 97.8129.0 99.6
           1135.0 99.0138.6100.4141.1102.2
NS         1        8.0        7.0        8.0        8.0        8.0        8.0
NS         1        8.0        8.0        8.0        8.0        8.0        8.0
NS         1        8.0        8.0        8.0        8.0        8.0        8.0
NS         1        8.0        8.0        8.0        8.0        8.0        8.0
NS         1        8.0        8.0        8.0        8.0        8.0        8.0
NS         1        8.0        8.0        8.0        8.0        7.0        7.0
NS         1        8.0        8.0        9.0
CAL1       1      99.63        467.
VEL1       1 0.00 0.00 0.00 0.00 0.40 0.00 0.00 0.30 2.40 3.60 4.30 0.00
VEL1       1 0.00 3.20 0.50 0.20 3.50 3.80 1.00 2.40 3.00 1.70 1.80 2.00
VEL1       1 4.20 0.00 1.00 0.00 0.10 1.10 2.00 2.70 3.30 1.00 2.50 1.10
VEL1       1 0.50 0.00 0.00
CAL2       1      99.30        245.
VEL2       1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 2.20 0.60 3.50 3.30 0.00
VEL2       1 0.00 4.40 0.00 0.40 3.90 2.40 0.00 1.80 2.80 0.60 2.10 2.40
VEL2       1 4.60 0.00 0.00 0.00 0.40 0.30 0.60 0.00 1.00 0.60 0.70 0.70
VEL2       1 0.00 0.00 0.00
CAL3       1      98.58        102.
VEL3       1 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 3.40 1.10 0.00
VEL3       1 0.00 0.00 3.10 0.70 3.60 1.20 0.00 1.00 1.00 0.20 2.00 1.80
VEL3       1 0.00 0.00 0.00 0.00 0.90 0.00 0.00 0.00 1.00 0.60 0.00 0.00
VEL3       1 0.00 0.00 0.00
XSEC       2      220.   .30         99.4
           2  0.0105.6  2.0105.0  6.5103.4 13.0102.8 14.5104.9 17.2103.3
           2 21.0103.4 22.3104.2 25.0102.0 26.5102.0 27.4102.9 29.0101.7
           2 32.0102.4 36.0101.4 39.0102.7 49.5100.6 59.0 99.4 65.0 99.5
NS         2        5.9        7.1        7.1        5.7        7.2        7.0
NS         2        7.1        7.5        7.1        7.3        7.6        7.6
NS         2        7.7        7.6        7.5        6.9        5.4        7.6
NS         2        6.7        7.7        5.5        7.2        5.9        7.2
NS         2        7.1        6.7        6.8        6.9
CAL1       2     104.52        378.
VEL1       2 0.00 0.00 0.00 0.30 0.00 0.30 0.40 1.10 1.70 1.10 1.80 1.20
VEL1       2 2.10 1.40 1.50 2.60 3.00 1.80 2.00 1.50 0.30 1.50 0.40 1.10
VEL1       2 0.00 1.30 0.00 0.00
CAL2       2     103.78        200.
VEL2       2 0.00 0.00 0.00 0.10 0.00 0.10 0.50 0.00 1.00 0.90 1.00 0.80
VEL2       2 0.00 0.90 0.40 1.00 2.20 1.20 0.00 0.70 0.20 0.00 0.00 0.00
VEL2       2 0.00 0.00 0.00 0.00
CAL3       2     103.45         59.
VEL3       2 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.30 0.30 0.50 0.30
VEL3       2 0.40 0.20 0.20 0.40 0.90 0.20 0.10 0.10 0.00 0.00 0.00 0.00
VEL3       2 0.00 0.00 0.00 0.00
XSEC       3      177.   .35        102.7
           3  0.0110.9  5.0107.5  6.0106.3  8.0106.3 17.0103.5 29.0102.7
           3 31.0103.0 36.5103.5 41.0105.6 44.0104.4 46.0105.5 47.5104.8
           3 51.9104.7 54.6103.9 57.0104.6 61.0104.0 67.0105.0 71.0104.5
           3 74.0105.1 79.0106.3 81.0106.9 82.2107.8
NS         3        7.7        7.6        7.5        7.4        7.4        7.3
NS         3        7.3        7.1        8.0        7.3        8.0        7.5
NS         3        7.4        7.6        7.7        7.2        7.2        6.4
NS         3        6.0        5.8        7.7        7.7
CAL1       3     106.87        445.
VEL1       3 0.00 0.00 0.00 0.10 2.00 3.90 3.10 2.60 2.60 1.90 3.20 2.80
VEL1       3 1.10 1.80 2.20 1.10 1.20 0.70 0.50 0.00 0.00 0.00
CAL2       3     105.98        113.
VEL2       3 0.00 0.00 0.00 0.00 1.70 2.00 0.90 0.70 0.80 0.50 1.00 1.30
VEL2       3 0.30 3.10 2.80 1.10 1.00 1.00 0.30 0.00 0.00 0.00
CAL3       3     105.39         85.
VEL3       3 0.00 0.00 0.00 0.00 0.80 1.20 1.20 1.70 0.00 0.20 0.00 2.20
VEL3       3 0.10 1.50 0.80 0.50 0.10 0.60 0.00 0.00 0.00 0.00
```

Appendix Table A2 (continued)

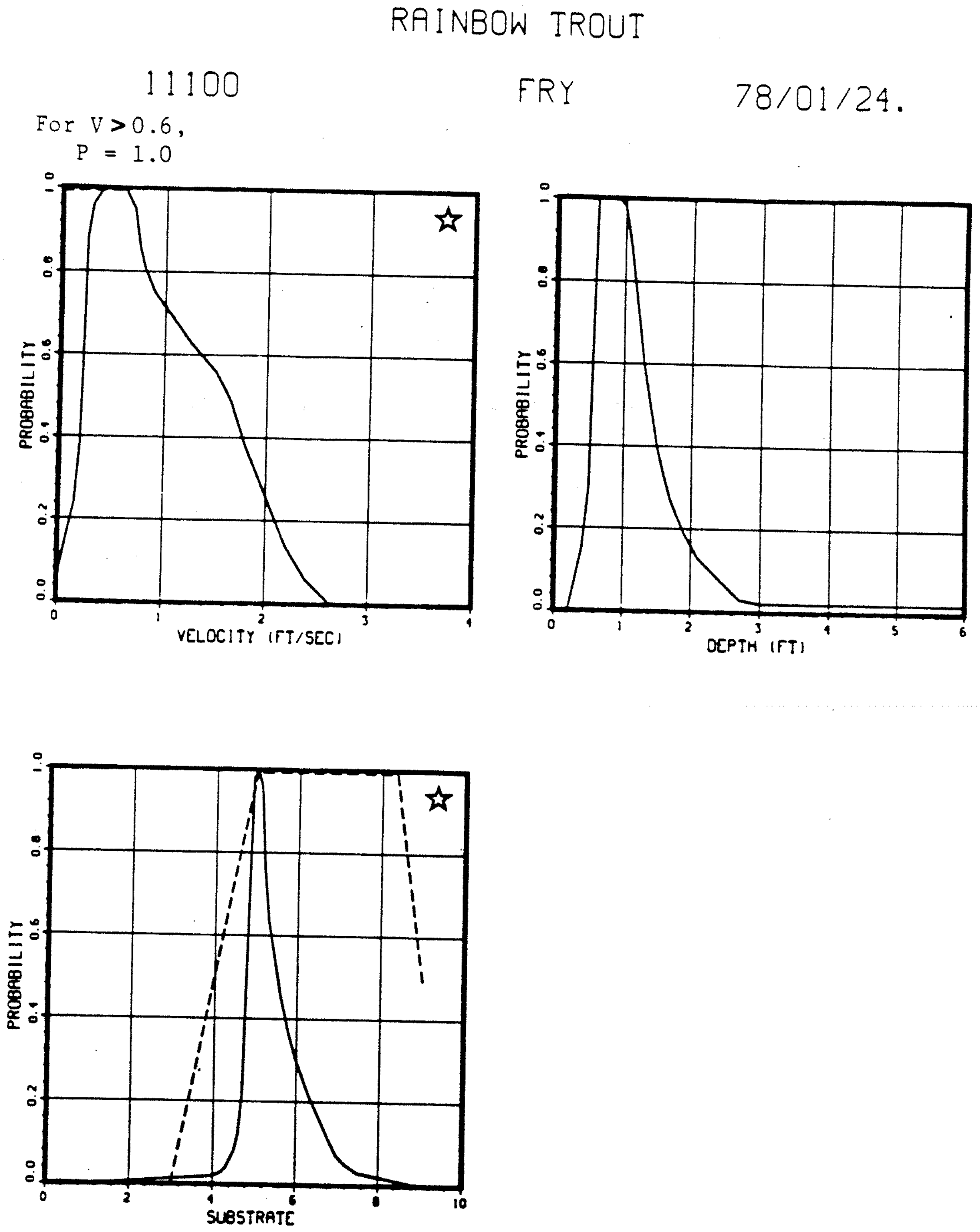
```
XSEC       4    215.   .40      106.8
           4  0.0112.7  8.5112.5 11.0111.6 15.2110.6 16.5111.5 21.0110.8
           4 23.0110.4 26.0109.5 27.2110.5 29.2109.5 32.5110.2 36.0109.8
           4 38.7111.7 41.0111.2 45.0110.1 49.0109.0 53.0107.9 57.0107.9
           4 63.0107.7 66.0107.9 76.0107.3 81.5106.8 84.0107.1 87.7111.6
           4 89.2113.1 91.2114.5
NS         4       7.5       7.4       7.1       7.5       7.6       7.7
NS         4       7.8       8.0       7.8       7.7       7.4       7.1
NS         4       7.4       7.7       7.3       6.8       6.5       6.3
NS         4       5.8       5.6       6.4       7.2       7.2       9.0
NS         4       9.0       9.0
CAL1       4    111.25      367.
