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DEVELOPMENT OF BROWN TROUT HABITAT SUITABILITY INDEX MODELS

by

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June, 1985

ABSTRACT

The brown trout Habitat Suitability Index Model for riverine systems, developed by the U.S. Fish and Wildlife Service (Raleigh et al., 1984) was tested with habitat and standing stock data collected from 33 study sites on 10 streams in southeast Wyoming. Results indicated that in its original form, the HSI model accounted for ten percent of the variation in brown trout population size. Following this initial test, individual HSI variables and other habitat variables developed by the authors were regressed against standing stocks. Statistically significant variables were then analyzed by multiple regression techniques to develop a model having the best possible predictive capability with a minimum of variables. The resultant three variable model, including measures of cover, water velocity, and baseflow regime, accounted for 63 percent of the variation in brown trout standing stocks.

TABLE OF CONTENTS

ACKNOWLEDGEMENTS

The authors wish to acknowledge the following individuals for their assistance in obtaining and analyzing data used in this report:

Mr. Robert Pistano - Wyoming Game and Fish Department

Mr. Robert Lanka - Zoology Department, University of Wyoming

Ms. Carrie Frye - Wyoming Water Research Center, University of Wyoming

Mr. Walter Eifert - Wyoming Water Research Center, University of Wyoming

Ms. Jan Wiley - Wyoming Water Research Center, University of Wyoming

Mr. Jim Sherman - Wyoming Water Research Center, University of Wyoming

Mrs. Ruth Daniels - Wyoming Water Research Center, University of Wyoming

Special appreciation is extended to Dr. Carl Armour and the staff of the Western Energy and Land Use Team, USFWS, Fort Collins, CO, for their support and assistance throughout the project.

INTRODUCTION

In recent years, environmental and fisheries managers have shown interest in the development of accurate, reliable and feasible models for prediction of trout standing crop. Fausch and Parsons (1984) identified 26 habitat models that predict standing crops of fish in riverine systems. Each model is based on water regime, geomorphologic, and/or habitat characteristics with the majority utilizing measures of instream habitat and water regime as predictors of standing crop. For instance, the most commonly used model in Wyoming is the Wyoming Habitat Quality Index (Binns 1979). With Binn's Model II, six instream habitat variables and three water regime variables are rated and combined in a multiple linear regression model to predict trout standing crop.

Certain models, as identified by Fausch and Parsons (1984), utilize only measures of geomorphology (Ziemer 1971, Burton and Wesche 1974, and Wesche et al. 1977). Platts (1979), Lanka (in press), and others combined measures of both instream habitat and geomorphology to assess trout standing crop.

Wesche (1980) published the Water Resources Research Institute trout cover rating model which was primarily oriented towards brown trout (*Salmo trutta*). Within this model, the length of overhead bank cover and area of rubble-boulder, each multiplied by a preference factor, resulted in a cover rating value to be utilized as a predictor of stream carrying capacity. Equations were developed for both small and large streams.

The United States Fish and Wildlife Service (USFWS) has also derived two models which utilize measures of water regime and habitat.

The first is the Physical Habitat Simulation (PHABSIM) system developed by the Cooperative Instream Flow Service Group. This system is a collection of computer programs used to relate changes in discharge or channel structure to physical habitat availability, based upon observed or predicted changes in water depth, velocity, substrate and cover. (Bovee and Milhous 1978, Bovee 1982).

Second, Habitat Suitability Index (HSI) models have been developed by the USFWS Western Energy and Land Use Team (WELUT) to be used in their Habitat Evaluation Procedures (HEP) (USFWS 1980). These models generally require the development of Suitability Index (SI) graphs for habitat variables believed to be important for the growth, survival, standing crop or other measures of species well-being. Although HSI models have been structured in many ways and most use different parameters, they all are based on the assumption that a relationship exists between various physical and chemical parameters of streams and carrying capacity. These models have been developed for many species, both terrestrial and aquatic; however, few have been validated with field data. Fish models that have been tested are presented in the proceedings of a workshop on fish habitat suitability index models (Terrell 1984).

The Wyoming Water Research Center and the Wyoming Cooperative Fishery and Wildlife Research Unit, both located at the University of Wyoming, Laramie, Wyoming, were contracted by WELUT to (1) test the Habitat Suitability Index Model developed by Raleigh et al. (1984) for brown trout in riverine systems; and, (2) modify the model to achieve the best predictive capability with a minimum of variables. This report presents the results of this research.

