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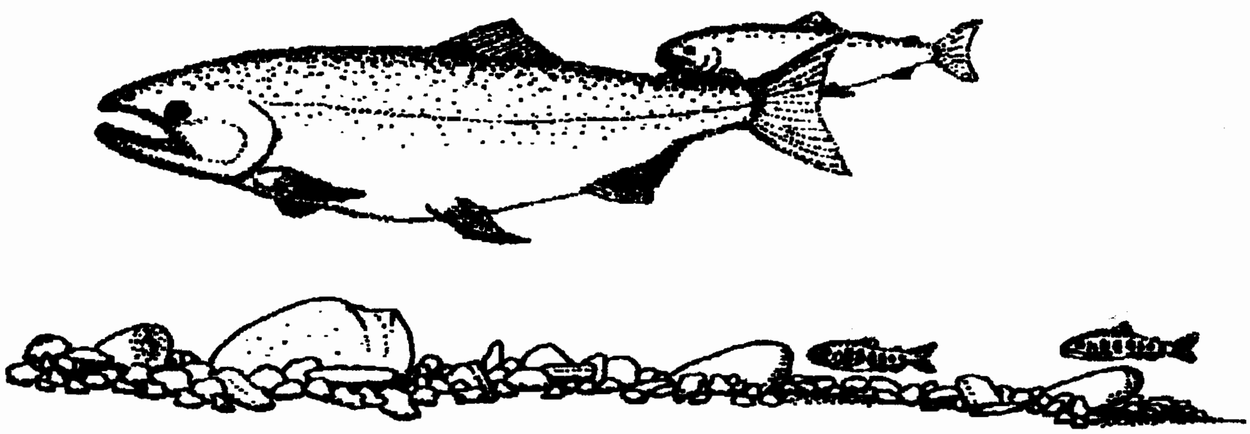
STEELHEAD TROUT HABITAT ANALYSIS USING THE INSTREAM FLOW INCREMENTAL METHODOLOGY FOR SIX TRIBUTARIES OF THE CLEARWATER RIVER, WASHINGTON



FISHERIES ASSISTANCE OFFICE

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Steelhead Trout Habitat Analysis
Using the Instream Flow Incremental Methodology
for Six Tributaries of the Clearwater River, Washington

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ABSTRACT

Habitat versus flow assessment using the Instream Flow Incremental Methodology (IFIM) was conducted on six tributaries of the Clearwater River, Washington, including Hurst Creek, Shale Creek, Miller Creek, Christmas Creek, Peterson Creek, and Bull Creek. Habitat versus flow relationships were determined for the steelhead life history stages of spawning, fry (0+ year class), and parr (1+ year class).

Field measurements were collected at a total of 11 sites in the six streams. Data collection included measurements of water depths, velocities, and substrate during high, medium, and low flows. The IFIM models developed with this information indicated peak spawning habitat at flows ranging from 40 cubic feet per second (cfs) at the Bull Creek site to 200 cfs at the upper Christmas Creek site. Peak fry habitat ranged from 1 cfs at the Bull Creek site to 60 cfs at the upper Christmas Creek site. However, the models indicated that fry habitat increased with no subsequent peak at the highest flows modeled at four of the sites, including Bull Creek. Models for six of the eleven sites indicated there was no peak in parr habitat over the range of flows modeled. Peak parr habitat for the five sites that did peak ranged from 90 cfs at the upper Hurst Creek site to 140 cfs at the middle Christmas Creek site.

PREFACE

This report provides steelhead trout (*Oncorhynchus mykiss*) habitat versus flow relationships for six tributaries (Hurst Creek, Shale Creek, Miller Creek, Christmas Creek, Peterson Creek, and Bull Creek) of the Clearwater River, Washington using the Instream Flow Incremental Methodology. The results presented in this report will provide information for additional analysis (see Study Objectives). The results in this report may also be used to provide baseline information or to determine flows that could maximize steelhead habitat for the various life stages in each of the six streams. However, several points must be considered: (1) steelhead life stages exist simultaneously in streams and maximizing the habitat availability for one life stage may result in a loss of habitat availability for another life stage; (2) a streamflow that maximizes habitat availability in one part of a stream may limit it in another part; (3) more water does not necessarily equate with more available habitat; if other species are included in the analysis, (4) a streamflow that is beneficial to one species may be detrimental to another; and (5) different species and life stages may need different streamflows at different times of the year (Bovee 1982).

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I. PROJECT BACKGROUND

Study Objectives

The primary objective of this Instream Flow Incremental Methodology (IFIM) study was to determine steelhead trout (*Oncorhynchus mykiss*) habitat availability for the various life stages in each of the six streams studied (Hurst Creek, Shale Creek, Miller Creek, Christmas Creek, Peterson Creek, and Bull Creek) at various streamflows. This information will be used by the senior author of this report as part of a dissertation for the doctoral program at the University of Washington. The dissertation will address the in-system movements of juvenile steelhead between and within the mainstem and tributaries of the Clearwater River basin. The results of this study may also assist the resource agencies and Quinault Indian Nation in the management of steelhead resources of the Clearwater River basin.

Participants

This study was made possible by the participation of the Washington Departments of Natural Resources, Wildlife, and Ecology, National Marine Fisheries Service, and the University of Washington.

Stream Descriptions

Clearwater River: The Clearwater River originates on the west side of the Olympic Mountains. From its headwaters at approximately river mile (RM) 36, the river flows southwesterly, until about RM 11 where it begins to flow essentially due south to its confluence with the Queets River (Figure 1). The river is high gradient in the headwaters but low to moderate throughout most of its length. Numerous tributaries enter the Clearwater River. Some of the larger tributaries include Hurst Creek (RM 2.2), Shale Creek (RM 11.0), Miller Creek (RM 11.9), and Christmas Creek (RM 13.5). Two of the smaller tributaries include Peterson Creek (RM 15.3) and Bull Creek (RM 19.4) (Phinney and Bucknell 1975).

Hurst Creek: Hurst Creek is approximately six miles in length and primarily low to moderate gradient throughout most of the study area. One major tributary, Boulder Creek, enters the Hurst Creek 0.8 miles above the mouth.

Shale Creek: Shale Creek is approximately five miles in length and low to moderate gradient throughout the study reach. One small, unnamed tributary enters Shale Creek about 0.6 miles above the mouth. Other small tributaries enter Shale Creek above the study reach.

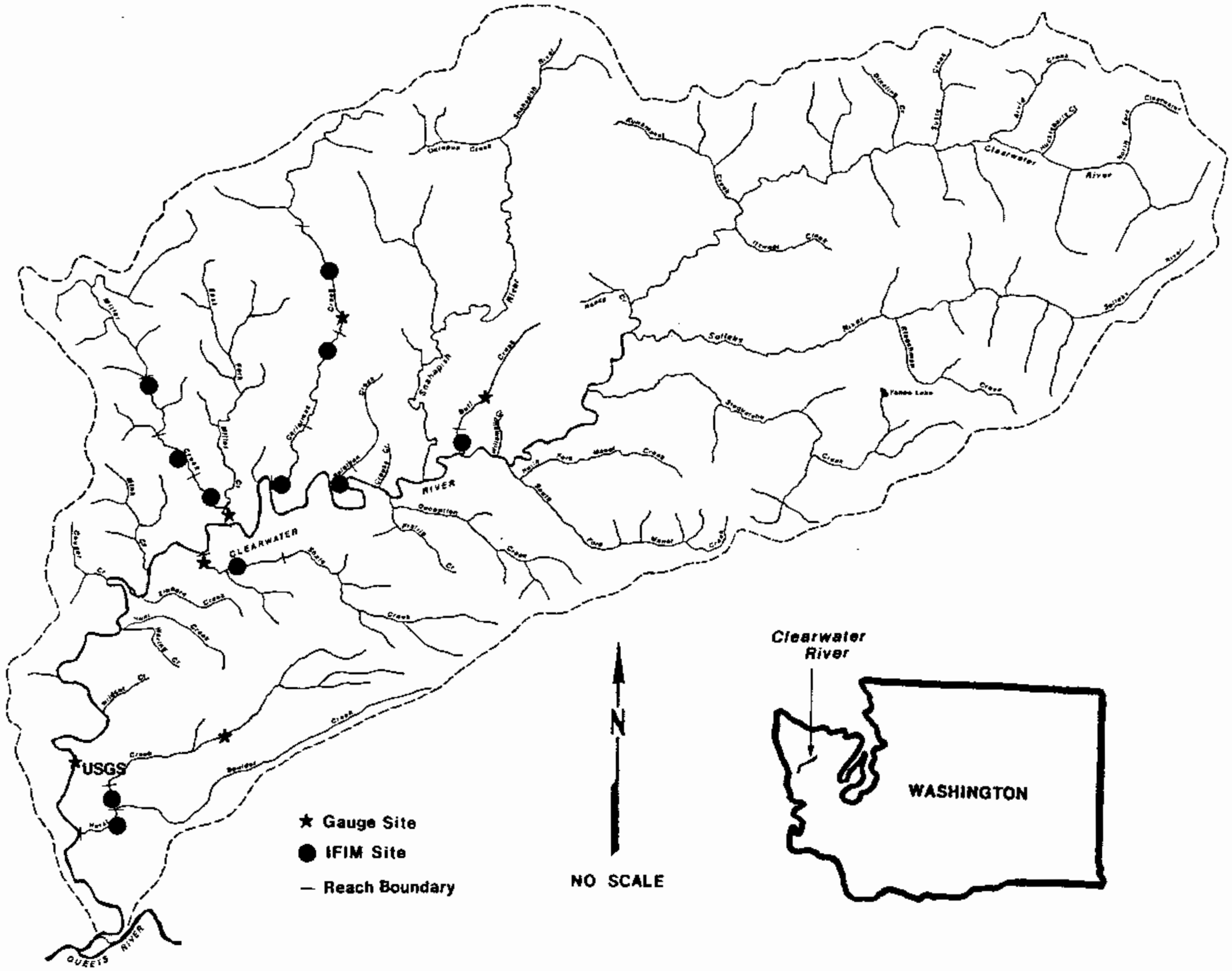

Figure 1. The Clearwater River basin, IFIM site locations and reach boundaries, and location of gauging stations.

Miller Creek: The mainstem of Miller Creek is approximately seven miles in length and moderate to high gradient. Numerous small tributaries enter the mainstem throughout its length. A major tributary, East Fork Miller Creek, enters 0.3 miles above the mouth.

Christmas Creek: Christmas Creek is over eight miles in length and moderate to high gradient. Two small, unnamed tributaries enter Christmas Creek over five miles above the mouth, above the study reach.

Peterson Creek: This stream is just over two miles in length and is moderate gradient near its mouth and high gradient above. No significant tributaries enter Peterson Creek.

Bull Creek: Bull Creek is also just over two miles in length and is essentially high gradient throughout its length. No significant tributaries enter Bull Creek.

Hydrology

The Clearwater River drains 150 square miles of intensively managed timber lands (Cederholm and Lestelle 1974). The river is fed primarily by surface runoff and groundwater with very little snowmelt. The median discharge near the town of Clearwater (USGS gauge 12040000 at RM 3.5), for the years 1932 and 1938-1949, ranges from about 410 cubic feet per second (cfs) to 2900 cfs from October through May (Figure 2). Median flows drop to about 130 cfs to 330 cfs from June through September. The peak flood of record is 37,400 cfs which occurred on November 3, 1955 (Amerman and Orsborn 1987).