VEL1       4 0.00 0.00 0.00 1.80 0.00 2.30 0.20 1.10 1.40 1.20 1.40 0.70
VEL1       4 0.20 1.50 0.80 2.30 2.00 2.90 2.60 2.80 2.10 1.80 1.50 0.00
VEL1       4 0.00 0.00
CAL2       4    110.45       89.
VEL2       4 0.00 0.00 0.00 0.00 0.00 0.00 0.30 0.10 0.00 0.10 0.10 0.10
VEL2       4 0.00 1.00 0.50 0.90 0.70 1.30 0.80 0.70 0.60 0.60 0.50 0.00
VEL2       4 0.00 0.00
CAL3       4    110.03       61.
VEL3       4 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00
VEL3       4 0.00 0.00 0.00 1.00 0.80 0.90 0.80 0.90 0.70 0.50 0.30 0.00
VEL3       4 0.00 0.00
ENDJ
```

Appendix Table A3. Velocity Adjustment Factors calculated for original and calibrated IFG-4 model.

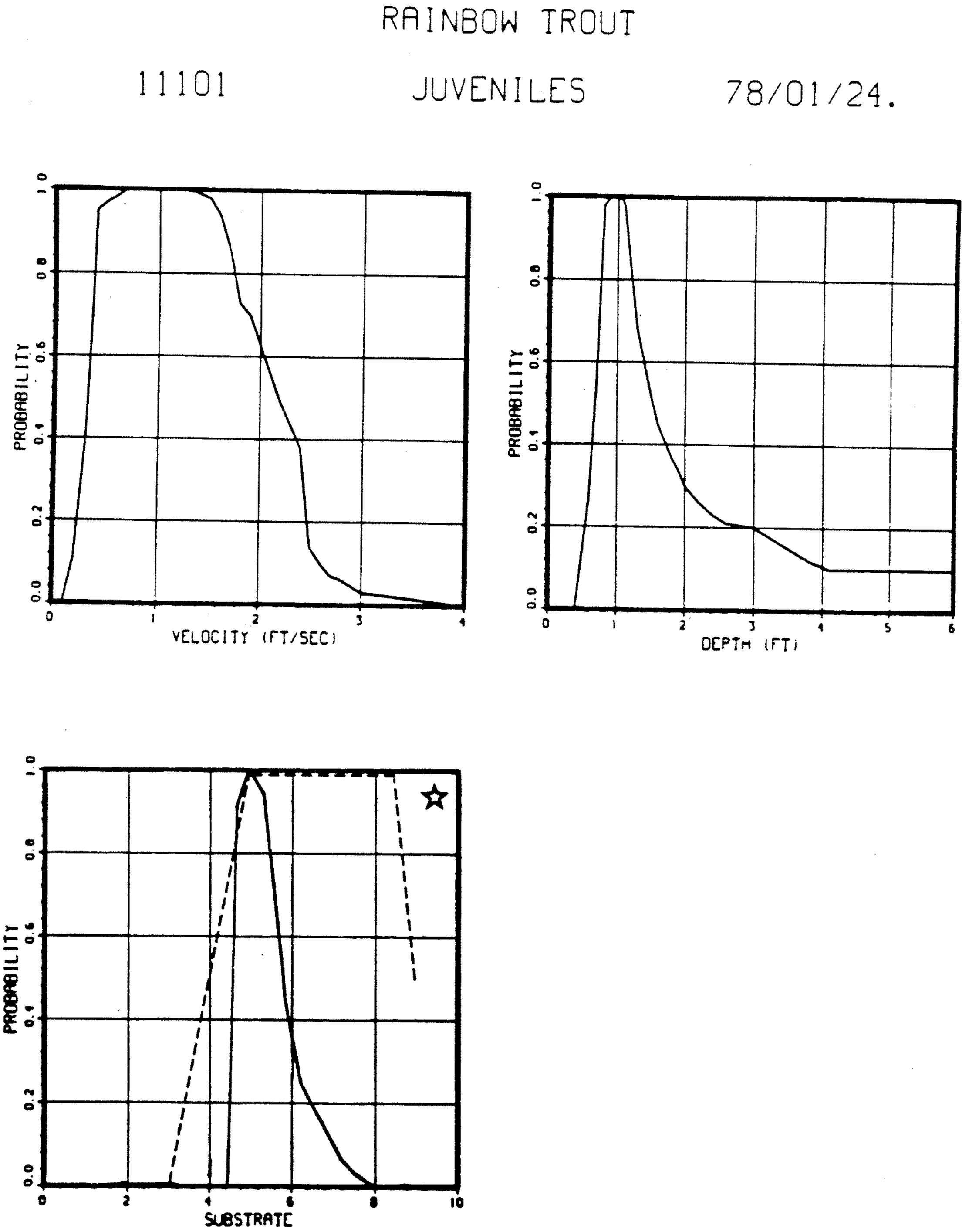
| Transect No. | Discharge Simulated | Original VAF | Calibrated VAF |
|---|---|---|---|
| 0 | 20 | 0.67 | - |
| 0 | 50 | 0.83 | - |
| 0 | 100 | 0.95 | - |
| 0 | 150 | 1.03 | - |
| 0 | 200 | 1.07 | - |
| 0 | 300 | 1.01 | - |
| 0 | 400 | 0.97 | - |
| 0 | 500 | 0.91 | - |
| 0 | 700 | 0.77 | - |
| 0 | 1000 | 0.54 | - |
| 1 | 20 | 1.34 | 0.88 |
| 1 | 50 | 0.94 | 0.93 |
| 1 | 100 | 1.00 | 0.96 |
| 1 | 150 | 1.02 | 0.96 |
| 1 | 200 | 1.05 | 0.99 |
| 1 | 300 | 1.09 | 1.02 |
| 1 | 400 | 1.03 | 1.01 |
| 1 | 500 | 0.96 | 0.98 |
| 1 | 700 | 0.80 | 0.91 |
| 1 | 1000 | 0.61 | 0.82 |
| 2 | 20 | 0.07 | 0.91 |
| 2 | 50 | 0.33 | 1.00 |