METHODS

An eight-step systematic approach was used to determine brown trout riverine HSI model performance and to develop a modified HSI model. Each step is detailed below:

1. Determine the variables in the published model for which field collected data are available.
2. Determine the variables in the published model of significance in southeastern Wyoming streams.
3. Develop Suitability Index (SI) curves for model variables using Wyoming data based upon two approaches, Maximum Performance (Li, et al., 1984) and Average Level (Layher and Maughan, 1984), and compare to published curves using available data.
4. Determine the correlation between the published HSI model predictions and field measured standing crops using published SI curves (Rank correlations and linear regression used as test statistics; both kg/ha and kg/km of brown trout used as measures of standing crop).
5. Determine correlations between the published model predictions of HSI and standing crop using newly developed SI curves.
6. Develop new aggregations of SI curves for computing HSI values using
   a. stepwise multiple regression,
   b. average value method (geometric mean),
   c. interacting limiting factor approach (product of SI values),
   d. lowest suitability index approach, and

   determine correlations with standing crop.

7. Perform the above steps accounting for competition with other salmonid species (assuming that where brown trout occur the aggregate trout biomass equals the brown trout biomass that would occur without competition).

8. Select the best HSI model using correlations with standing stock as the selection criteria.

Data were collected at 33 different study sites within 10 streams, all located in southeast Wyoming and all predominated by naturally-reproducing brown trout (with the exception of Pelton Creek). Brown trout abundance in Pelton Creek was slightly exceeded by that of brook trout (<u>Salvelinus</u> <u>fontenalis</u>). A description of each site is included as Appendix I. For more detailed descriptions of the study streams, the reader is referred to Wesche 1973, Wesche 1974, Wesche et al. 1977, Wesche 1980 and Eifert and Wesche 1982.

While data utilized for this project were from many sources, the majority of information was obtained from work conducted by the authors between 1973 and 1976 at sites throughout southeast Wyoming (Wesche 1973; Wesche 1974; Wesche 1980; and Eifert and Wesche 1982). Data were also obtained from the Wyoming Game and Fish Department and the Water Resources Data System (WRDS) at the Wyoming Water Research Center. Funding for the research work which led to the development of this habitat data base was provided by the U.S. Department of the Interior, Office of Water Research and Technology; Wyoming Game and Fish Department; Wyoming State Engineer's Office; and, the University of Wyoming.

Sampling procedures at each study reach are detailed in Wesche 1973, Wesche 1974, Wesche 1980, and Eifert and Wesche 1982. Sufficient information was collected at each study reach to enable the development of a data set from which the validity of the HSI model for brown trout, as proposed by Raleigh et al (1984), could be tested.

Fish population estimates for all study streams, with the exception of the Encampment River study reaches, were derived by electrofishing, utilizing the Delury Removal Method (Delury 1947 and 1951). Sodium cyanide was employed to sample Encampment River sites under the supervision of the Wyoming Game and Fish Department.

A data matrix consisting of habitat measurements from the 33 study reaches was developed. Variables analyzed included 14 of the 18 required for the computation of the Brown Trout Riverine HSI Model (Table 1). Additional variables analyzed are included within Table 2.

Table 2 includes as a habitat variable the Trout Cover Rating Model for both small and large streams as developed by Wesche (1980). Also included is a rated cross-section velocity (RCSVEL) variable which rates velocity in feet per second as follows:

1. (Poor) is < 0.10 m/sec or ≥ 0.45 m/sec
2. (Moderate) is ≥ 0.10 m/sec and < 0.2 m/sec or > 0.30 m/sec and ≤ 0.45 m/sec
3. (Optimum) is ≥ 0.20 m/sec or ≤ 0.30 m/sec

This study rating classification was developed based upon the shape of curve resulting when cross-section velocity was plotted against brown trout standing crop. Fishing pressure at each site was also rated from heavy to moderate to light based on observations recorded during field data collection and the availability of access to each site.