Figures 2 through 6 exhibit the annual exceedence-frequency hydrographs for the Clearwater River, Hurst Creek, Shale Creek, Miller Creek, and Christmas Creek, respectively. The median flow is the 50% exceedence flow and signifies the best estimation of a normal flow. The 90% exceedence flow is essentially equaled or exceeded 90% of the time. Similarly, the 10% exceedence flow is only exceeded 10% of the time.

Wooldridge, et al. (1975), Larson and Jacoby (1976), Larson and Jacoby (1977), Abercrombie, et al. (1978), and Abercrombie, et al. (1979) collected five years of flow records on Shale, Miller, and Christmas creeks. Wooldridge, et al. (1975), Larson and Jacoby (1976), and Larson and Jacoby (1977) collected three years of flow records on Hurst Creek. This information was used to develop the exceedence-frequency hydrographs for those streams (Figures 3-6). However, a minimum of ten years of flow records is generally considered necessary to develop an adequate exceedence-frequency hydrograph. Therefore, the hydrographs for

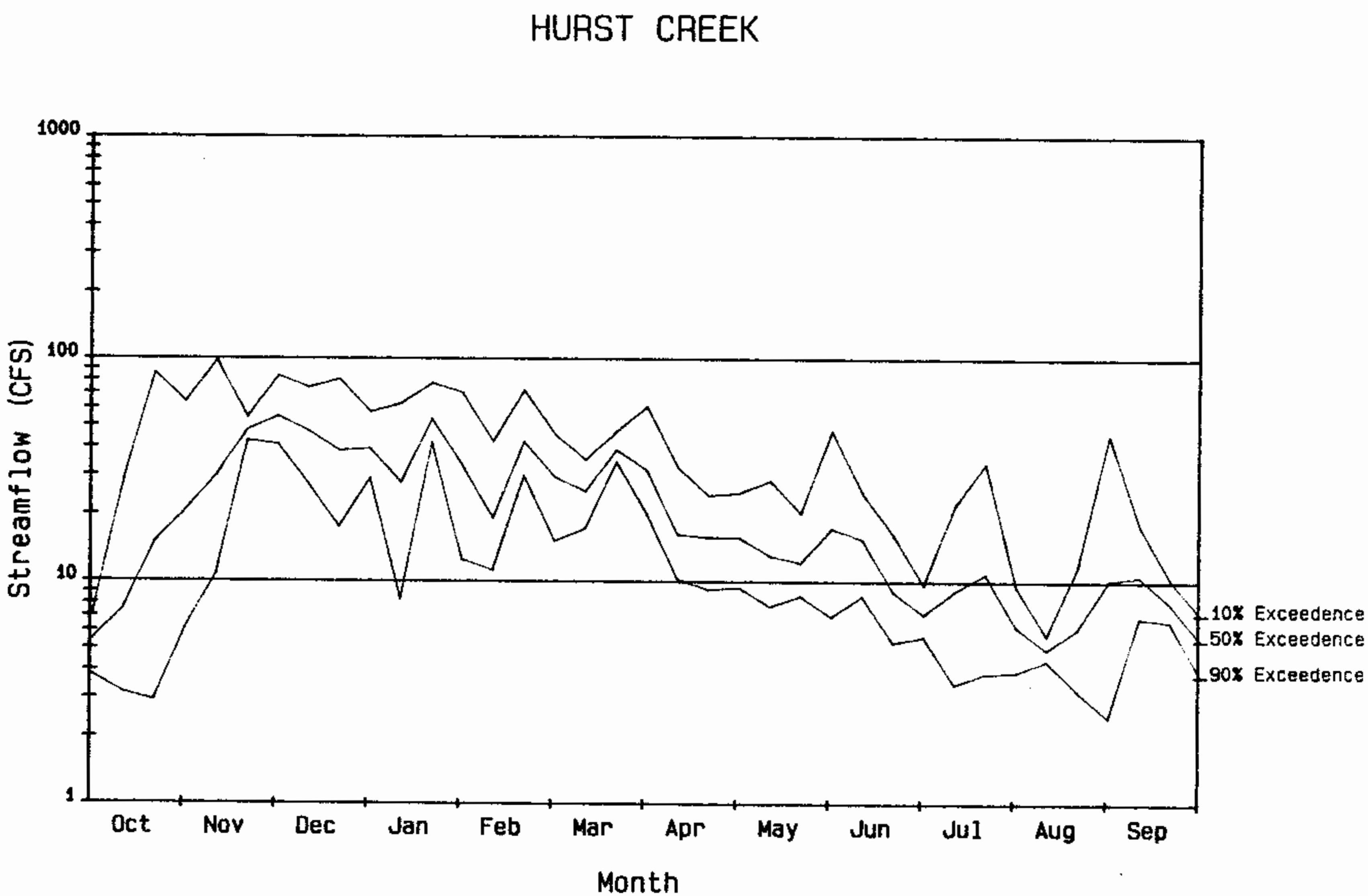

Figure 3. Exceedence-frequency hydrograph for Hurst Creek, period October 1973 - September 1976.

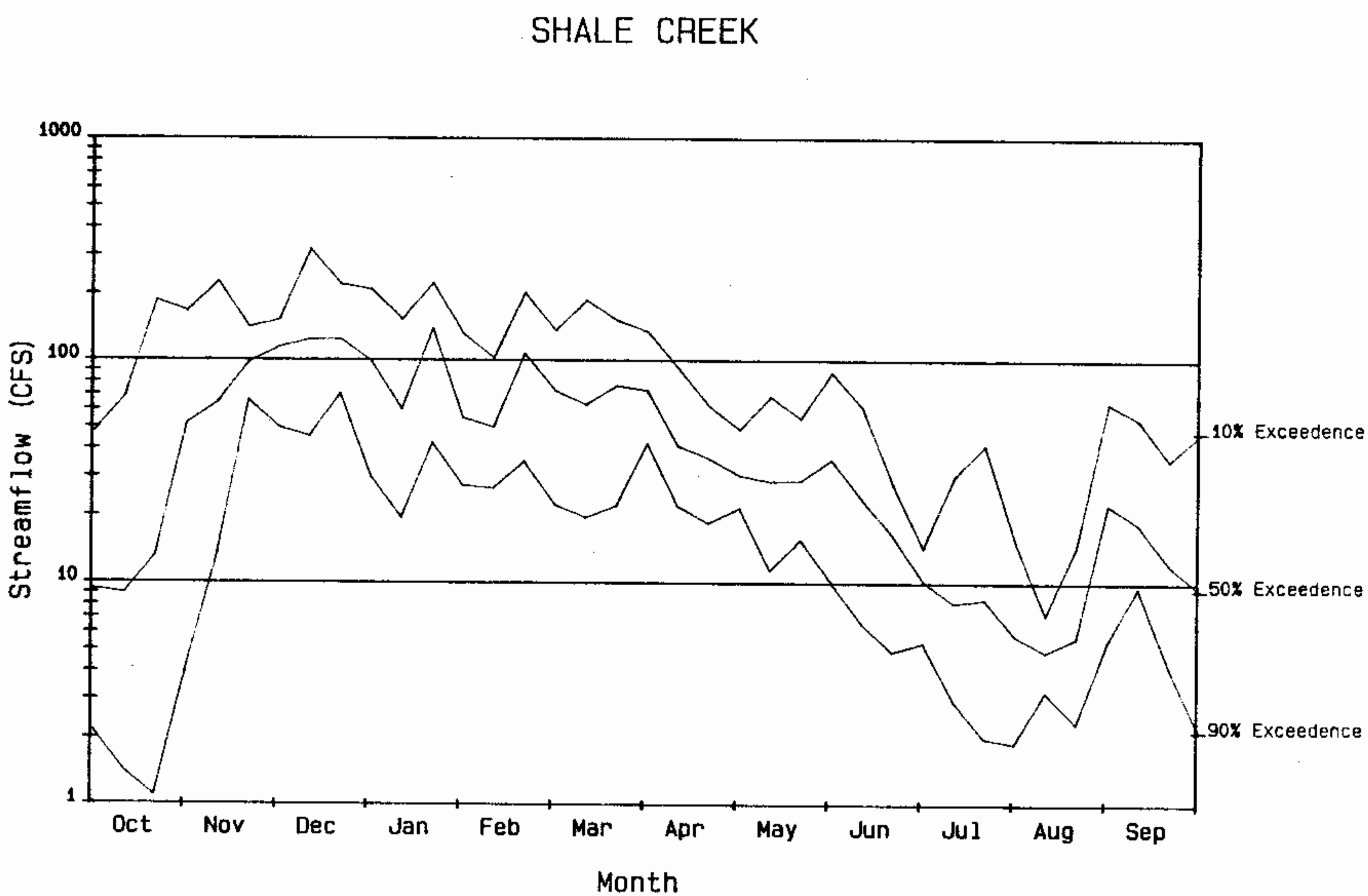

Figure 4. Exceedence-frequency hydrograph for Shale Creek, period October 1973 - September 1978.

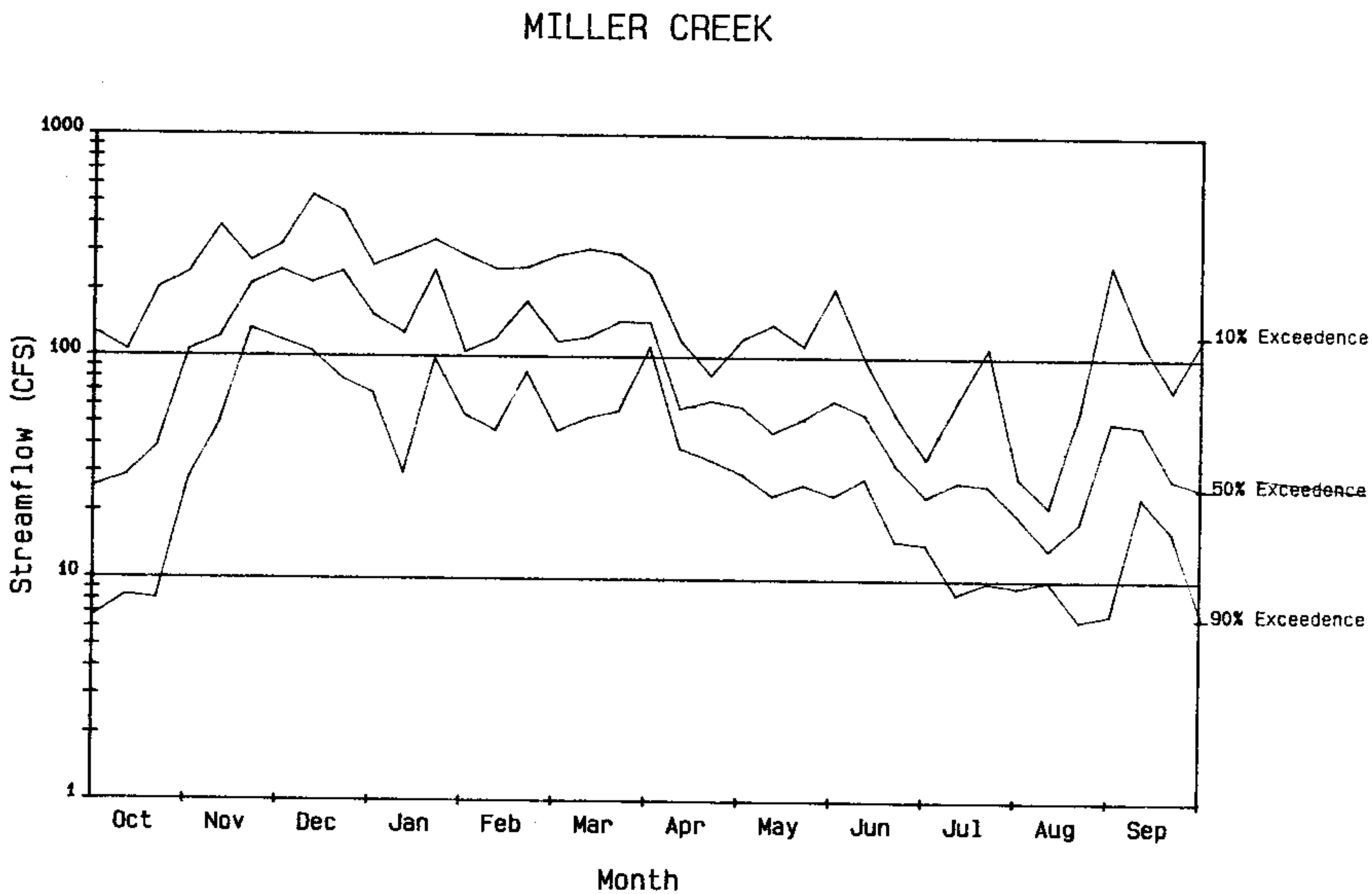

Figure 5. Exceedence-frequency hydrograph for West Fork Miller Creek, period October 1973 - September 1978.