| 2 | 100 | 0.69 | 1.01 |
| 2 | 150 | 0.88 | 1.00 |
| 2 | 200 | 0.97 | 0.99 |
| 2 | 300 | 1.01 | 0.97 |
| 2 | 400 | 0.97 | 0.95 |
| 2 | 500 | 0.88 | 0.93 |
| 2 | 700 | 0.64 | 0.90 |
| 2 | 1000 | 0.37 | 0.85 |
| 3 | 20 | 1.25 | 1.09 |
| 3 | 50 | 1.12 | 1.05 |
| 3 | 100 | 1.06 | 1.04 |
| 3 | 150 | 1.05 | 1.04 |
| 3 | 200 | 1.04 | 1.04 |
| 3 | 300 | 1.02 | 1.02 |
| 3 | 400 | 1.00 | 1.00 |
| 3 | 500 | 0.98 | 0.98 |
| 3 | 700 | 0.95 | 0.94 |
| 3 | 1000 | 0.92 | 0.88 |
| 4 | 20 | 1.07 | 1.02 |
| 4 | 50 | 1.04 | 1.02 |
| 4 | 100 | 1.02 | 1.01 |
| 4 | 150 | 1.01 | 1.01 |
| 4 | 200 | 1.00 | 1.01 |
| 4 | 300 | 0.96 | 0.99 |
| 4 | 400 | 0.92 | 0.97 |
| 4 | 500 | 0.89 | 0.96 |
| 4 | 700 | 0.85 | 0.92 |
| 4 | 1000 | 0.80 | 0.88 |

# APPENDIX B

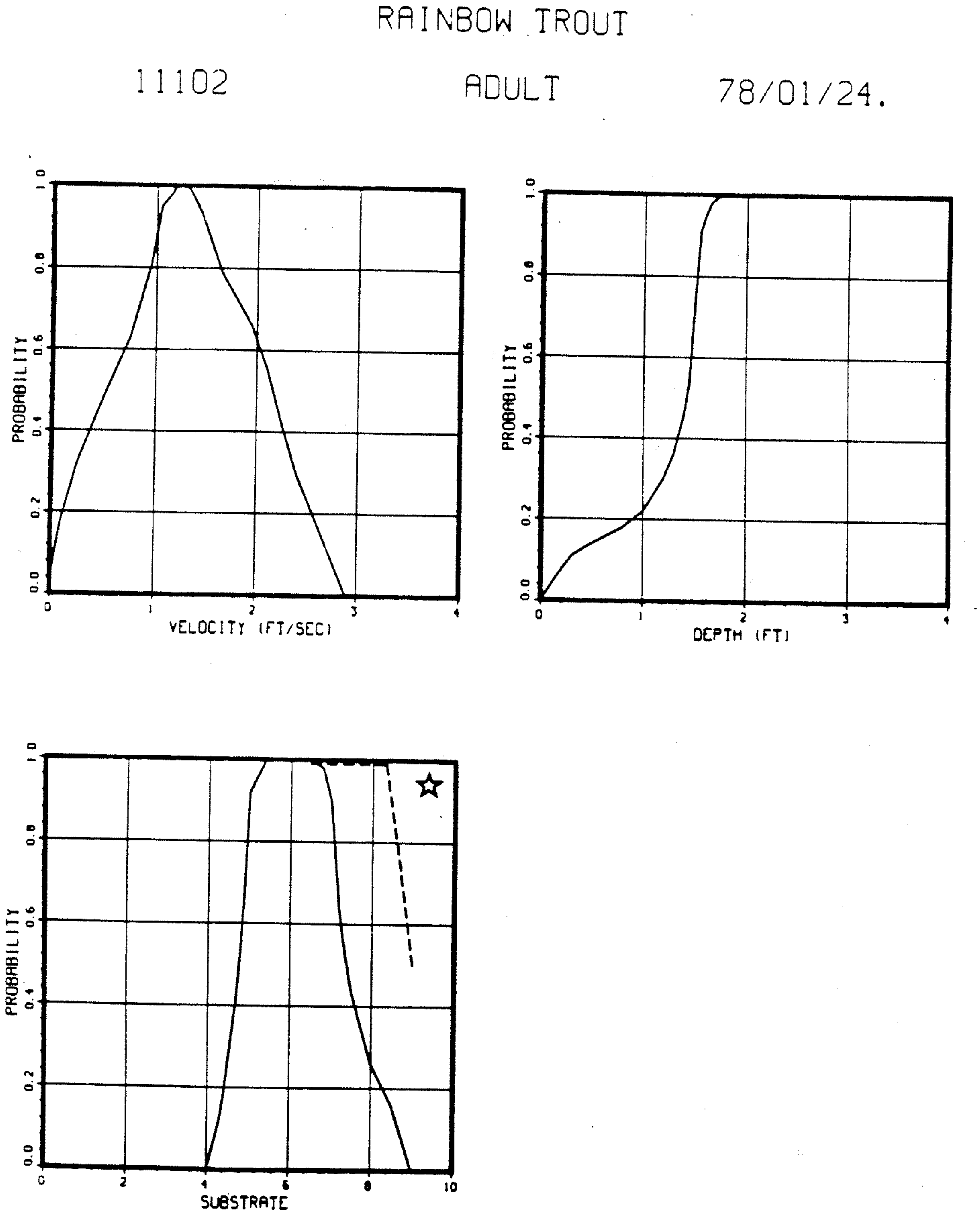
Suitability-of-use criteria are illustrated in Figures B1 through B12 for the various salmonid species/life stages known to occur in the South Fork Snoqualmie River. Revisions to the original suitability functions published by the Instream Flow Group (Bovee 1978) appear as dashed lines in figures denoted by a ☆ .



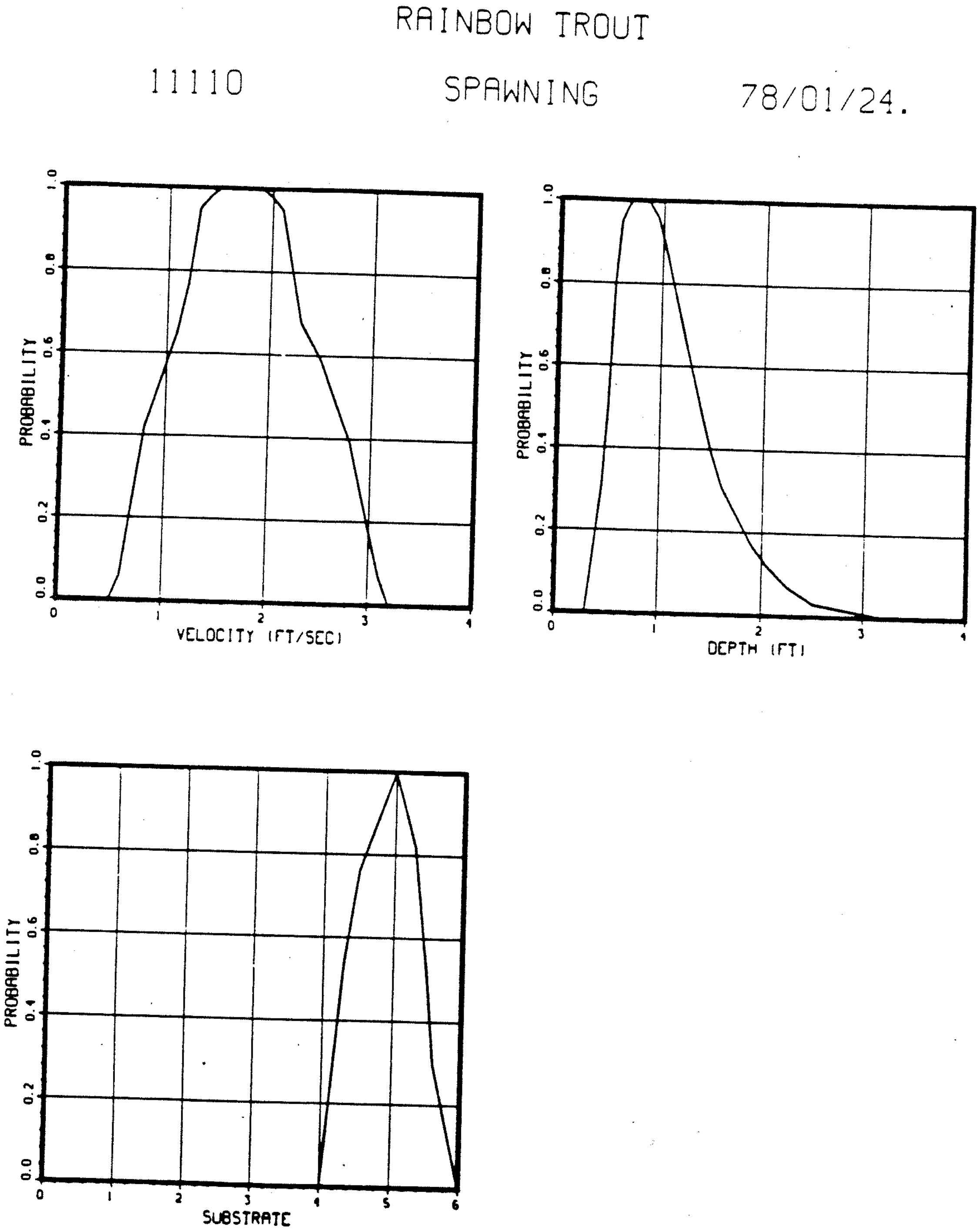
Appendix Figure B1. Suitability-of-use criteria for rainbow trout fry.



Appendix Figure B2. Suitability-of-use criteria for rainbow trout juveniles.



Appendix Figure B3. Suitability-of-use criteria for rainbow trout adult.