Suitability index ratings were derived by using the suitability index curves published by Raleigh et al. (1984). The corresponding

TABLE 1. SUITABILITY INDEX VARIABLES FOR BROWN TROUT RIVERINE MODEL TESTING

	VARIABLE	UNITS	SOURCE AND/OR COMMENTS
V_1	Average maximum water temp.	°Centigrade	Derived from data collected 1973-1976.
V_2	Average maximum water temp. during embryo development	- - - - -	Data not available.
V_3	Average dissolved O_2	Milligrams/liter	Derived from data collected 1973-1976.
V_4	Average Thalweg depth	Meters	Derived from cross-sectional transect data.
V_5	Average velocity over-spawning areas	- - - - -	Data not available.
V_6	Percent cover during the late growing season low water periods	Percent (%)	Considered % instream cover in water _ 15 (cm) in depth Derived from cross-sectional data and corresponding sub strate information.
V_7	Average substrate size in spawning areas	Percent (%)	Data not available.
V_8	Percent of substrate (10-40 cm)	Percent (%)	Derived from cross-sectional transect data.
V_9	Dominant substrate type	- - - - -	Derived from cross-sectional data and analysis of photographs.
V_{10}	Percent pools	Percent (%)	Considered percent deep water habitat _ 30 cm depth. Derived from cross-section data.
V_{11}	Average percent vegetation	Percent (%)	Derived from study reach photographs.
V_{12}	Average percent rooted vegetation	Percent (%)	Considered similar to V_{11}. Since optional, this variable not included.
V_{13}	Maximum pH	- - - - -	Data not available.
V_{14}	Average annual baseflow as a percent of Average Annual Daily Flow (ADV)	Percent (%)	Derived from gaging station information where available. For ungaged streams, data were developed based on gaged streams of similar elevation and characteristics. Used either late summer or winter low flowvalues which ever lowest.
V_{15}	Pool class rating	- - - - -	Derived from study reach photographs.
V_{16}	Percent fines	Percent (%)	Derived from cross-sectional information and substrate records.
V_{17}	Percent of stream area shaded	Percent (%)	Derived from study reach photographs.
V_{18}	Nitrate nitrogen	Milligrams/liters	Derived from Wyoming Water Research Center and Wyoming Game and Fish Department records where available.

TABLE 2. ADDITIONAL VARIABLES ANALYZED FOR EACH STUDY SITE

Abbreviation	Description	Source
RUB 15	Percent substrate (10-40 cm) with water at a depth _ 15 cm	Wesche, 1980
WAT45	Percent deep water habitat _ 45 cm	Wesche, 1980
BARE	Percent bareground	- - - - - - - - - -
TCRS	Trout cover rating for small streams	Wesche, 1980
TCRL	Trout cover rating for large streams	Wesche, 1980
LOBC	Length of overhead bank cover divided by length of of thalweg line through the section	Wesche, 1980
ARB	Area of rubble-boulder divided by surface area	Wesche, 1980
VEL	Time-of-travel reach velocity	Wesche, 1973 and Binns, 1979
HQILSSF	Binn's HQI rating for late summer streamflow attribute	Binns, 1979
AQVEG	Percent aquatic vegetation	Binns, 1979 and Wesche, 1980
FLOWVAR	Average streamflow variation	Binns, 1979
HQIASWV	Binn's HQI rating for average streamflow variation	Binns, 1979
WIDTH	Average stream width	Platts, et al. 1983
CVWIDTH	Coefficient of variation of stream width	Hermansen and Krog, 1984
DEPTH	Average depth	Platts, et al. 1983
CVDEP	Coefficient of variation of depth	Hermansen and Krog, 1984
CSVEL	Cross-sectional velocity	Platts, et al., 1983
RCSVEL	Rated cross-sectional velocity	- - - - - - - - - -
CVVEL	Coefficient of variation of velocity	Hermansen and Krog, 1984
WDDEP	Width/depth ratio	Platts, et al., 1983
GRAD	Percent gradient	Platts, et al., 1983
SINUOS	Sinuosity	Platts, et al., 1983
FISHING	Rated fishing pressure	- - - - - - - - - -
AASBF	Average annual summer base flow expressed as a percent of average discharge	Raleigh et al., 1984
AAWBF	Average annual winter base flow expressed as a percent of average discharge	Raleigh et al., 1984

Habitat Suitability Index computations for various brown trout life stages were included as variables for model development (Table 3).

Data for variables V_2 (average maximum water temperature during embryo development), V_5 (average velocity over spawning areas during spawning and embryo development), V_7 (average size of substrate in spawning areas) and V_{13} (annual maximal or minimal pH) were not available. As the brown trout populations involved were naturally reproducing and water quality conditions were near pristine at the study sites, it was assumed that model performance would not be effected if variables for which data were missing were given an optimal suitability index rating of 1.0.

Suitability index curves were re-calibrated by utilizing the maximum performance and average value methods (Li et al. 1984) and (Layher and Maughan 1984). The brown trout HSI model was run with the re-calibrated curves to compare with the results obtained when utilizing the original HSI curves.