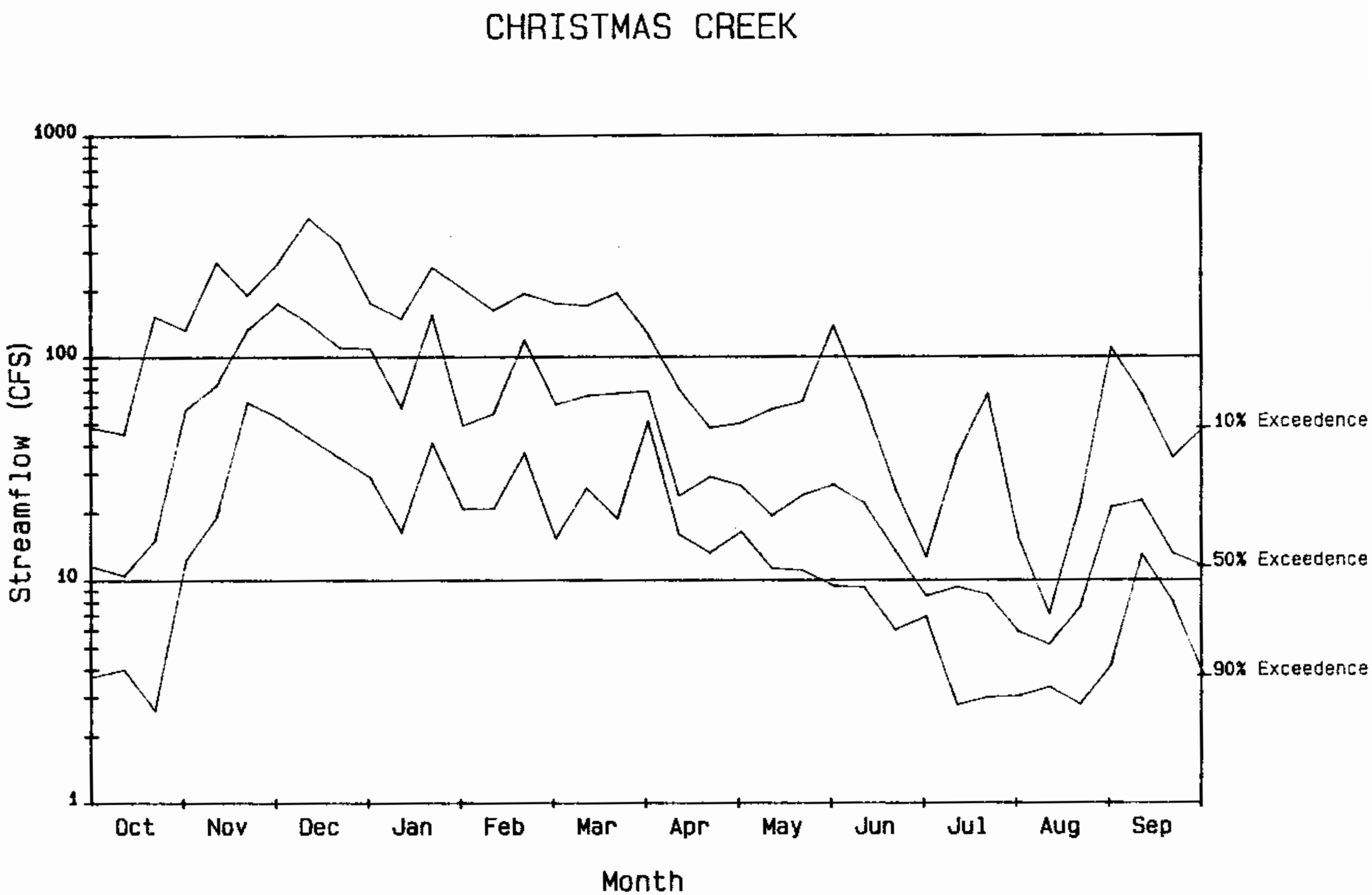

Figure 6. Exceedence-frequency hydrograph for Christmas Creek, period October 1973 - September 1978.

these streams should be used with caution.

The authors were unable to uncover any stream gauge data for Peterson Creek. However, Wooldridge et al. (1975) collected stream flow information on Bull Creek from October 1973 through September 1974 (Table 1). Unfortunately, this period of record is not adequate to develop a meaningful exceedence-frequency hydrograph.

BULL CREEK
BASIN AREA =1470 ACRES

DISCHARGE IN CUBIC FEET PER SECOND WATER YEAR OCTOBER 1973 TO SEPTEMBER 1974

DAY	OCT.	NOV.	DEC.	JAN.	FEB.	MAR.	APRIL	MAY	JUNE	JULY	AUG.	SEPT.
1	0.3	6.1	51.1	5.2	46.4	32.1	49.6	11.3	13.5	2.7	4.1	2.0
2	0.3	5.9	61.7	3.8	50.0	23.0	46.4	9.8	12.8	2.5	4.0	2.0
3	0.3	5.8	98.0	3.0	136.2	16.3	39.4	8.3	26.6	6.3	3.8	4.8
4	0.3	7.4	55.3	2.3	75.9	27.8	31.3	7.5	45.3	5.4	3.5	2.3
5	0.3	8.4	20.4	2.1	32.0	36.6	37.2	7.1	36.5	3.5	3.3	1.1
6	0.3	6.7	82.6	2.5	18.2	23.3	51.6	8.2	27.9	3.0	3.1	1.1
7	0.3	11.4	89.9	2.7	16.9	15.1	42.1	7.6	22.5	2.7	2.9	1.1
8	0.5	10.9	33.7	2.6	16.2	16.9	26.1	7.0	18.2	2.6	2.8	20.3
9	0.4	49.1	15.7	2.4	12.0	91.2	16.4	10.8	15.3	5.4	2.7	12.6
10	0.4	50.3	16.6	2.2	9.2	131.4	14.0	13.6	13.1	23.6	2.6	6.0
11	0.5	40.6	113.3	2.1	7.5	72.3	41.6	19.5	11.5	26.1	2.5	3.7
12	8.0	47.6	214.4	31.9	8.2	51.7	25.4	18.2	10.1	22.8	2.4	2.8
13	42.9	60.0	175.7	158.4	31.6	38.0	15.0	16.8	8.9	14.3	2.3	2.4
14	2.7	69.8	82.3	215.8	63.1	28.1	11.4	42.5	8.0	10.9	2.2	2.1
15	1.0	51.2	529.9	119.1	39.2	135.3	9.3	30.7	7.2	12.6	2.2	1.9
16	0.9	43.8	181.7	106.0	38.2	219.4	7.8	24.0	6.5	20.8	2.1	1.7
17	0.9	25.2	66.0	40.1	27.1	91.4	5.6	19.0	5.9	55.5	2.1	1.5
18	1.0	19.9	36.9	95.0	31.7	47.8	4.6	15.4	5.5	31.2	2.1	1.4
19	0.9	39.1	16.1	57.5	38.1	31.0	4.4	13.5	4.8	20.8	2.1	1.3
20	5.5	45.3	32.1	31.5	30.0	21.1	4.9	11.6	4.6	15.9	2.1	1.3
21	2.4	25.6	24.8	39.6	29.4	15.6	3.8	10.2	4.3	12.8	2.0	1.2
22	1.5	17.1	18.3	65.6	22.1	11.6	9.4	13.9	4.0	11.5	2.0	1.2
23	1.7	47.7	19.0	76.6	18.7	8.9	8.9	69.1	3.8	9.6	2.3	1.2
24	11.7	46.0	69.7	100.9	23.1	5.9	7.3	94.9	3.6	8.3	2.1	1.1
25	6.4	72.0	30.0	89.4	39.6	7.4	5.6	113.5	3.8	7.4	2.0	1.1
26	4.4	42.2	15.2	55.9	32.0	20.1	4.7	76.2	4.9	6.7	2.0	1.1
27	9.0	104.7	12.7	54.4	23.5	33.6	3.9	46.8	4.3	6.0	2.0	1.1
28	25.5	110.0	13.7	32.5	33.0	100.0	3.2	32.6	3.3	5.6	2.0	1.1
29	14.5	52.5	9.1	35.0		62.4	2.7	24.6	2.9	5.2	2.0	1.1
30	18.6	34.1	5.8	29.7		37.1	2.5	19.2		4.8	2.0	1.1
31	9.7		3.4	54.6		28.7		15.9		4.3	2.0	
MEAN	5.6	38.5	70.8	49.1	33.9	47.8	17.9	26.4	11.5	12.0	2.5	2.8
MAX	156.4	218.4	1098.3	226.3	230.4	308.9	60.7	132.3	72.2	71.1	4.2	61.4
MIN	0.3	5.2	2.5	2.0	7.3	4.7	2.3	6.7	2.7	2.4	1.9	1.1
IN	2.8	18.7	35.5	24.6	15.4	24.0	8.7	13.3	5.6	6.0	1.3	1.4

Table 1. Average daily flows for Bull Creek from October 1973 to September 1974 (from Wooldridge et al. 1975).