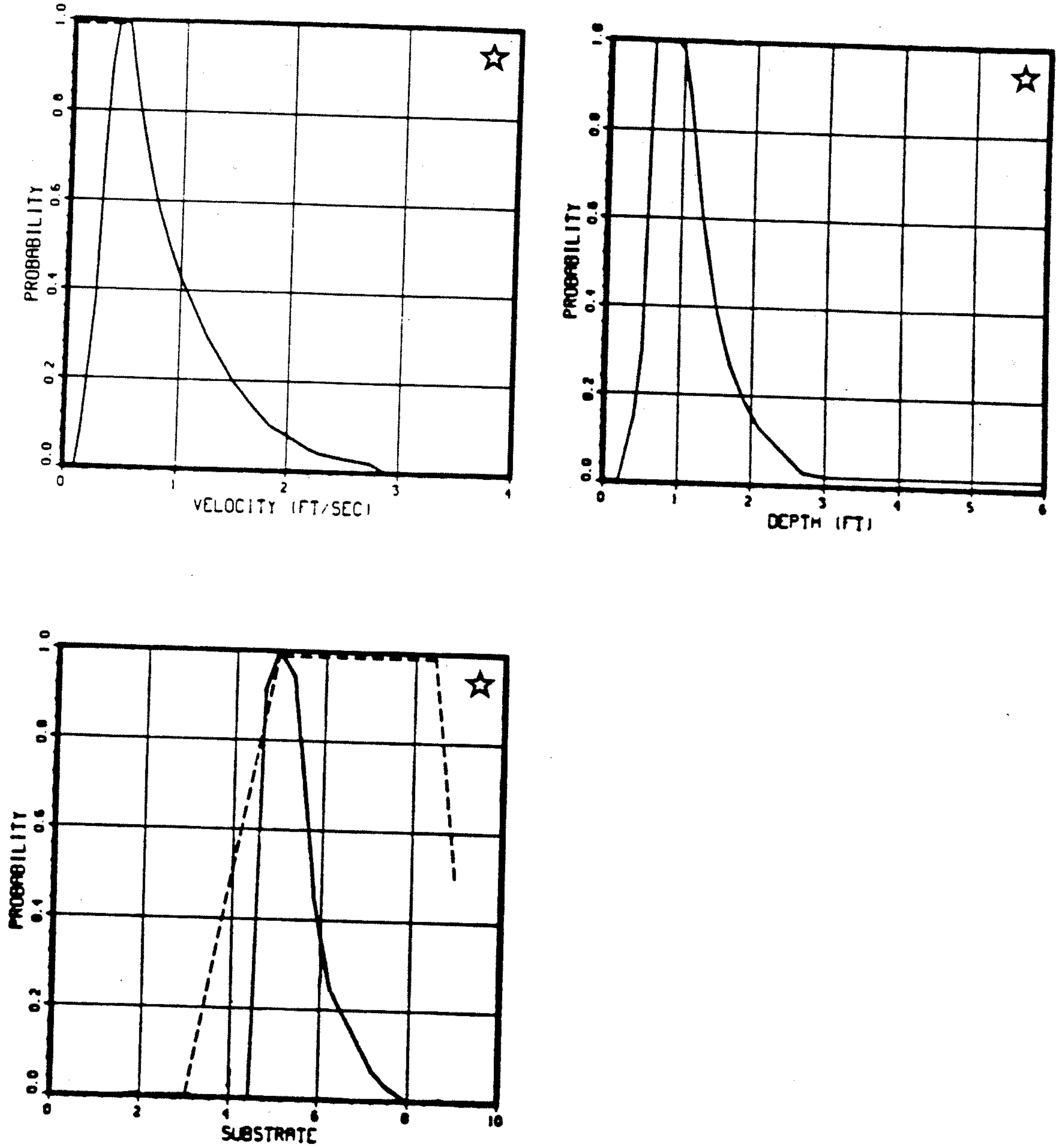


Appendix Figure B4. Suitability-of-use criteria for rainbow trout spawning.

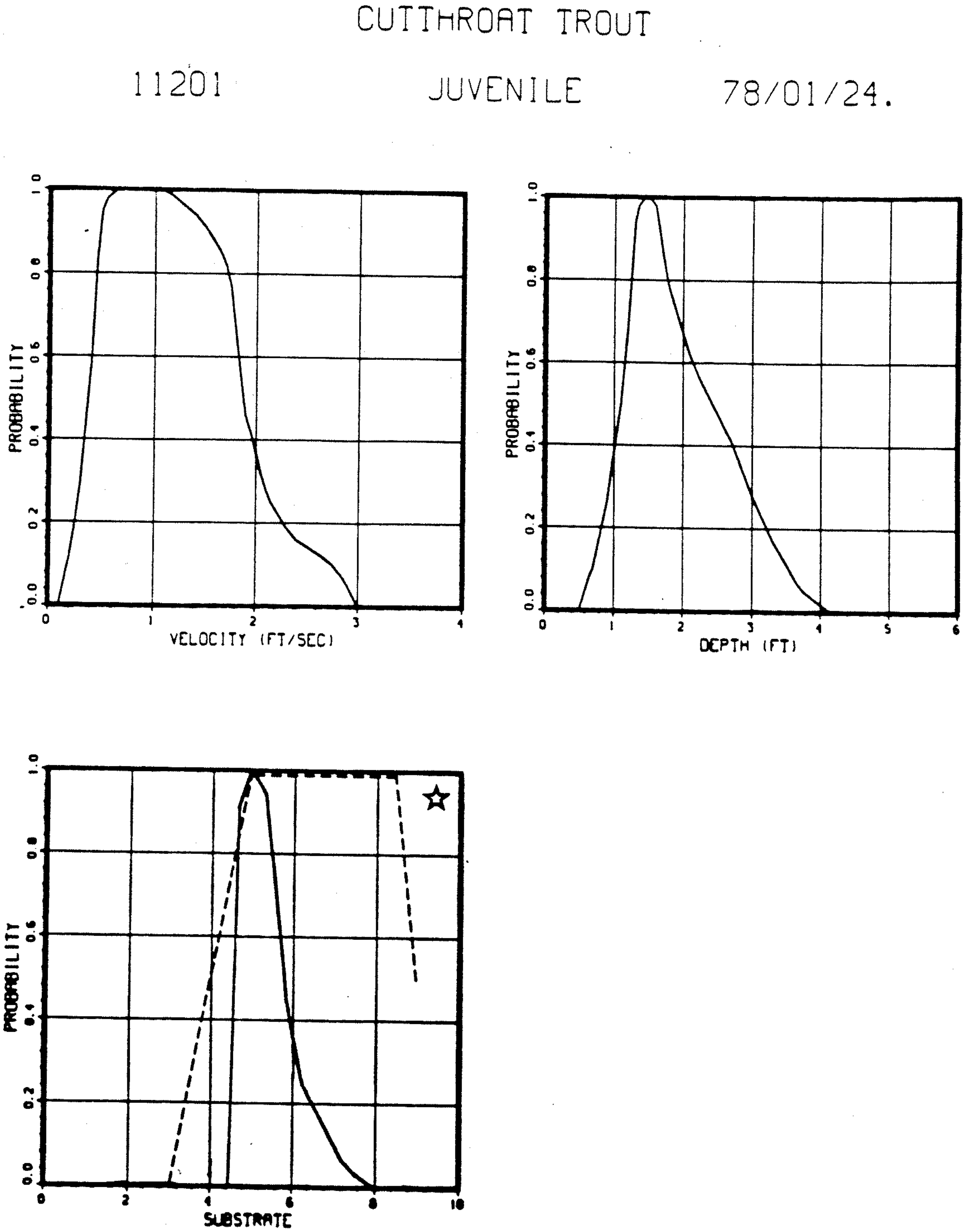
CUTTHROAT TROUT

11200 FRY 78/01/24.

For V >0.5,
P = 1.0



Appendix Figure B5. Suitability-of-use criteria for cutthroat trout fry.