Simple regression analysis was used to determine the relation between each independent variable and brown trout standing stock. Visual inspection of normality and residual plots indicated that some predictor variables violated regression assumptions. Log transformations were used to correct for assumption violation (Zar 1974). Those variables significantly correlated ($P \leq 0.10$) to trout standing stock were used with all subsets regression and multiple linear regression for model development. Both the Statistical Package for Social Science (SPSS) and the Biomedical Data Analysis Programs (BMDP) on the University of Wyoming Cyber computer system were utilized for regression analysis and model testing and development.

TABLE 3. VARIABLES INCLUDED AS SUITABILITY INDEX RATINGS AND HABITAT SUITABILITY INDEX COMPUTATIONS FOR BROWN TROUT RIVERINE MODEL TESTING

ABBREVIATIONS	DESCRIPTION
V_{1A}	Suitability Index Rating for Variable 1 - Adults and Juveniles
V_{1B}	Suitability Index Rating for Variable 1 - Fry
V_2	Suitability Index Rating for Variable V_2
V_3	Suitability Index Rating for Variable V_3
V_4	Suitability Index Rating for Variable V_4
V_5	Suitability Index Rating for Variable V_5
V_6	Suitability Index Rating for Variable V_6
V_7	Suitability Index Rating for Variable V_7
V_8	Suitability Index Rating for Variable V_8
V_9	Suitability Index Rating for Variable V_9
V_{10}	Suitability Index Rating for Variable V_{10}
V_{11}	Suitability Index Rating for Variable V_{11}
V_{12}	Suitability Index Rating for Variable V_{12}
V_{13}	Suitability Index Rating for Variable V_{13}
V_{14}	Suitability Index Rating for Variable V_{14}
V_{15}	Suitability Index Rating for Variable V_{15}
V_{16A}	Suitability Index Rating for Variable V_{16} - Spawning
V_{16B}	Suitability Index Rating for Variable V_{16} - Riffle-Run
V_{17}	Suitability Index Rating for Variable V_{17}
V_{18}	Suitability Index Rating for Variable V_{18}
CA	Riverine Model - Adult Life Stage Computation
CJ	Riverine Model - Juvenile Life Stage Computation
CF	Riverine Model - Fry Life Stage Computation
CE	Riverine Model - Embryo Life Stage Computation
CO	Riverine Model - (Other) Computation
ECMHSI	Equal Component Method Habitat Suitability Index Computation
COF	Subcomponent (Food) Computation
COQ	Subcomponent (Water Quality) Computation
NCOHSI	Noncompensatory Option Habitat Suitability Index Computation
COHSI	Compensatory Option Habitat Suitability Index Computation

RESULTS

Habitat Suitability Index (HSI) Model performance is presented in Table 4. Many of the model components were statistically significant but generally accounted for less than ten percent of the variation in standing stock. Suitability Index ratings were redetermined using re-calibrated field suitability index curves and model components were recalculated, but performance of the model was not improved.

Only three original suitability index variables yielded ratings significantly correlated with brown trout standing stock. These include variables V_9 (Dominant Substrate Type), V_{14} (Average Annual Baseflow as a percent of Average Daily Flow), and V_{17} (Percent Shade). The regression equation for each significant variable is presented in Table 5.

TABLE 5. ORIGINAL SUITABILITY INDEX VARIABLES OF SIGNIFICANCE

VARIABLE	SIGNIFICANCE	PROBABILITY	REGRESSION EQUATION
V_9	r = -0.35	p = 0.024	y = 119.658 - (-83.292)X
V_{14}	r = 0.65	p = 0.00002	y = -16.783 + 208.593X
V_{17}	r = 0.48	p = 0.002	y = -7.783 + 170.587X

Many of the additional variables which were analyzed (Table 2) correlated significantly with brown trout standing stock at the p _ .10 level. These variables are presented with their significance values and linear regression equations in Table 6. Log transformations did not significantly improve accounted for variation. Accounted for variation was in fact reduced in most cases when log transformations were used.