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3	0.3	5.8	98.0	3.0	136.2	16.3	39.4	8.3	26.6	6.3	3.8	4.8
4	0.3	7.4	55.3	2.3	75.9	27.8	31.3	7.5	45.3	5.4	3.5	2.3
5	0.3	8.4	20.4	2.1	32.0	36.6	37.2	7.1	36.5	3.5	3.3	1.1
6	0.3	6.7	82.6	2.5	18.2	23.3	51.6	8.2	27.9	3.0	3.1	1.1
7	0.3	11.4	89.9	2.7	16.9	15.1	42.1	7.6	22.5	2.7	2.9	1.1
8	0.5	10.9	33.7	2.6	16.2	16.9	26.1	7.0	18.2	2.6	2.8	20.3
9	0.4	49.1	15.7	2.4	12.0	91.2	16.4	10.8	15.3	5.4	2.7	12.6
10	0.4	50.3	16.6	2.2	9.2	131.4	14.0	13.6	13.1	23.6	2.6	6.0
11	0.5	40.6	113.3	2.1	7.5	72.3	41.6	19.5	11.5	26.1	2.5	3.7
12	8.0	47.6	214.4	31.9	8.2	51.7	25.4	18.2	10.1	22.8	2.4	2.8
13	42.9	60.0	175.7	158.4	31.6	38.0	15.0	16.8	8.9	14.3	2.3	2.4
14	2.7	69.8	82.3	215.8	63.1	28.1	11.4	42.5	8.0	10.9	2.2	2.1
15	1.0	51.2	529.9	119.1	39.2	135.3	9.3	30.7	7.2	12.6	2.2	1.9
16	0.9	43.8	181.7	106.0	38.2	219.4	7.8	24.0	6.5	20.8	2.1	1.7
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21	2.4	25.6	24.8	39.6	29.4	15.6	3.8	10.2	4.3	12.8	2.0	1.2
22	1.5	17.1	18.3	65.6	22.1	11.6	9.4	13.9	4.0	11.5	2.0	1.2
23	1.7	47.7	19.0	76.6	18.7	8.9	8.9	69.1	3.8	9.6	2.3	1.2
24	11.7	46.0	69.7	100.9	23.1	5.9	7.3	94.9	3.6	8.3	2.1	1.1
25	6.4	72.0	30.0	89.4	39.6	7.4	5.6	113.5	3.8	7.4	2.0	1.1
26	4.4	42.2	15.2	55.9	32.0	20.1	4.7	76.2	4.9	6.7	2.0	1.1
27	9.0	104.7	12.7	54.4	23.5	33.6	3.9	46.8	4.3	6.0	2.0	1.1
28	25.5	110.0	13.7	32.5	33.0	100.0	3.2	32.6	3.3	5.6	2.0	1.1
29	14.5	52.5	9.1	35.0		62.4	2.7	24.6	2.9	5.2	2.0	1.1
30	18.6	34.1	5.8	29.7		37.1	2.5	19.2		4.8	2.0	1.1
31	9.7		3.4	54.6		28.7		15.9		4.3	2.0	
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MIN	0.3	5.2	2.5	2.0	7.3	4.7	2.3	6.7	2.7	2.4	1.9	1.1
IN	2.8	18.7	35.5	24.6	15.4	24.0	8.7	13.3	5.6	6.0	1.3	1.4

Table 1. Average daily flows for Bull Creek from October 1973 to September 1974 (from Wooldridge et al. 1975).

II. METHODS OF STUDY

The IFIM was selected for this study as the best available methodology for predicting changes in the amount of steelhead trout habitat at various streamflows.

Description of the Instream Flow Incremental Methodology

The IFIM was developed by the U. S. Fish and Wildlife Service in the 1970's as a tool to assist water and resource managers to estimate impacts of water development or other projects. The IFIM allows for a systematic evaluation of different management options by providing quantitative estimates of fish habitat available under each option (Bovee 1982).

The IFIM begins with a five step scoping process: (1) define the problem and the objectives; (2) determine the geographic boundaries of the study area; (3) determine the environmental variables that must be studied and those variables that may be safely excluded from analysis; (4) select the evaluation species; and (5) determine the lifestages and types of microhabitat that must be evaluated for each month (Bovee 1982). The scoping process is assisted by convening a meeting of the parties with interest in the IFIM study to discuss each of the steps above. Once agreement is reached, field data collection is begun using generally standardized techniques (see Trihey and Wegner 1981).

The basic habitat accounting unit is referred to as the river segment and is identified during the scoping process. The river segment is a relatively long reach of stream that exhibits homogeneity in channel characteristics and flow regime (Bovee 1982). Within each river segment, study sites and transects are located. Measurements of physical microhabitat parameters including water depth, velocity, substrate, and cover are made at intervals along each transect at usually one or three different flows. The point on a transect at which a measurement is made is referred to as a vertical (Bovee 1982). Each vertical delineates a stream cell.

An hydraulic model, commonly referred to as IFG4, is generated using the field data to simulate changes in each of the variables noted above for each cell as a function of discharge (Bovee and Milhous 1978). Discharge and channel structure combine to delimit the range of physical microhabitat conditions available to each species (Bovee 1982). Other program options are also available.

A biological model is also developed. The biological model consists of habitat-use curves delineating the preference of each species and lifestage for depth, velocity, substrate, and cover. The use of substrate and cover involves the development of a numerical code to describe the numerous types and combinations of the two characteristics, and a curve to depict the preferences of the species for each combination (Bovee 1982).

Once the hydraulic and biological models are constructed, they are combined in a collection of computer programs referred to as the physical habitat simulation (PHABSIM) system. PHABSIM is based on the principles that: (1) each species and lifestage exhibits preferences within a range of physical conditions; (2) these ranges can be defined; and (3) the area of stream containing these conditions can be quantified as a function of discharge and channel structure (Bovee 1982).

PHABSIM estimates a joint preference of a species lifestage for each cell by the multiplication of the weighting factors (preferences) for each variable and the area of that cell at each flow. For example (modified from Caldwell and Hirschey 1989), a velocity preference of 1.0 multiplied times a depth preference of 0.9 times a substrate/cover preference of 0.8 generates a preference factor of 0.72 for that cell at a specific flow. If the area of the cell is 2 square feet, the amount of habitat available for that cell is 0.72 times 2 square feet which equals 1.44 square feet. This result is summed with the habitat available in all of the other cells at all transects. PHABSIM lists the results for each flow in terms of square feet of habitat per 1,000 feet of stream, referred to as Weighted Useable Area (WUA). The total amount of habitat available for a given flow, species and lifestage in a river segment with multiple study sites is computed by (from Bovee 1982):

$$HA = WUA_1 \times L_1 + WUA_2 \times L_2 + \ldots WUA_n \times L_n$$

where: HA = total habitat area in ft^2 or m^2

WUA_1 = weighted useable area per unit length of stream represented by the first study site

L_1 = the length of stream represented by the first study site

WUA_n = weighted useable area per unit length of stream represented by the n^{th} study site

L_n = the length of stream represented by the n^{th} study site

Study Site and Transect Selection

Hurst, Shale, Miller, Christmas, Peterson, and Bull creeks were selected for study primarily because extensive anadromous salmonid weir trapping data was available for these streams.

Preliminary analysis of this data indicated that some of the streams annually produce more steelhead smolts (2+ year class) than parrs (1+ year class), some more parrs than smolts, and others that may only act as rearing areas for relatively small numbers of immigrants. To distinguish between movement out of a stream and movement just within a stream, only streams that had weir traps located near their mouths were selected for study. For this reason, the Snahapish River, another Clearwater River tributary that has been extensively trapped, was not selected for study using the IFIM.

During the period May to October 1987, a large portion of each of the six streams was surveyed. Although known or suspected adult steelhead migration barriers were encountered, surveys often continued for some distance above these locations since it was beyond the scope of this study to verify migration barriers. The distance (number of paces) of riffles, pools, and runs were noted during the surveys. Individual sites within each stream were later selected based on the ability of that site to represent habitat types within the corresponding stream reach being modeled and on the site's accessibility. Figure 1 identifies site locations and reach boundaries.

Field Procedures

Measurements of water surface elevations, stream bank profiles, water depths, velocities, and substrate composition at each site were begun in the summer of 1988. Water surface elevations and stream bank profiles were determined using a tripod mounted transit level and stadia rod. Survey points were referenced to an arbitrary bench mark. Mean column cell velocities were measured using a Swoffer velocity meter with a top-set wading rod. Substrate composition was determined by visually estimating the amount (percent) of the two dominant particle size classes according to a scale recommended by the Washington Department of Wildlife (Table 2).

Site Descriptions and Conditions During Measurements

All site descriptions are based on field observations during low flow periods. Characterizations of stream habitat as riffle, run or glide could change at higher flows.

Lower Hurst Creek Site (RM 0.6)

The lower Hurst Creek site represents the stream from RM 0.0 to RM 0.8 (Table 3). The stream in this reach was composed of 52% pools, 32% riffles, and 16% runs (Table 4). The substrate at the site was primarily cobble and gravel with some bedrock located at transect 6. Transects 1 and 2 represented shallow runs, transects 3 and 4 riffles, transect 5 a pool, and transect 6

Table 2. Substrate code adapted from Washington Department of Wildlife's substrate and cover code dated April 17, 1990.

The three-digit code used describes the dominant substrate (the first number), the subdominant substrate substrate (the second number), and the percent of only the dominant substrate (the third number). The percent of the subdominant substrate can be determined by substraction. Dominant substrate is determined by the largest quantity of a certain substrate, not by the size of the substrate. The sum of the percent dominant and the percent subdominant substrate will total 100 percent. The coding will not allow the dominant percent to be less than 50 percent, or greater than 90 percent. All other preference values are determined by using weighted averages. The value of the dominant substrate is multiplied by the percent of the dominant substrate substrate, and the product is added to the product of the subdominant substrate times the percent of the subdominant substrate. The sum of all the codes observed times their preference value will be a value between 0.0 and 1.0. Where there is a situation where addition of two values could equal more than 1.0, the value will default to 1.0.

Code	Substrate Size (inches)	Steelhead Life Stage and Value of Substrate		
		Spawning	Fry	Parr
0 Detritus		0	.1	.1
1 Silt, clay		0	.1	.1
2 Sand		0	.1	.1
3 Small Gravel	0.1-0.5	.5	1.0	.1
4 Medium Gravel	0.5-1.5	1.0	1.0	.2
5 Large Gravel	1.5-3.0	1.0	1.0	.3
6 Small Cobble	3.0-6.0	1.0	1.0	.5
7 Large Cobble	6.0-12.0	.3	1.0	.7
8 Boulder		0	1.0	1.0
9 Bedrock		0	.1	.3
0.1 Undercut Bank		---	1.0	1.0
0.3 Rootwad		---	1.0	1.0

Table 3. IFIM sites, stream miles the site represents (River Reach), site location (River Mile), site length, approximate site slope, and the number of transects in each site.

Site Name	River Reach	River Mile	Site Length (ft.)	Site Slope (%)	Number Transects
Hurst Creek (Lower)	0.0-0.8	0.6	293.9	0.35	6
Hurst Creek (Upper)	0.8-1.2	0.9	111.7	0.90	7
Shale Creek	0.0-1.5	0.8	323.1	0.63	9
Miller Creek (Lower)	0.3-1.0	0.8	110.5	1.43	5
Miller Creek (Middle)	1.0-2.0	1.5	222.4	0.89	6
Miller Creek (Upper)	2.0-3.0	2.9	100.3	1.02	5
Christmas Creek (Lower)	0.0-1.5	0.2	178.4	0.50	4
Christmas Creek (Middle)	1.5-3.2	3.0	217.0	0.37	6
Christmas Creek (Upper)	3.2-4.8	4.4	140.0	1.84	5
Peterson Creek	0.0-0.5	0.1	37.2	2.72	4
Bull Creek	0.0-0.4	0.2	40.0	1.76	4

Table 4. Percent of pool, riffle, and run stream habitat for each stream reach during low flow conditions.