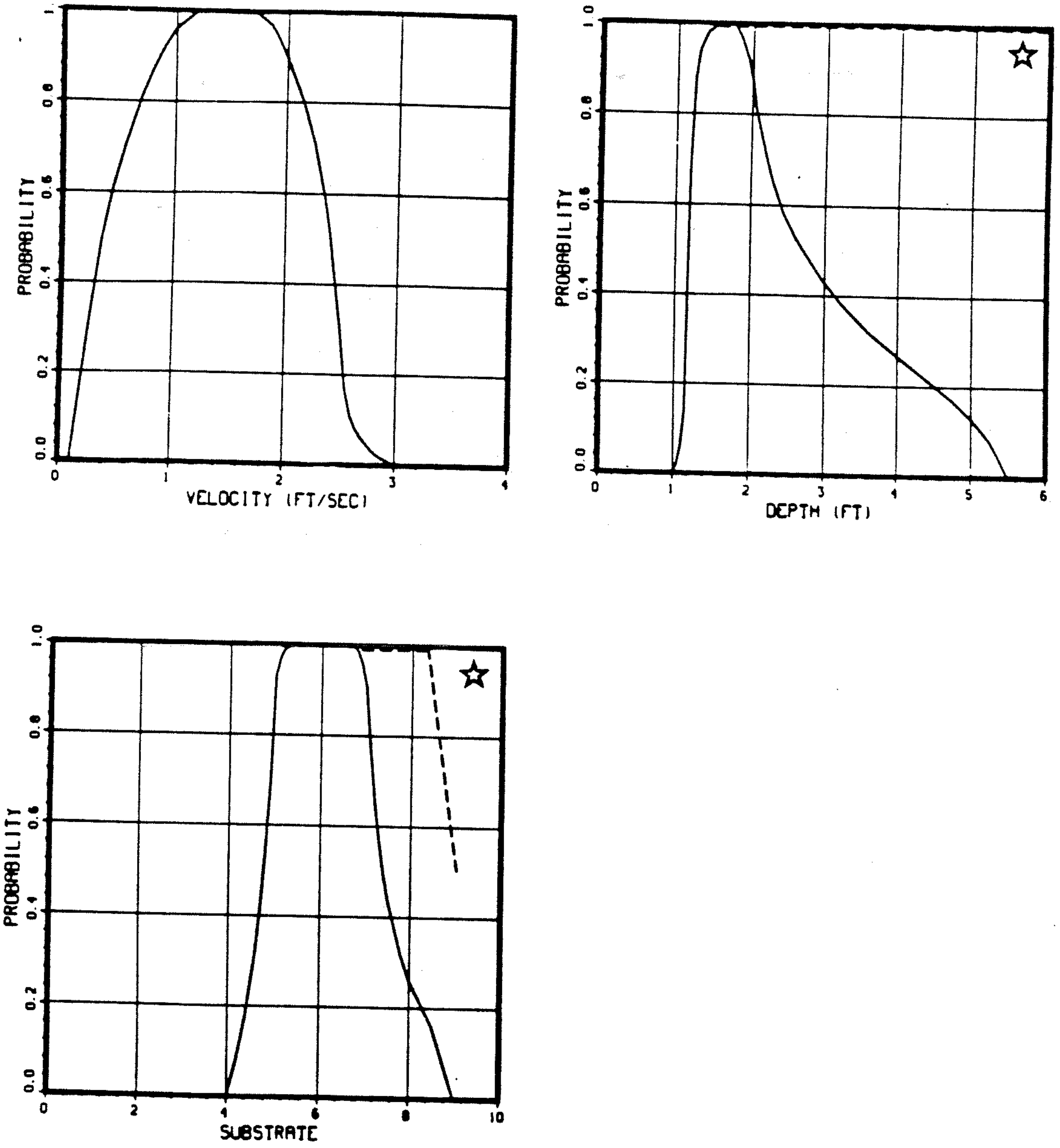


Appendix Figure B6. Suitability-of-use criteria for cutthroat trout juvenile.

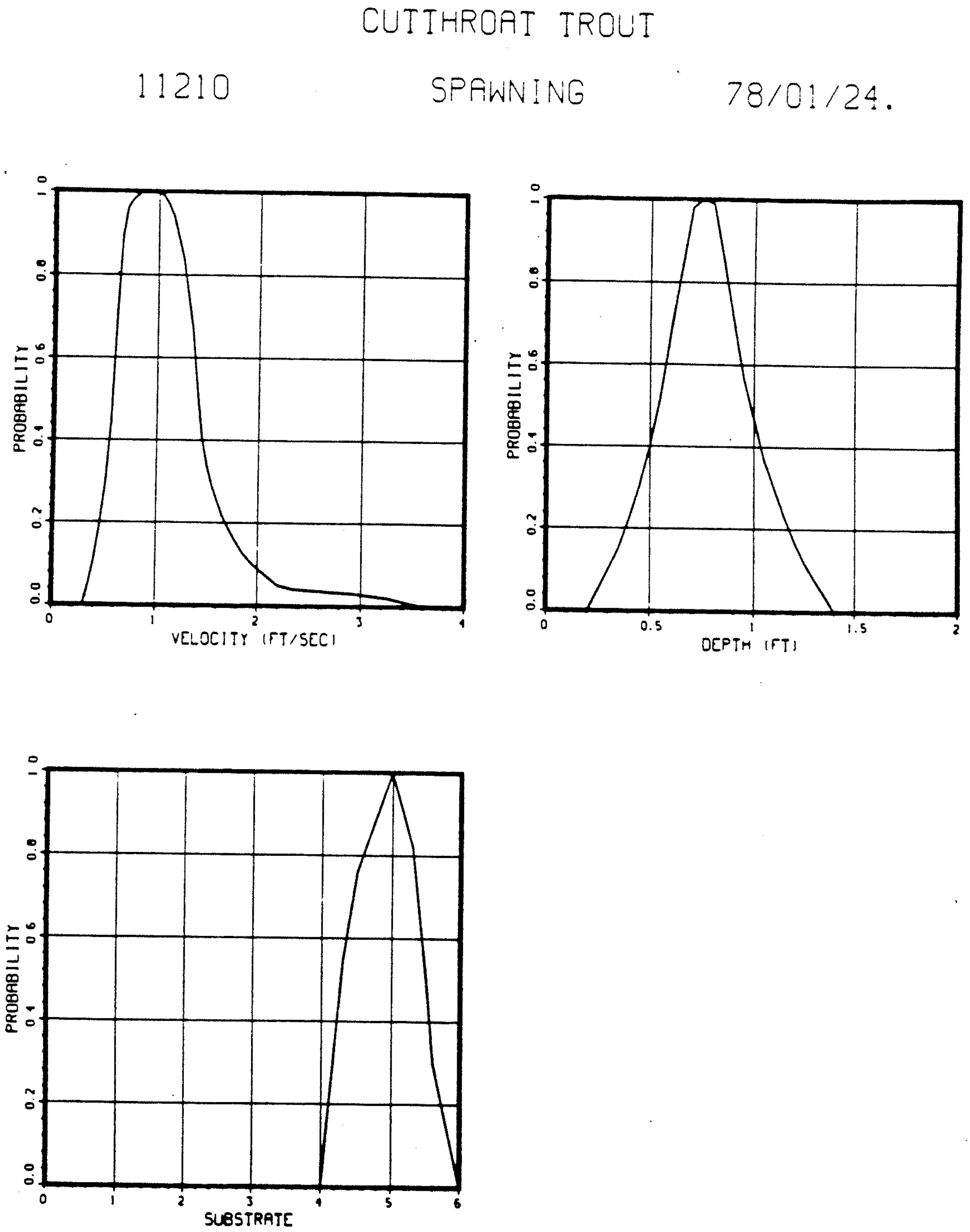
CUTTHROAT TROUT