Site Name	River Miles	Percent Pool	Percent Riffle	Percent Run
Hurst Creek (Lower)	0.0-0.8	52	32	16
Hurst Creek (Upper)	0.8-1.2	53	35	12
Shale Creek	0.0-1.5	48	38	15
Miller Creek (Lower)	0.3-1.0	33	42	25
Miller Creek (Middle)	1.0-2.0	53	35	12
Miller Creek (Upper)	2.0-3.0	45	37	18
Christmas Creek (Lower)	0.0-1.5	44	37	19
Christmas Creek (Middle)	1.5-3.2	45	42	13
Christmas Creek (Upper)	3.2-4.8	44	42	14
Peterson Creek	0.0-0.5	28	63	10
Bull Creek	0.0-0.4	38	45	17

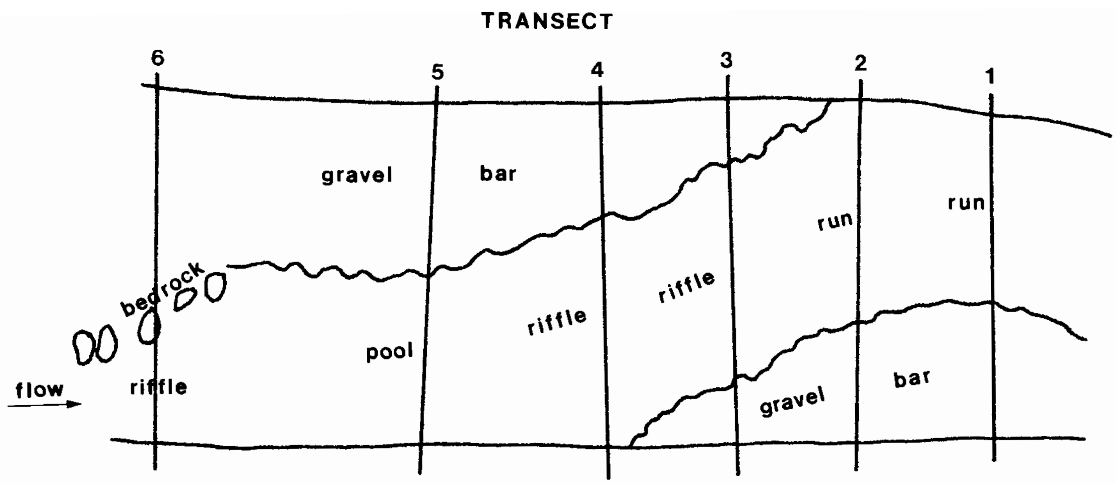

Figure 7. Site and transect map of the lower Hurst Creek site.

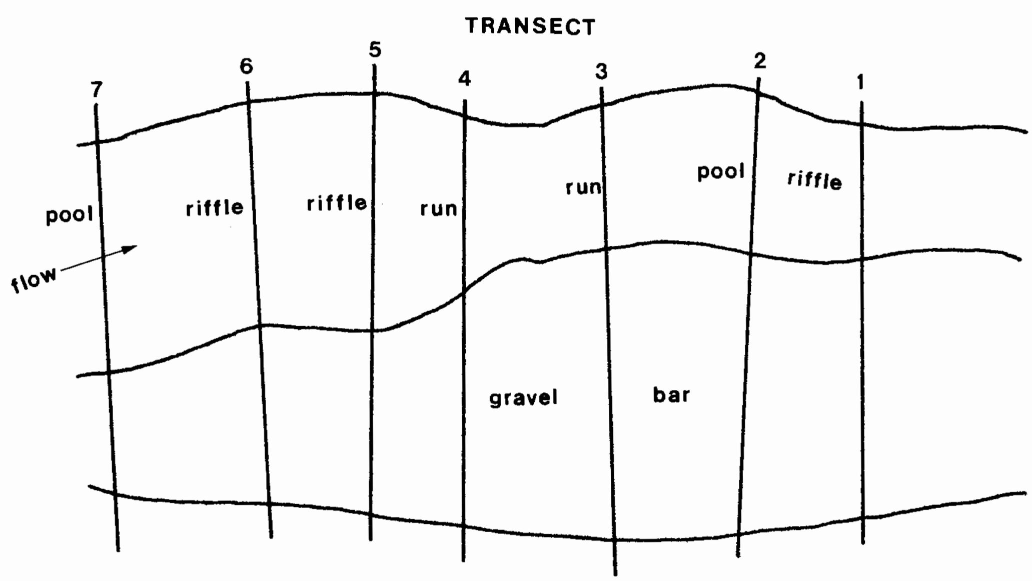

Figure 8. Site and transect map of the upper Hurst Creek site.

Table 5. Measured calibration flows and dates (in parentheses) of measurements for each IFIM site.

Site Name	Mean Relative Flow		
	Low	Medium	High
Hurst Creek (Lower)	(8-2-88) 2.27	(11-16-88) 43.87	(11-7-88) 92.33
Hurst Creek (Upper)	(8-1-88) 1.65	(11-16-88) 33.32	(1-11-89 86.78
Shale Creek	(8-9-88) 3.38	(11-17-88) 33.50	(1-20-89) 71.58
Miller Creek (Lower)	(8-3-88) 5.85	(12-1-88) 61.36	(1-11-89) 93.67
Miller Creek (Middle)	(8-3-88) 5.29	(12-2-88) 82.13	(1-19-89) 126.08
Miller Creek (Upper)	(8-2-88) 3.71	(12-1-88) 38.73	(12-22-88) 56.74
Christmas Creek (Lower)	(8-5-88) 5.40	(11-30-88) 66.21	(12-29-88) 144.18
Christmas Creek (Middle)	(8-4-88) 5.03	(12-3-88) 65.08	(1-5-89) 138.81
Christmas Creek (Upper)	(8-4-88) 4.16	(12-3-88) 42.71	(1-4-89) 153.67
Peterson Creek	(11-18-88) 3.62	(12-16-88) 5.92	(11-8-88) 15.31
Bull Creek	(8-8-88) 0.03	(12-21-88) 1.79	(11-8-88) 15.76

another riffle (Figure 7). Measured flows were 2.27, 43.87, and 92.33 cfs (Table 5).

Upper Hurst Creek Site (RM 0.9)

The upper Hurst Creek site was located just upstream of Boulder Creek and represents the stream from RM 0.8 to RM 1.2 (Table 3). The stream in this reach was composed of 53% pools, 35% riffles, and 12% runs (Table 4). The substrate at the site was primarily cobble, boulder, and gravel. Transect 1 represents a riffle, transect 2 a pool, transects 3 and 4 runs, transects 5 and 6 riffles, and transect 7 a pool (Figure 8). Measured flows were 1.65, 33.32, and 86.78 cfs (Table 5).

Shale Creek Site (RM 0.8)

The Shale Creek site is located above the adult capture and juvenile imprinting facility. The site represents the stream from RM 0.0 to RM 1.5 (Table 3). The stream in this reach was composed of 48% pools, 38% riffles, and 15% runs (Table 4). The substrate at the site was primarily boulder and cobble with gravel scattered throughout. Transect 1 represents a shallow run, transect 2 a riffle, transect 3 a shallow pool, transect 4 a deeper run, transect 5 a riffle, transect 6 a deeper pool, transect 7 a deeper run, transect 8 a shallow run, and transect 9 a deep pool (Figure 9). Measured flows were 3.38, 33.50, and 71.58 cfs (Table 5).

Lower Miller Creek Site (RM 0.8)

The lower Miller Creek site is located on the West Fork of Miller Creek above the downstream migrant weir trap position. The site represents Miller Creek from RM 0.3 (confluence of the West and East forks) to RM 1.0 (Table 3). The stream in this reach was composed of 33% pools, 42% riffles, and 25% runs (Table 4). The substrate at the site was primarily boulder and cobble with bedrock at transect 4. Transect 1 represents a shallow run, transects 2 and 3 riffles, transect 4 a deeper run, and transect 5 a pool (Figure 10). Measured flows were 5.85, 61.36, and 93.67 cfs (Table 5).

Middle Miller Creek Site (RM 1.5)

The middle Miller Creek site, also on the West Fork, represents the stream from RM 1.0 to RM 2.0 (Table 3). The stream in this reach was composed of 53% pools, 35% riffles, and 12% runs (Table 4). The substrate at the site was primarily composed of cobble, boulder, and gravel. Transect 1 represented a riffle, transect 2 a narrow pool, transect 3 a riffle, transect 4 a broader pool, transect 5 another riffle, and transect 6 another run (Figure 11). A large, fallen log crossed the stream between transects 4 and 5 but did not intersect the water surface. Measured flows

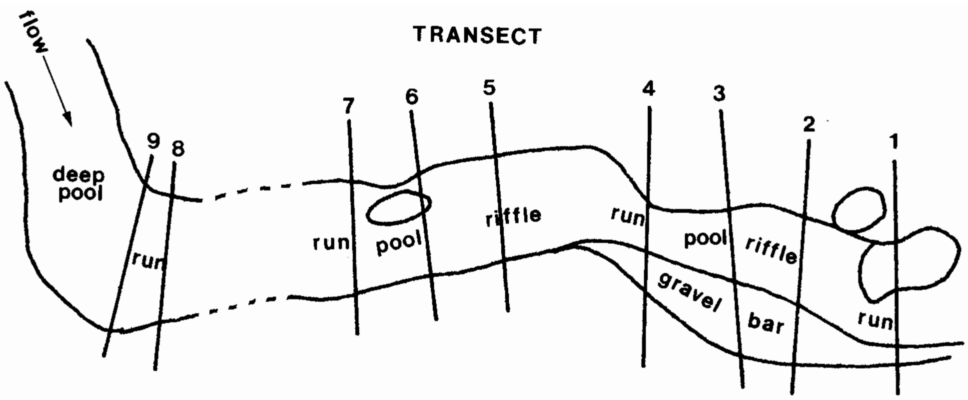

Figure 9. Site and transect map of the Shale Creek site.

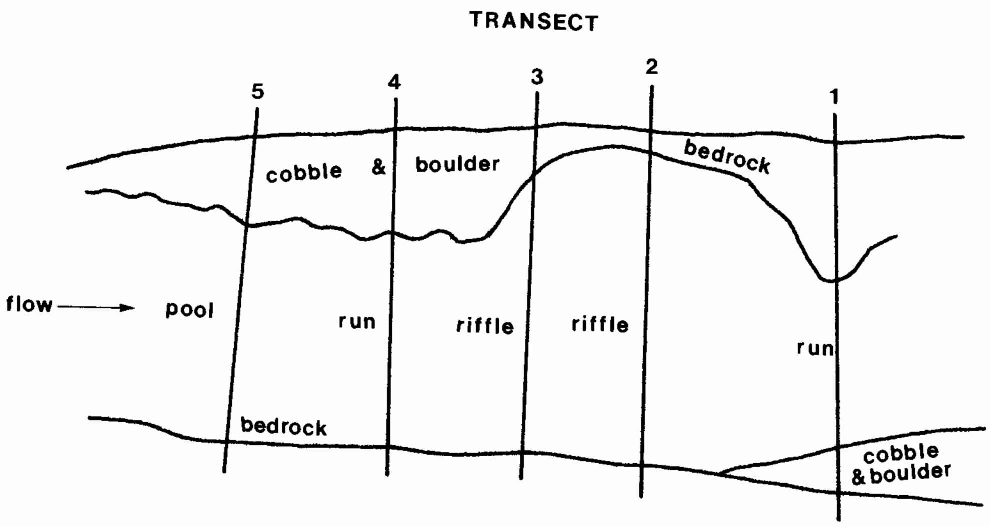

Figure 10. Site and transect map of the lower Miller Creek site.