11202 ADULTS 78/01/24.

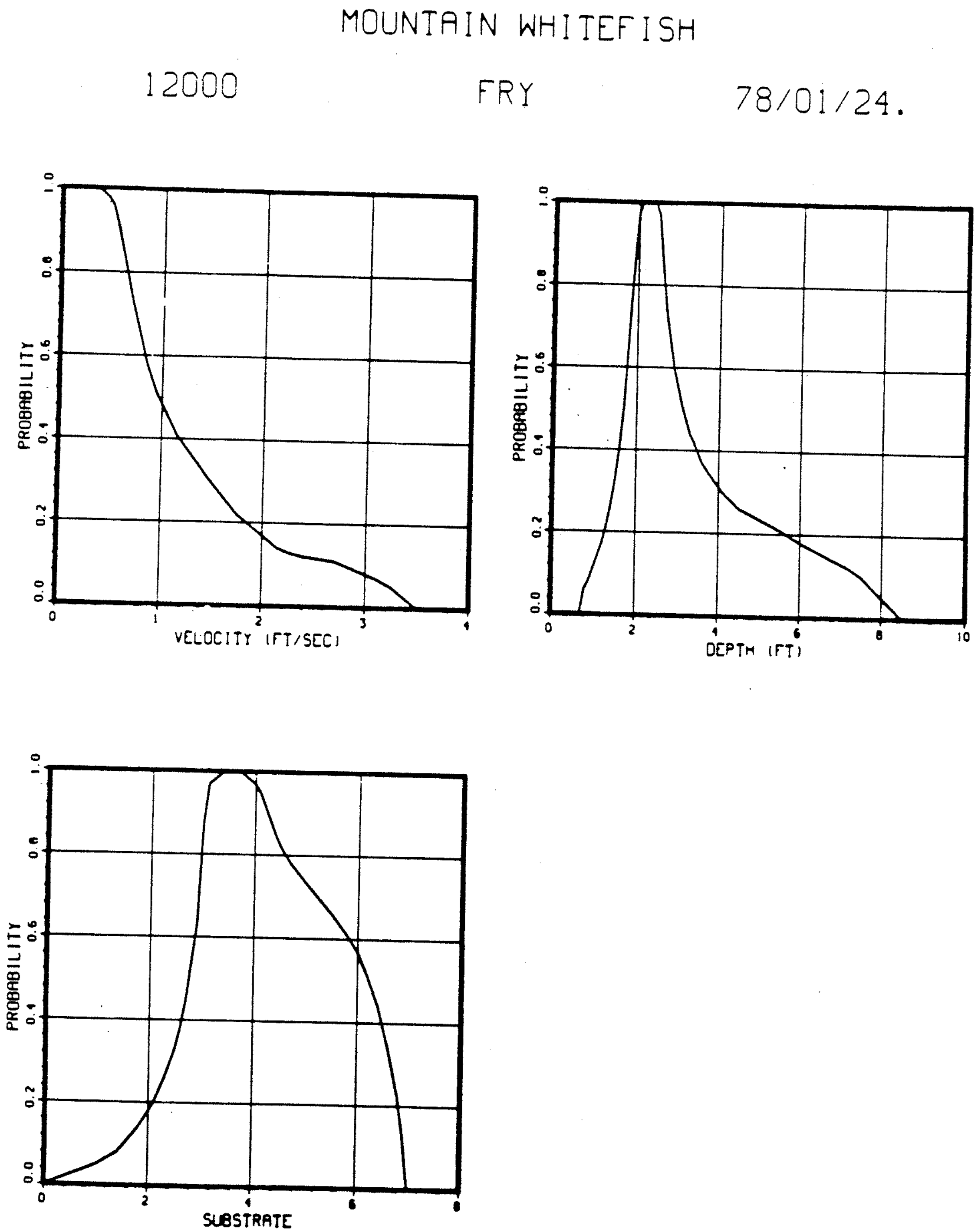
For D > 1.5,
P = 1.0



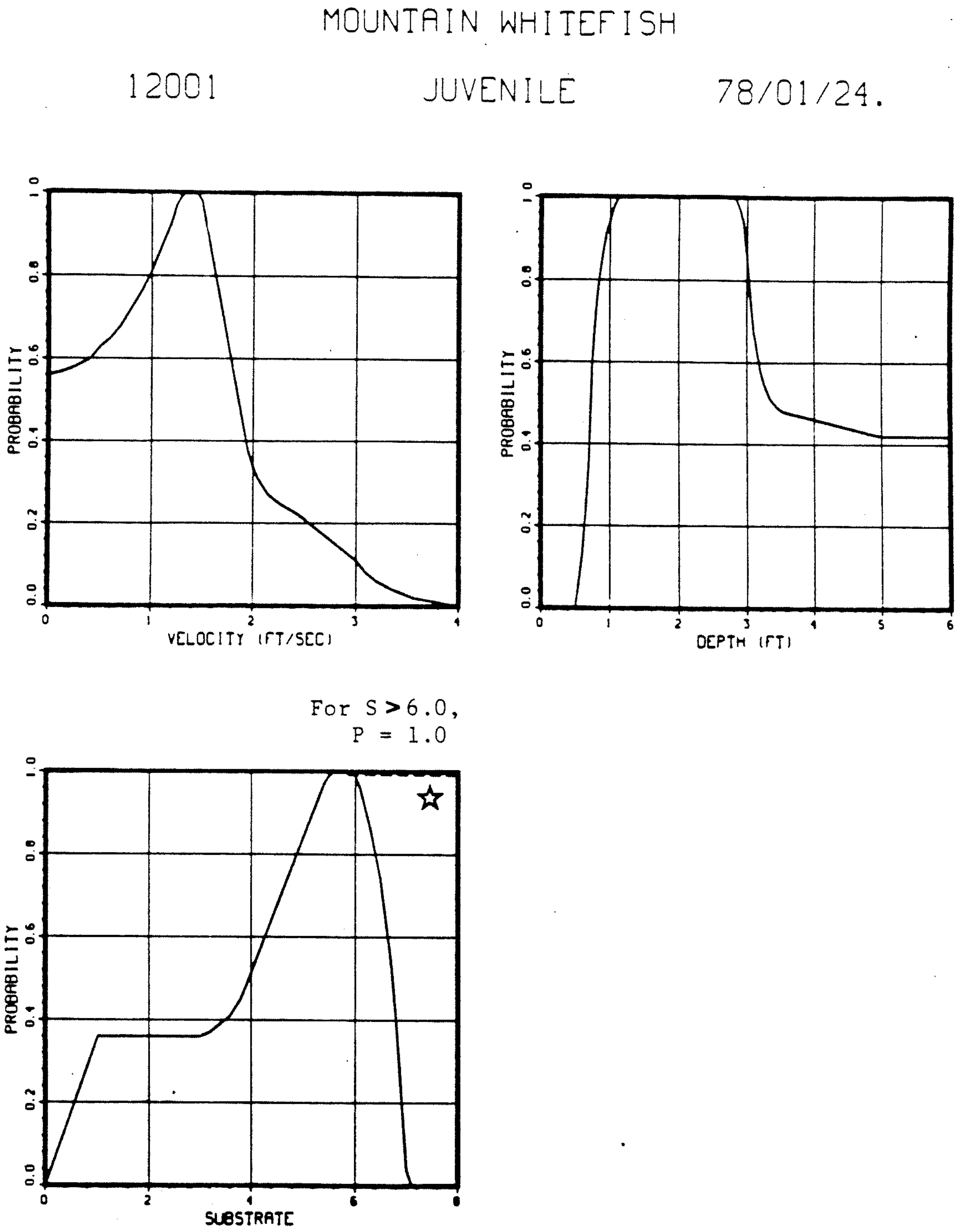
Appendix Figure B7. Suitability-of-use criteria for cutthroat trout adults.



Appendix Figure B8. Suitability-of-use criteria for cutthroat trout spawning.

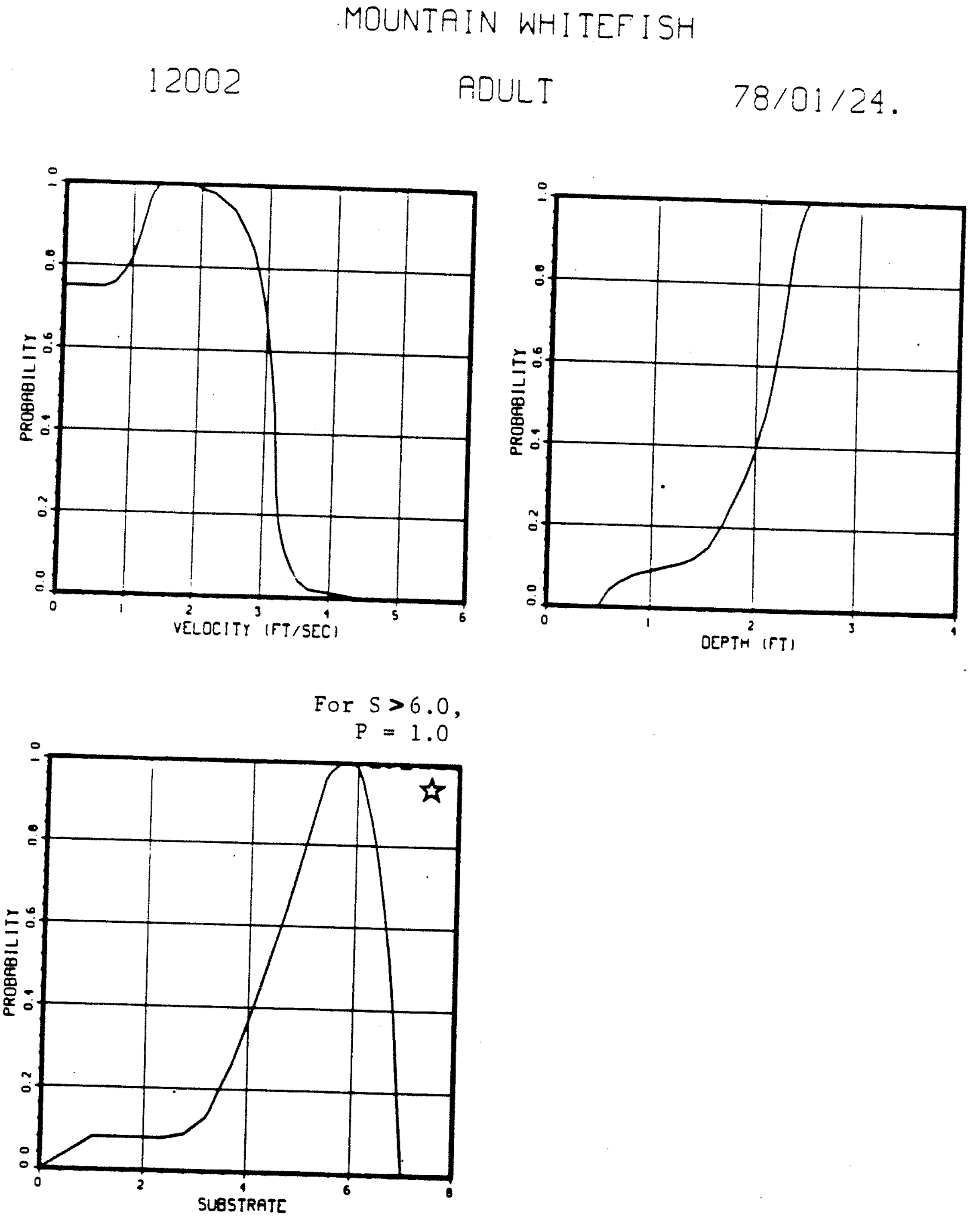


Appendix Figure B9. Suitability-of-use criteria for mountain whitefish fry.