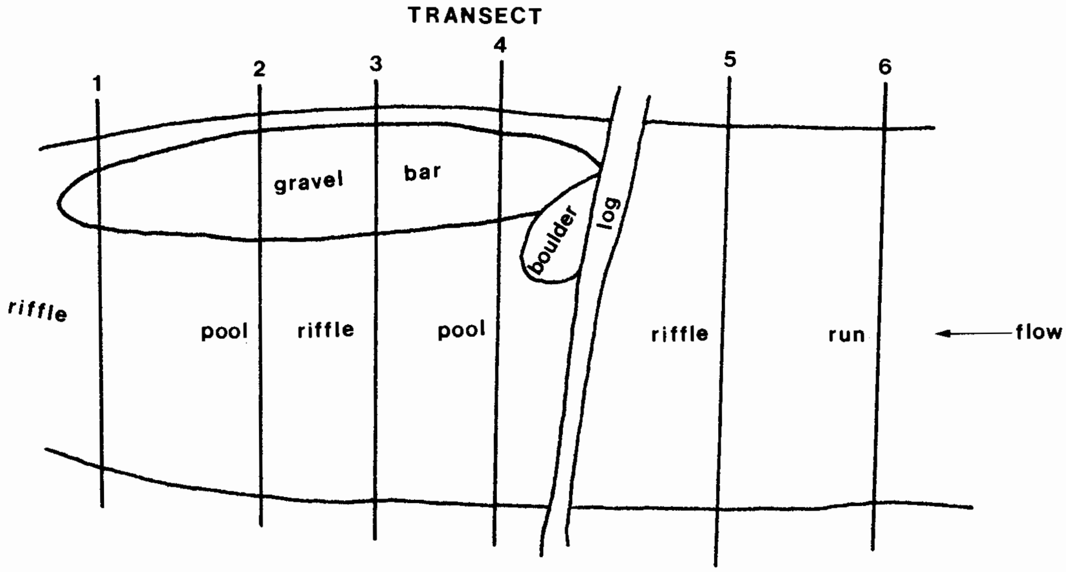

Figure 11. Site and transect map of the middle Miller Creek site.

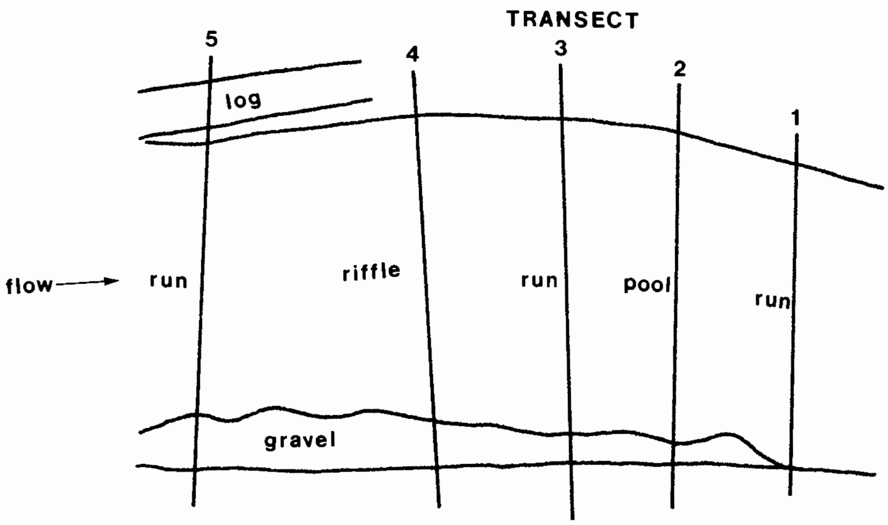

Figure 12. Site and transect map of the upper Miller Creek site.

were 5.29, 82.13, and 126.08 cfs (Table 5).

Upper Miller Creek Site (RM 2.9)

The upper Miller Creek site, on the West Fork, represents the stream from RM 2.0 to RM 3.0 (Table 3). The stream in this reach was composed of 45% pools, 37% riffles, and 18% runs (Table 4). The substrate at the site was mostly boulder and cobble. Transect 1 represents a deep run, transect 2 a pool, transect 3 a shallower run, transect 4 a riffle, and transect 5 a shallow run (Figure 12). Measured flows were 3.71, 38.73, and 56.74 cfs (Table 5).

Lower Christmas Creek Site (RM 0.2)

The lower Christmas Creek site represents the stream from RM 0.0 to RM 1.5 (Table 3). The stream in this reach was composed of 44% pools, 37% riffles, and 19% runs (Table 4). The substrate at the site was primarily cobble and boulder with gravel throughout and some bedrock at transect 1. Transect 1 represents a run, transect 2 a pool, transect 3 a riffle, transects 3 and 4 riffles, transect 5 a shallow pool, and transect 6 a run (Figure 13). Measured flows were 5.40, 66.21, and 144.18 cfs (Table 5).

Middle Christmas Creek Site (RM 3.0)

The middle Christmas Creek site represents the stream from RM 1.5 to RM 3.2 (Table 3). The stream in this reach was composed of 45% pools, 42% riffles, and 13% runs (Table 4). The substrate at the site was primarily gravel and boulder in the lower transects but boulder and cobble in the upper transects. Transect 1 represents a riffle, transect 2 a shallow run, transect 3 a broad, deeper pool, transect 4 a shallow pool, transect 5 a deeper run, and transect 6 a riffle (Figure 14). Measured flows were 5.03, 65.08, and 138.81 cfs (Table 5).

Upper Christmas Creek Site (RM 4.4)

The upper Christmas Creek site represents the stream from RM 3.2 to RM 4.8 (Table 3). The stream in this reach was composed of 44% pools, 42% riffles, and 14% runs (Table 4). The substrate at the site was mostly cobble and boulder. Transect 1 represents a riffle, transect 2 a run, transect 3 a pool, transect 4 a riffle, and transect 5 a shallower run (Figure 15). Measured flows were 4.16, 42.71, and 153.67 cfs (Table 5).

Peterson Creek Site (RM 0.1)

The Peterson Creek site represents the stream from RM 0.0 to RM 0.5 (Table 3). The stream in this reach was composed of 28% pools, 63% riffles, and 10% runs (Table 4). The substrate at the site was mostly cobble and gravel. Transect 1 represents a

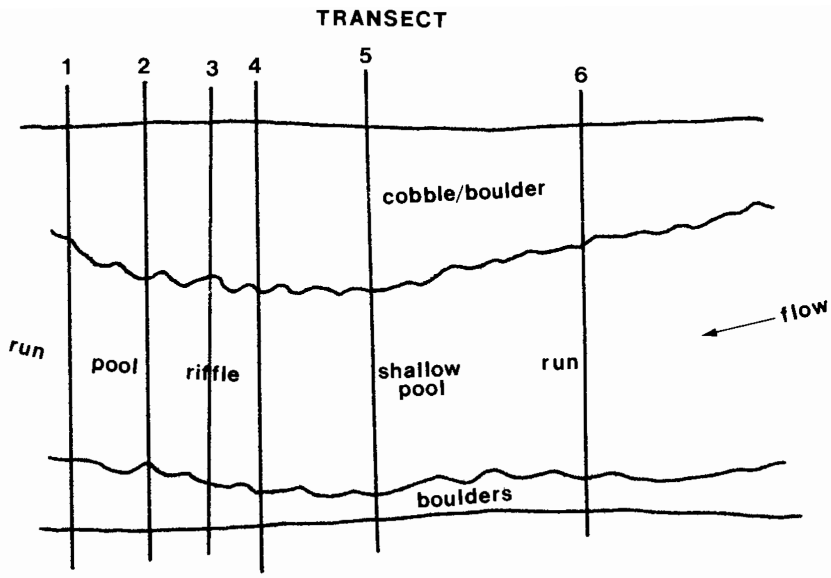

Figure 13. Site and transect map of the lower Christmas Creek site.

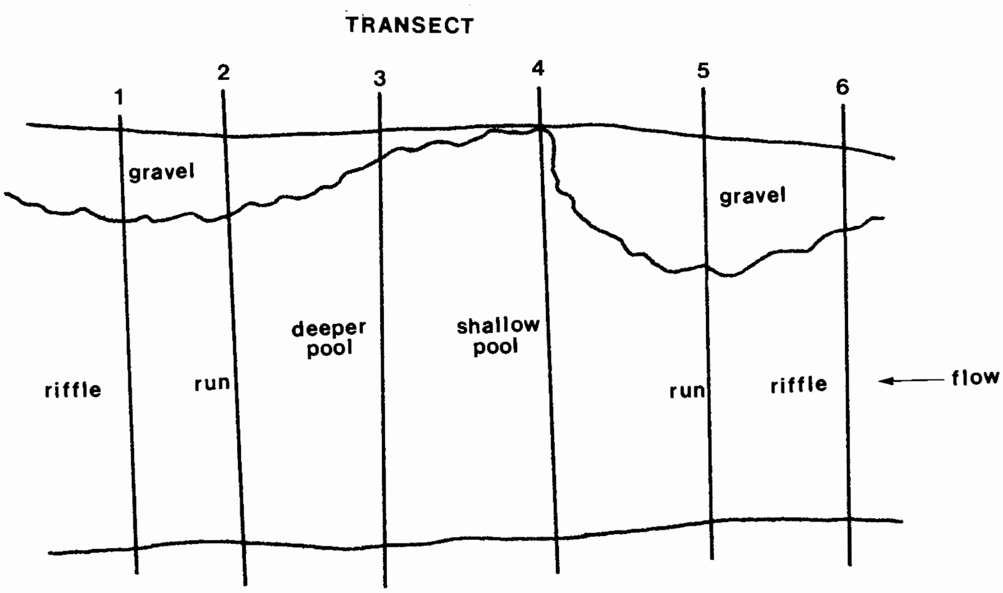

Figure 14. Site and transect map of the middle Christmas Creek site.

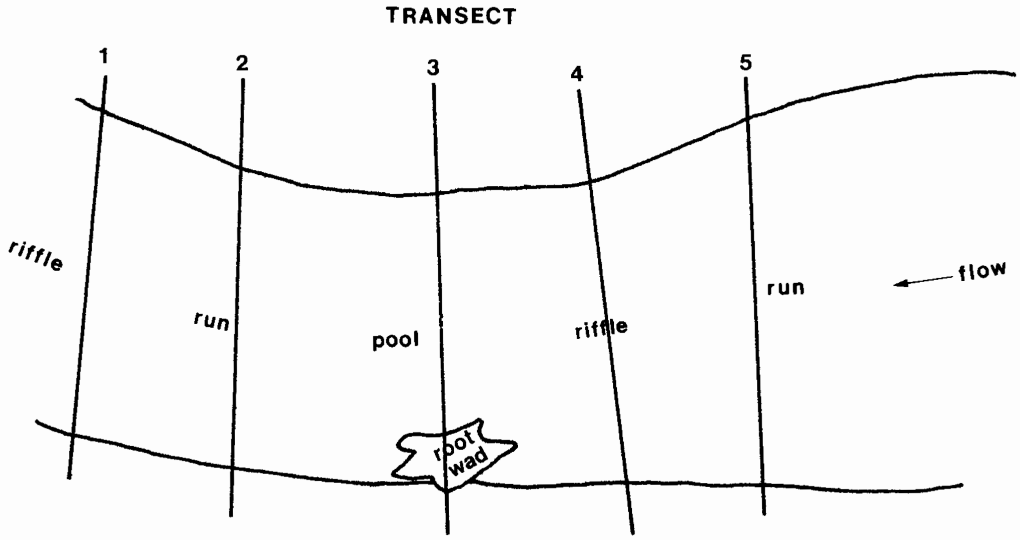

Figure 15. Site and transect map of the upper Christmas Creek site.