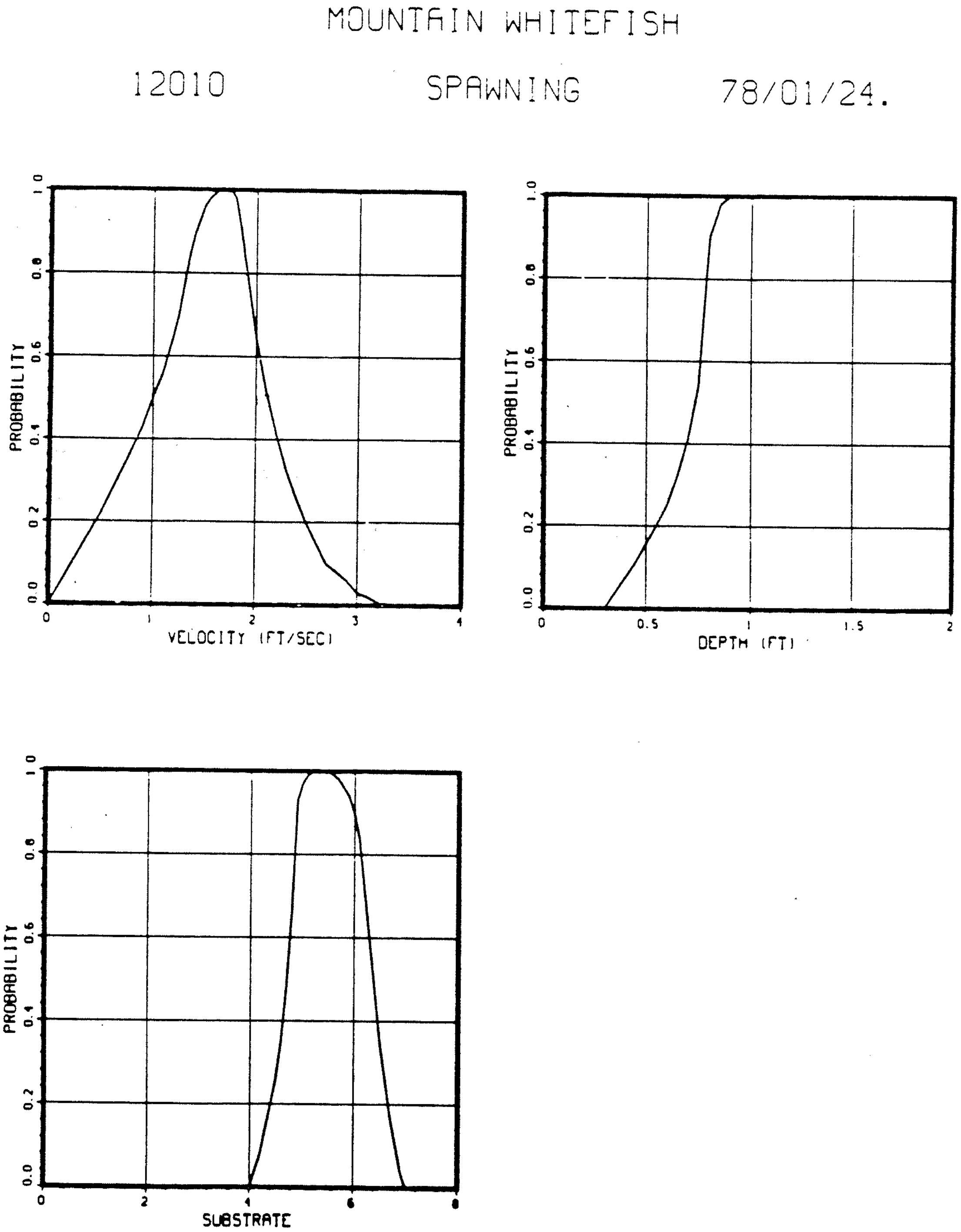
For S > 6.0,
P = 1.0

Appendix Figure B10. Suitability-of-use criteria for mountain whitefish juvenile.



For S >6.0,
P = 1.0

Appendix Figure B11. Suitability-of-use criteria for mountain whitefish adult.



Appendix Figure B12. Suitability-of-use criteria for mountain whitefish spawning.

# APPENDIX C

Streamflow requirements under normal and critical water year conditions are presented for trout and whitefish life stages inhabiting the South Fork Snoqualmie River as determined from their respective $Q_E$, and $Q_{90}$ through $Q_{50}$ values. Monthly median and critical flows are indicated at the head of each column in the following tables.

Appendix Table C1. $Q_E$-based streamflow requirements for a normal water year.

| Species | Life stage | $Q_E$ | 550 | 375 | 320 | 470 | 750 | 638 | 239 | 104 | 113 | 227 | 423 | 485 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 104 | 113 | 130 | 130 | 130 |
| | Adult | 260 | 260 | 260 | 260 | 260 | 260 | 260 | 239 | 104 | 113 | 227 | 260 | 260 |
| | Spawning | 460 | | | | | 460 | 460 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 104 | 113 | 180 | 180 | 180 |
| | Adult | 220 | 220 | 220 | 220 | 220 | 220 | 220 | 220 | 104 | 113 | 220 | 220 | 220 |
| | Spawning | 340 | | | | | 340 | 340 | 239 | | | | | |
| Mountain whitefish | Fry | 30 | | | | 30 | 30 | 30 | 30 | 30 | 30 | | | |
| | Juvenile | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 104 | 113 | 140 | 140 | 140 |
| | Adult | 370 | 370 | 370 | 370 | 370 | 370 | 370 | 239 | 104 | 113 | 227 | 370 | 370 |
| | Spawning | 190 | | | | | | | | | | 190 | 190 | 190 |

Appendix Table C2. $Q_E$-based streamflow requirements for a critical water year.

| Species | Life stage | $Q_E$ | 257 | 160 | 215 | 295 | 512 | 362 | 112 | 63 | 64 | 100 | 271 | 260 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 112 | 63 | 64 | 100 | 130 | 130 |
| | Adult | 260 | 257 | 160 | 215 | 260 | 260 | 260 | 117 | 63 | 64 | 100 | 260 | 260 |
| | Spawning | 460 | | | | | 460 | 362 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 180 | 180 | 160 | 180 | 180 | 180 | 180 | 112 | 63 | 64 | 100 | 180 | 180 |
| | Adult | 220 | 220 | 160 | 215 | 220 | 220 | 220 | 112 | 63 | 64 | 100 | 220 | 220 |
| | Spawning | 340 | | | | | 340 | 340 | 112 | | | | | |
| Mountain whitefish | Fry | 30 | | | | 30 | 30 | 30 | 30 | 30 | 30 | | | |
| | Juvenile | 140 | 140 | 140 | 140 | 140 | 140 | 140 | 112 | 63 | 64 | 100 | 140 | 140 |
| | Adult | 370 | 257 | 160 | 215 | 295 | 370 | 362 | 112 | 64 | 64 | 100 | 271 | 260 |
| | Spawning | 190 | | | | | | | | | | 100 | 190 | 190 |

Appendix Table C3. $Q_{90}$-based streamflow requirements for a normal water year.

| | | | 550 | 375 | 320 | 470 | 750 | 638 | 239 | 104 | 113 | 227 | 423 | 485 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life stage | $Q_{90}$ | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 46 | | | | | | | 46 | 46 | 46 | 46 | | |
| | Juvenile | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | Adult | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 177 | 104 | 113 | 177 | 177 | 177 |
| | Spawning | 403 | | | | | 403 | 403 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 126 | 126 | 126 | 126 | 126 | 126 | 126 | 126 | 104 | 113 | 126 | 126 | 126 |
| | Adult | 165 | 165 | 165 | 165 | 165 | 165 | 165 | 165 | 104 | 113 | 165 | 165 | 165 |
| | Spawning | 321 | | | | | 321 | 321 | 239 | | | | | |
| Mountain whitefish | Fry | 22 | | | | 22 | 22 | 22 | 22 | 22 | 22 | | | |
| | Juvenile | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 104 | 108 | 108 | 108 | 108 |
| | Adult | 292 | 292 | 292 | 292 | 292 | 292 | 292 | 239 | 104 | 113 | 227 | 292 | 292 |
| | Spawning | 156 | | | | | | | | | | 156 | 156 | 156 |

Appendix Table C4. $Q_{90}$-based streamflow requirements for a critical water year.