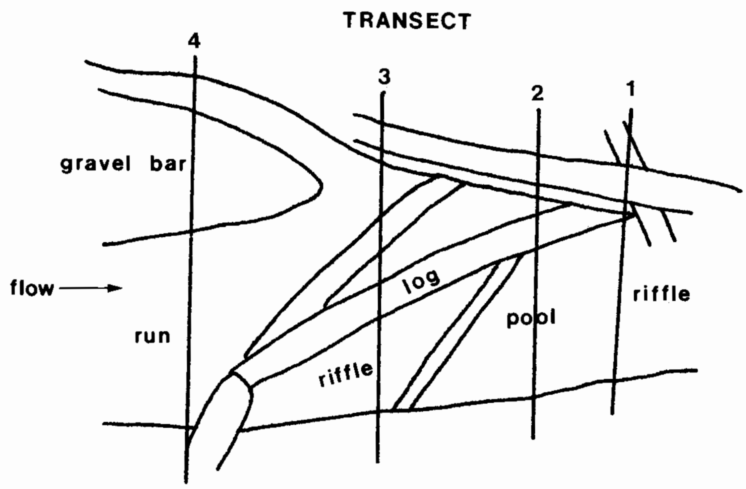

Figure 16. Site and transect map of the Peterson Creek site.

riffle, transect 2 a pool, transect 3 another riffle, and transect 4 a run (Figure 16). Many fallen logs crossed over the stream, from bank to bank. However, a couple of logs did angle into the stream and affected flow patterns at the higher flow. Measured flows were 3.62, 5.92, and 15.31 cfs (Table 5).

<u>Bull Creek Site (RM 0.2)</u>

The Bull Creek site represents the stream from RM 0.0 to RM 0.4 (Table 3). The stream in this reach was composed of 38% pools, 45% riffles, and 17% runs (Table 4). The substrate at the site was mostly gravel and cobble. Transect 1 represents a riffle, transect 2 a run, transect 3 pool, and transect 4 another riffle (Figure 17). Measured flows were 0.03, 1.79, and 15.76 cfs (Table 5). The stream flow was primarily subsurface at the lowest measured flow.

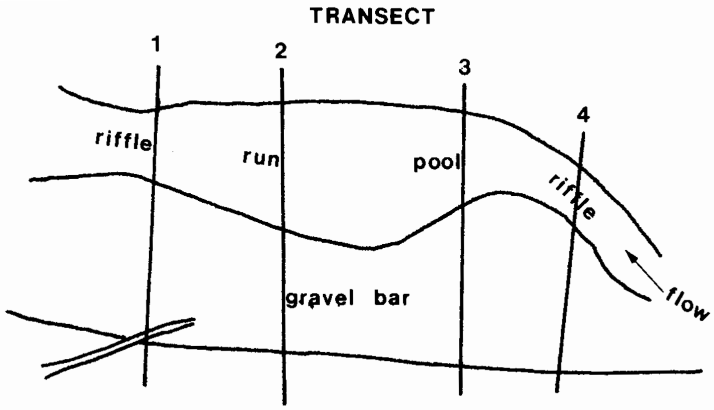

Figure 17. Site and transect map of the Bull Creek site.

III. HYDRAULIC MODEL

Calibration Philosophy

For one and two flow hydraulic models, as used in this report (no three-flow models were used), calibration primarily involves comparing the depths and velocities measured in the field to those predicted by the models. Depths and velocities at high and low flows are inspected to ascertain if they are reasonable.

Calibration consists of checking each cell for each transect and deciding whether the predicted cell velocity is accurate. When comparing predicted to measured velocities, the predicted velocity should generally be within 0.2 feet per second (fps) of the measured velocity; the 0.2 fps amount is within the normal range of velocity measurement error (Caldwell and Hirschey 1989). When examining the velocities of extrapolated flows above the highest measured flows, the predicted velocities should not exceed 16.0 fps (Beecher undated).

For this study, actual velocity field measurements were modified by no more than ± 0.2 fps in the two-flow hydraulic models when those changes significantly increased the accuracy of simulated velocities. Velocities were not modified in any of the one-flow models. Additionally, the roughness factor (Manning's N) was specified for, primarily, edge cells when it was necessary to "slow" water flows in those areas to more accurately reflect actual conditions.

A measurement of model accuracy is the Velocity Adjustment Factor (VAF). The VAF for a three-flow or two-flow model indicates whether the flow, for each transect, predicted from the velocity/discharge regressions matches the flow predicted from the stage/discharge regression (Caldwell and Hirschey 1989). The VAF is multiplied times the velocities predicted from the velocity/discharge regressions to duplicate the flow predicted from the stage/discharge regression (Milhous undated). A VAF of 1.0 indicates both methods are predicting the same flow. A VAF in the range from 0.9 to 1.1 is considered good, 0.85 to 0.9 or 1.1 to 1.15 is fair, 0.80 to 0.85 or 1.15 to 1.20 is marginal, 0.70 to 0.80 or 1.20 to 1.30 is poor, and less than 0.70 or greater than 1.30 is very poor (Milhous et al. 1984).

The VAF range above does not pertain to VAFs generated in one-flow models. Instead of predicting velocities from a velocity/discharge regression as in the three-flow or two-flow IFG4, the velocities are predicted via Manning's equation using a constant N (Caldwell and Hirschey 1989). Manning's N is highest at low flow and decreases as flow increases. Since the N estimated by the computer model is constant, the N value used to predict the velocities at higher flows will usually be too high.

The VAF will correct this error by modifying the predicted velocities to achieve the flow predicted in the stage/discharge regression (Caldwell and Hirschey 1989). The VAF for a one-flow model should essentially be 1.0 at the measured flow and usually less than 1.0 for lower flows and greater than 1.0 for higher flows.

Options Used in Hydraulic Model

Over 20 options are available for the IFG4 (see Milhous et al. 1989). For this study, only the standard method, setting all options to zero except for option eight which is set at two, was used.

Site Specific Calibration

In the three-flow IFG4, the range of flows used should generally be spaced such that the next highest flow measured is twice the next lowest (i.e., Q, 2Q, 4Q; where Q = flow). For the most part, the flows measured for each site did not meet this criteria, particularly the low flows. As a result, both three-flow and one-flow IFG4 models did not adequately predict discharge. Additionally, even when a three-flow IFG4 model did adequately predict streamflow over the range of flows measured, the cell velocity predictions were often in error. Therefore, either two two-flow, a two-flow and a one-flow, or three one-flow IFG4 models were used in combination for each site to achieve accurate flow and velocity predictions. However, it was necessary to include only two discharge and water surface elevations (high and medium or medium and low) in the one-flow models to allow more accurate model predictions.

It is recognized that a two-flow IFG4 model may produce erroneous results when it is extrapolated much beyond the calibration flows used in the model. However, with appropriate calibration of the two-flow hydraulic model and with a conservative limitation on the extrapolation range, the two-flow model should produce reasonable results.

It should be noted that many cell velocities in some sites were increased from 0.0 to 0.02 or 0.05 cfs during calibration. These cells were wetted during field measurements but no velocities were measured. Although the fewest possible modifications should be made during calibration, the changes above represented minimal cell velocity increases while substantially increasing the ability of the IFG4 models to accurately simulate cell velocities.

Lower Hurst Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix A.

For the High-Medium flow model, the worst VAFS are 1.003 for 43 cfs, 0.991 for 92 cfs, and 0.915 for 150 cfs. The velocity and depth predictions are adequate for the extrapolation range of 43 to 150 cfs. VAFS drop as low as 0.811 at a flow of 230 cfs. Extrapolation to 230 cfs is not recommended.

For the Medium-Low flow model, the worst VAFS are 0.950 at 2.0 cfs and 0.991 at 44 cfs. The velocity and depth predictions are adequate for the extrapolation range of 2 to 44 cfs.

Upper Hurst Creek Site Calibration

Two one-flow (High and Medium) and one two-flow (Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix B.

For the High flow model, the worst VAFS are 0.768 at 60 cfs and 1.540 at 150 cfs. The High flow model is adequate for the extrapolation range of 60 to 150 cfs. Extrapolation beyond 150 cfs is not recommended.

For the Medium flow model, the worst VAFS are 0.991 at 37.0 cfs and 1.122 at 60 cfs. The velocity and depth predictions are adequate for the extrapolation range of 37 to 60 cfs.

For the Medium-Low flow model, the worst VAFS are 1.042 at 2 cfs and 0.948 at 37 cfs. The velocity and depth predictions are adequate for the extrapolation range of 2 to 37 cfs.

Shale Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix C.

For the High-Medium flow model, the worst VAFS are 0.954 for 34 cfs, 0.939 for 72 cfs, and 0.737 for 100 cfs. The velocity and depth predictions are adequate for the extrapolation range of 34 to 72 cfs. Extrapolation beyond 100 cfs should be made with caution.

For the Medium-Low flow model, the worst VAFS are 0.596 at 3.0 cfs, 1.226 at 10 cfs, and 0.947 at 34 cfs. Extrapolation to 3 cfs is not recommended. Extrapolation to 10 cfs should be done with caution.

Lower Miller Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix D.

For the High-Medium flow model, the worst VAFS are 0.962 for 61 cfs, 0.995 for 94 cfs, and 0.674 for 150 cfs. The velocity and depth predictions are adequate for the extrapolation range of 61 to 94 cfs. Extrapolation beyond 150 cfs is not recommended.

For the Medium-Low flow model, the worst VAFS are 0.945 at 6.0 cfs and 1.015 at 61 cfs. The velocity and depth predictions are adequate for the extrapolation range of 6 to 61 cfs.

Middle Miller Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix E.

For the High-Medium flow model, the worst VAFS are 0.873 for 74 cfs, 0.977 for 127 cfs, and 0.766 for 200 cfs. The velocity and depth predictions are adequate for the extrapolation range of 34 to 127 cfs. Extrapolation beyond 200 cfs should be made with caution.

For the Medium-Low flow model, the depth measurements from the low flow data set were used for Transect 5 instead of the high flow data set. This resulted in the depth measurement for 1 cell increasing by 0.4 feet, 2 by 0.2, and 1 by 0.1. Eleven cells were decreased by 0.1 feet, 10 by 0.2, 13 by 0.3, and 4 by 0.5. The depths for 8 cells did not change. The worst VAFS for this model are 0.965 at 5.0 cfs and 0.973 at 74 cfs. The velocity and depth predictions are adequate for the extrapolation range of 5 to 74 cfs.

Upper Miller Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix F.

For the High-Medium flow model, the worst VAFS are 0.916 for 34 cfs, 0.985 for 58 cfs, and 0.798 for 200 cfs. The velocity and depth predictions are adequate for the extrapolation range of 34 to 100 cfs.

For the Medium-Low flow model, the worst VAFS are 0.929 at 3.0 cfs and 1.013 at 34 cfs. The velocity and depth predictions are adequate for the extrapolation range of 3 to 34 cfs.