| | | | 257 | 160 | 215 | 295 | 512 | 362 | 112 | 63 | 64 | 100 | 271 | 260 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life stage | $Q_{90}$ | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 46 | | | | | | | 46 | 46 | 46 | 46 | | |
| | Juvenile | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 63 | 64 | 90 | 90 | 90 |
| | Adult | 177 | 177 | 160 | 177 | 177 | 177 | 177 | 112 | 63 | 64 | 100 | 177 | 177 |
| | Spawning | 403 | | | | | 403 | 362 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 126 | 126 | 126 | 126 | 126 | 126 | 126 | 112 | 63 | 64 | 100 | 126 | 126 |
| | Adult | 165 | 165 | 160 | 165 | 165 | 165 | 165 | 112 | 63 | 64 | 100 | 165 | 165 |
| | Spawning | 321 | | | | | 321 | 321 | 112 | | | | | |
| Mountain whitefish | Fry | 22 | | | | 22 | 22 | 22 | 22 | 22 | 22 | | | |
| | Juvenile | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 108 | 63 | 64 | 100 | 108 | 108 |
| | Adult | 292 | 257 | 160 | 215 | 292 | 292 | 292 | 112 | 63 | 64 | 100 | 271 | 260 |
| | Spawning | 156 | | | | | | | | | | 100 | 156 | 156 |

Appendix Table C5. $Q_{80}$-based streamflow requirements for a normal water year.

| Species | Life stage | $Q_{80}$ | 550<br>J | 375<br>F | 320<br>M | 470<br>A | 750<br>M | 638<br>J | 239<br>J | 104<br>A | 113<br>S | 227<br>O | 423<br>N | 485<br>D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 |
| | Adult | 132 | 132 | 132 | 132 | 132 | 132 | 132 | 132 | 104 | 113 | 132 | 132 | 132 |
| | Spawning | 376 | | | | | 376 | 376 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 |
| | Adult | 139 | 139 | 139 | 139 | 139 | 139 | 139 | 139 | 104 | 113 | 139 | 139 | 139 |
| | Spawning | 304 | | | | | 304 | 304 | 239 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | |
| | Juvenile | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 |
| | Adult | 234 | 234 | 234 | 234 | 234 | 234 | 234 | 234 | 104 | 113 | 227 | 234 | 234 |
| | Spawning | 140 | | | | | | | | | | 140 | 140 | 140 |

Appendix Table C6. $Q_{80}$-based streamflow requirements for a critical water year

| Species | Life stage | $Q_{80}$ | 257<br>J | 160<br>F | 215<br>M | 295<br>A | 512<br>M | 362<br>J | 112<br>J | 63<br>A | 64<br>S | 100<br>O | 271<br>N | 260<br>D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 74 | 63 | 64 | 74 | 74 | 74 |
| | Adult | 132 | 132 | 132 | 132 | 132 | 132 | 132 | 112 | 63 | 64 | 100 | 132 | 132 |
| | Spawning | 376 | | | | | 376 | 362 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 100 | 63 | 64 | 100 | 100 | 100 |
| | Adult | 139 | 139 | 139 | 139 | 139 | 139 | 139 | 112 | 63 | 64 | 100 | 139 | 139 |
| | Spawning | 304 | | | | | 304 | 304 | 112 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | |
| | Juvenile | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 85 | 63 | 64 | 85 | 85 | 85 |
| | Adult | 234 | 234 | 160 | 215 | 234 | 234 | 234 | 112 | 63 | 64 | 100 | 234 | 234 |
| | Spawning | 140 | | | | | | | | | | 100 | 140 | 140 |

Appendix Table C7. $Q_{70}$-based streamflow requirements for a normal water year.

| | | | 550 | 375 | 320 | 470 | 750 | 638 | 239 | 104 | 113 | 227 | 423 | 485 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life stage | $Q_{70}$ | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| | Adult | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 104 | 107 | 107 | 107 | 107 |
| | Spawning | 355 | | | | | 355 | 355 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 |
| | Adult | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 104 | 113 | 114 | 114 | 114 |
| | Spawning | 289 | | | | | 289 | 289 | 239 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | |
| | Juvenile | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 |
| | Adult | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 180 | 104 | 113 | 180 | 180 | 180 |
| | Spawning | 125 | | | | | | | | | | 125 | 125 | 125 |

Appendix Table C8. $Q_{70}$-based streamflow requirements for a critical water year.

| | | | 257 | 160 | 215 | 295 | 512 | 362 | 112 | 63 | 64 | 100 | 271 | 260 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life stage | $Q_{70}$ | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| | Adult | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 107 | 63 | 64 | 100 | 107 | 107 |
| | Spawning | 355 | | | | | 355 | 355 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 63 | 64 | 86 | 86 | 86 |
| | Adult | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 112 | 63 | 64 | 100 | 114 | 114 |
| | Spawning | 289 | | | | | 289 | 289 | 112 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | 20 | | |
| | Juvenile | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 65 | 63 | 64 | 65 | 65 | 65 |
| | Adult | 180 | 180 | 160 | 180 | 180 | 180 | 180 | 112 | 63 | 64 | 100 | 180 | 180 |
| | Spawning | 125 | | | | | | | | | | 100 | 125 | 125 |

Appendix Table C9. $Q_{60}$-based streamflow requirements for a normal water year.

| | | | 550 | 375 | 320 | 470 | 750 | 638 | 239 | 104 | 113 | 227 | 423 | 485 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life stage | $Q_{60}$ | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |
| | Adult | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 |
| | Spawning | 335 | | | | | 335 | 335 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| | Adult | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 |
| | Spawning | 277 | | | | | 277 | 277 | 239 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | |
| | Juvenile | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| | Adult | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 104 | 113 | 130 | 130 | 130 |
| | Spawning | 110 | | | | | | | | | | 110 | 110 | 110 |

Appendix Table C10. $Q_{60}$-based streamflow requirements for a critical water year.

| | | | 257 | 160 | 215 | 295 | 512 | 362 | 112 | 63 | 64 | 100 | 271 | 260 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Species | Life stage | $Q_{60}$ | J | F | M | A | M | J | J | A | S | O | N | D |
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |
| | Adult | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 86 | 63 | 64 | 86 | 86 | 86 |
| | Spawning | 335 | | | | | 335 | 335 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 63 | 64 | 75 | 75 | 75 |
| | Adult | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 90 | 63 | 64 | 90 | 90 | 90 |
| | Spawning | 277 | | | | | 277 | 277 | 112 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | |
| | Juvenile | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 | 44 |
| | Adult | 130 | 130 | 130 | 130 | 130 | 130 | 130 | 112 | 63 | 64 | 100 | 130 | 130 |
| | Spawning | 110 | | | | | | | | | | 100 | 110 | 110 |

Appendix Table C11. $Q_{50}$-based streamflow requirements for a normal water year.

| Species | Life stage | $Q_{50}$ | 550<br>J | 375<br>F | 320<br>M | 470<br>A | 750<br>M | 638<br>J | 239<br>J | 104<br>A | 113<br>S | 227<br>O | 423<br>N | 485<br>D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 |
| | Adult | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 |
| | Spawning | 315 | | | | | 315 | 315 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| | Adult | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 |
| | Spawning | 266 | | | | | 266 | 266 | 239 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | |
| | Juvenile | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| | Adult | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 89 |
| | Spawning | 93 | | | | | | | | | | 93 | 93 | 93 |

Appendix Table C12. $Q_{50}$-based streamflow requirements for a critical water year.

| Species | Life stage | $Q_{50}$ | 257<br>J | 160<br>F | 215<br>M | 295<br>A | 512<br>M | 362<br>J | 112<br>J | 63<br>A | 64<br>S | 100<br>O | 271<br>N | 260<br>D |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rainbow trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 | 43 |
| | Adult | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 67 | 63 | 64 | 67 | 67 | 67 |
| | Spawning | 315 | | | | | 315 | 315 | 70 | | | | | |
| Cutthroat trout | Fry | 20 | | | | | | | 20 | 20 | 20 | 20 | | |
| | Juvenile | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 | 61 |
| | Adult | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 75 | 63 | 64 | 75 | 75 | 75 |
| | Spawning | 266 | | | | | 266 | 266 | 112 | | | | | |
| Mountain whitefish | Fry | 20 | | | | 20 | 20 | 20 | 20 | 20 | 20 | | | |
| | Juvenile | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 | 30 |
| | Adult | 89 | 89 | 89 | 89 | 89 | 89 | 89 | 112 | 63 | 64 | 89 | 89 | 89 |
| | Spawning | 93 | | | | | | | | | | 93 | 93 | 93 |