Lower Christmas Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix G.

For the High-Medium flow model, the worst VAFS are 0.928 for 66 cfs, 1.010 for 144 cfs, and 0.868 for 250 cfs. The velocity and depth predictions are adequate for the extrapolation range of 66 to 250 cfs.

For the Medium-Low flow model, the worst VAFS are 0.945 at 5.0 cfs and 1.064 at 66 cfs. The velocity and depth predictions are adequate for the extrapolation range of 5 to 66 cfs.

Middle Christmas Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix H.

For the High-Medium flow model, the worst VAFS are 0.942 for 63 cfs, 0.981 for 140 cfs, and 0.659 for 250 cfs. The velocity and depth predictions are adequate for the extrapolation range of 63 to 140 cfs. Extrapolation to 250 cfs should be made with caution.

For the Medium-Low flow model, the worst VAFS are 1.038 at 6.0 cfs and 1.009 at 63 cfs. The velocity and depth predictions are adequate for the extrapolation range of 6 to 63 cfs.

Upper Christmas Creek Site Calibration

Two two-flow (High-Medium and Medium-Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix I.

For the High-Medium flow model, the worst VAFS are 0.987 for 43 cfs, 1.015 for 154 cfs, and 0.856 for 270 cfs. The velocity and depth predictions are adequate for the extrapolation range of 43 to 270 cfs.

For the Medium-Low flow model, the worst VAFS are 0.935 at 4.0 cfs and 0.990 at 43 cfs. The velocity and depth predictions are adequate for the extrapolation range of 4 to 43 cfs.

Peterson Creek Site Calibration

Three one-flow (High, Medium, and Low) IFG4 models were run for this site using the standard options.

A copy of the IFG4 input files, summaries of the calibration details, data changes, and VAFS are included as Appendix J.

For the High flow model, the worst VAFS are 1.182 at 11 cfs, 0.989 at 16 cfs, and 1.227 at 30 cfs. The High flow model is adequate for the extrapolation range of 11 to 16 cfs. Extrapolation to 30 cfs should be made with caution.

For the Medium flow model, the worst VAFS are 1.180 at 5 cfs, 0.990 at 6 cfs, and 1.396 at 11 cfs. Extrapolation above and below 6 cfs should be done with caution.

For the Low flow model, the worst VAFS are 0.999 at 4 cfs and 1.131 at 5 cfs. The velocity and depth predictions are adequate for the extrapolation range of 4 to 5 cfs.

Bull Creek Site Calibration

Although three sets of depth and velocity measurements were taken at this site, only one two-flow IFG4 model was run using the standard options. The lowest flow measured, 0.03 cfs, could not be adequately modeled.

A copy of the IFG4 input file, summaries of the calibration details, data changes, and VAFS are included as Appendix K.

The depth measurements from the medium flow data set were used for Transect 4 instead of the high flow data set. This resulted in the depth measurements for 3 cells decreasing by 0.1 feet, 5 by 0.2, 2 by 0.3, and 1 by 0.4. The depths for 22 cells did not change. The worst VAFS for this model are 1.039 at 2 cfs, 1.024 at 15 cfs, and 0.859 at 25 cfs. The velocity and depth predictions are adequate for the extrapolation range of 2 to 25 cfs.

Transect Weighting

PHABSIM automatically calculates the length of each transect cell based on the distance between adjacent transects and on an upstream weighting factor (default value of 0.5). An alternative method, the "habitat mapping" approach, is to set the distance between transects based on the amount of habitat in the stream reach that cell is meant to depict and to set the weighting factor to 1.0 (Bovee undated). It should be noted that setting all weighting factors to 1.0 requires the use of a dummy transect above the uppermost measured transect, otherwise there would be no distance upstream to weight for the last transect. The "habitat mapping" approach was used in this study to more accurately represent the amount (percent) of each habitat type (riffle, pool, run) observed in each stream reach (Table 6).

Table 6. Transect weighting for each IFIM site using the habitat mapping approach (see Bovee undated). Weighting was fixed n terms of feet/1000 feet with the weighting factor set at 1.0. The last transect for each site is a "dummy" transect.

Site	Transect 1	2	3	4	5	6	7	8	9	10
Lower Hurst	0	80	80	107	107	520	107			
Upper Hurst	0	117	265	60	60	117	117	265		
Shale Creek	0	38	190	160	38	190	160	38	38	160
Lower Miller	0	125	210	210	125	330				
Middle Miller	0	117	265	117	265	117	120			
Upper Miller	0	60	450	60	370	60				
Lower Xmas	0	95	220	185	185	220	95			
Middle Xmas	0	210	65	225	225	65	210			
Upper Xmas	0	210	70	440	210	70				
Peterson	0	315	280	315	100					
Bull	0	225	170	380	225					

IV. HABITAT-USE CURVES

PHABSIM requires biological models of water depths, velocities, and substrate/cover, as preferred by the fish species under evaluation, to compare to those same variables as predicted by the IFG4 hydraulic model. These models are referred to as habitat-use curves. Velocity, depth, and substrate/cover habitat-use curves for the steelhead life stages of spawning, fry (0+ age class), and parr (1+ age class) were provided by Dr. Hal Beecher (Washington Department of Wildlife, Olympia, Washington).

The velocity and depth habitat-use curves were "smoothed" for this study to more accurately, presumably, reflect actual habitat use by steelhead. For example, part of the parr velocity preference curve indicated the following:

Preference	Velocity (fps)
0.99	1.30-1.39
1.00	1.40-1.49
0.93	1.50-1.59
1.00	1.60-1.79
0.79	1.80-1.99
0.71	2.00-2.09
0.97	2.10-2.19
0.99	2.19-2.39

The above curve was smoothed to represent a preference value of 1.00 for the velocity range of 1.30-2.40 fps. The changes were made because: (1) preferences of 0.97 and 0.99 are essentially 1.00; and (2) it is unlikely that steelhead parr would "prefer" velocities of 1.50-1.59 and 1.80-2.09 less than velocities both immediately higher and lower, the trend suggested higher preferences. Similar reasoning was followed to smooth the rest of the curves. The depth and velocity habitat-use curves used in this study are presented in (Appendix L).

The sediment/cover codes and values used are listed in Table 2. The codes and values were not modified for this study.

V. FISH SPECIES AND OPTIONS USED IN HABTAT PROGRAM

Fish Species Used in HABTAT

The depths and velocities predicted in the IFG4 hydraulic model are combined, in the HABTAT program, with the depths and velocities provided in the habitat-use curves to calculate WUA versus flow relationships. WUA versus flow relationships were only calculated for steelhead trout since steelhead are the focus of additional analysis. The input data for the IFG4 hydraulic model could also be used to develop WUA versus flow relationships for coho and chinook salmon since those species are also present in the Clearwater River.

Options Used in HABTAT

There are 18 options available in HABTAT. For this study, options 1, 8, and 10 were set to one with all other options set to zero.

VI. RESULTS

The WUA versus flow results for each site are depicted in Appendix M. Peak WUA versus flow results are presented in Table 7.

The results for both of the sites on Hurst Creek were quite similar. Peak spawning WUA occurred at 150 cfs for the lower site and 140 cfs at the upper site. Fry WUA peaked at 5 cfs for both sites. Peak parr WUA occurred at 100 cfs at the lower site and 90 cfs at the upper site.

The peak spawning WUA occured at 90 cfs for the Shale Creek site. Fry WUA peaked at 7 cfs but began to rise again at 60 cfs and did not peak a second time. No peak parr WUA was identified.

The three sites on Miller Creek resulted in some similar and some different estimates of peak WUA. Peak spawning WUA occurred at 120 cfs, 150 cfs, and 80 cfs for the lower, middle, and upper sites. Fry WUA was essentially maximized at similar flows, 10 cfs, 10 cfs, and 8 cfs for the lower, middle, and upper sites. However, fry WUA decreased from these peaks and began to rise again at both the lower and upper sites. The models indicated that parr WUA peaked at 110 cfs for the middle site but no peaks were identified for the lower and upper sites; WUA continued to increase with increasing flow.

Some variation was also exhibited at the three sites on Christmas Creek. Peak spawning WUA increased from 130 cfs to 160 cfs to 200 cfs at the lower, middle, and upper sites. Fry WUA peaked at 20 cfs, 15 cfs, and 60 cfs for the lower, middle, and upper sites. Parr WUA peaked at 110 cfs for the lower site and at 140 cfs for the middle site. However, no parr WUA peak was identified for the upper site; WUA continued to increase slightly with increasing discharge.

Bull Creek and Peterson Creek, the two smallest streams, are similar in terms of the flows needed to provide peak habitat for the steelhead life history stages of spawning, fry, and parr. Peak spawning WUA occurred at 45 cfs for Peterson Creek and 40 cfs for Bull Creek. Peak fry WUA peaked at extremely low flows, 8 cfs for Peterson Creek and 1 cfs for Bull Creek. However, fry WUA in Bull Creek began to increase again at 12 cfs with no resultant second peak. No peak parr WUA was determined for either stream; WUA continued to increase with increasing discharge.

Table 7. Flows that provide peak weighted useable area (WUA) versus flow for steelhead spawning, fry, and parr life history stages.

Site	Peak WUA Flow in cfs		
	Spawning	Fry	Parr
Lower Hurst Creek	150	5	100
Upper Hurst Creek	140	5	90
Shale Creek	90	7[A]	NP[B]
Lower Miller Creek	120	10[A]	NP[B]
Middle Miller Creek	150	10	110
Upper Miller Creek	80	8[A]	NP[B]
Lower Christmas Creek	130	20	110
Middle Christmas Creek	160	15	140
Upper Christmas Creek	200	60	NP[B]
Peterson Creek	45	8	NP[B]
Bull Creek	40	1[A]	NP[B]

[A] Lower peak only. WUA-versus-flow curve decreased, then increased again at higher flows with no additional peak over the range of flows modeled.

[B] No peak (NP) over the range of flows modeled. WUA continued to increase with increasing streamflow.

VII. RECOMMENDATION FOR USE OF WUA RESULTS

As discussed previously, the IFIM allows for a systematic evaluation of different management options by providing quantitative estimates of fish habitat available under each option. The IFIM was not intended to generate a single solution (Bovee 1982). Setting a minimum flow that would maximize habitat for one lifestage may adversely impact another lifestage of the same species. For example, setting a flow that maximizes steelhead spawning habitat availability could result in depths and velocities too great for rearing steelhead. Setting a minimum flow for steelhead could also adversely impact another species, such as coho or chinook salmon. However, this report only provides WUA information for steelhead so impacts to coho or chinook cannot be determined without additional analysis.

The use of two-flow hydraulic models provided discharge and velocity predictions adequate for the objectives of this study but may not meet agency requirements for the establishment of an instream flow regime. Other considerations include water quality, fish passage, inflow from tributaries and groundwater, etc. In any case, the authors are unaware of any development proposals that would allow the manipulation of flows within the six streams studied.

WUA can also be used as a method to determine fish production potential. However, WUA is only an index of fish habitat. Converting WUA into an estimate of the potential size of a fish population requires assumptions not considered in the IFIM, such as: (1) the number of fish that would use a square foot of habitat; (2) there are no other factors affecting fish numbers (food abundance, disease, fishing pressure); and (3) the population of one lifestage does not limit the population of the following lifestage over time (Caldwell and Hirschey 1989). Fish production estimates based on WUA should be viewed with caution.

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