A multiple regression model was derived based on best accounted for variation. This three variable equation included the Trout Cover Rating

TABLE 4. PERFORMANCE OF ORIGINAL HSI MODEL

HSI COMPUTATIONS	VARIABLES INVOLVED	DESCRIPTION	SIGNIFICANCE	PROBABILITY
CA	V_4, V_6, V_{10}, V_{15}	Adult Life Stage Computation	N.S.	- - - -
CJ	V_6, V_{10}, V_{15}	Juvenile Life Stage Computation	r = 0.32	p = 0.034
CF	V_8, V_{10}, V_{16B}	Fry Life Stage Computation	r = 0.29	p = 0.053
CE	$V_2, V_3, V_5, V_7, V_{16A}$	Embryo Life Stage Computation	N.S.	- - - -
CO	$V_1, V_3, V_9, V_{11}, V_{13}$ $V_{14}, V_{16B}, V_{17}, V_{18}$	"Other" Computation	N.S.	- - - -
ECMHSI	CA,CJCF,CE,CO	Equal Component Method Habitat Suitability Index Computation	r = 0.33	p = 0.030
COF	$V_9, V_{11}, V_{16}, V_{18}$	Subcomponent "Food" Computation	N.S.	- - - -
COQ	V_1, V_3, V_{13}, V_{14}	Subcomponent "Water Quality" Computation	r = 0.35	p = 0.023
NCOHSI	CA,CJ,CF,CE,COF,COQ	Noncompensatory Option Habitat Suitability Index Computation	r = 0.32	p = 0.036
COHSI	CA,CJ,CF,CE,COF	Compensatory Option Habitat Suitability Index Computation	r = 0.32	p = 0.033

N.S. = Not Significant

r = Correlation coefficient

TABLE 6. VARIABLES WHICH PROVED SIGNIFICANT FOR BROWN TROUT HSI MODEL DEVELOPMENT

VARIABLE ABBREVIATION	SIGNIFICANCE	PROBABILITY	REGRESSION EQUATION
DOMSUB	r = -0.35	p = 0.024	y = 126.303 - (-29.379)X
WAT45	r = 0.38	p = 0.018	y = 45.630 + 1.817X
AASBF	r = 0.28	p = 0.068	y = 31.026 + .807X
HQILSSF	r = 0.35	p = 0.23	y = -22.803 + 35.144X
SHADE	r = 0.49	p = 0.02	y = 40.314 + 2.462X
NO3	r = 0.53	p = 0.010	y = 45.712 + 263.075X
TCRL	r = 0.57	p = 0.001	y = 9.905 + 117.854X
ARB	r = -0.35	p = 0.042	y = 93.521 + (-102.033)X
FLOWVAR	r = -0.30	p = 0.051	y = 88.630 + (-.221)X
HQIASWV	r = 0.55	p = 0.0005	y = -20.225 + 55.135X
CVDEPTH	r = 0.58	p = 0.0003	y = -30.936 + 2.425X
CVVEL	r = 0.34	p = 0.040	y = 32.284 + 0.855X
WIDDEP	r = -0.28	p = 0.059	y = 100.835 + (-.834)X
FISHING	r = -0.34	p = 0.028	y = 118.759 + (-25.663)X
RCSVEL	r = 0.51	p = 0.005	y = -62.211 + 54.823X

Model for larger streams (TCRL), rated cross-section velocity (RCSVEL) and average annual baseflow as a percent of average annual daily flow (V14). The mathematical relationship is expressed as follows:

$$\text{Brown Trout (kg/Ha)} = -104.7 + 65.1\ \text{TCRL} + 29.6\ \text{RCSVEL} + 186.8\ V_{14}$$

This relationship was found to explain 63 percent of the accounted for variation in brown trout standing crops.

DISCUSSION

Study streams located in southeast Wyoming provided an optimum situation for testing and development of riverine brown trout HSI models for several reasons:

1. Each stream contained a naturally reproducing population of brown trout;
2. There were no known water quality limitations;
3. Land use impacts on the watersheds were minimal; and,
4. There was relatively low fishing pressure on these streams compared to most other states and regions.

When habitat suitability index values were computed for each stream reach using the suitability index curves published by Raleigh et al. (1984), the HSI models accounted for only ten percent of the variation in brown trout standing stock. Model performance was not improved when suitability index curves were modified to better reflect brown trout habitat data from southeastern Wyoming. Therefore, additional variables were analyzed in an attempt to develop a new regression model which more adequately predicted brown trout standing stock. The multiple regression model developed, containing instream and water regime variables widely recognized as critical for brown trout habitat, appears to be a relatively accurate predictor of standing stocks, accounting for 63 percent of the variation in population levels for the southeast Wyoming study streams.

Parameter Measurement

The three variables which comprise the model are all rather easily measured parameters which do not require lengthy field visits or sophisticated equipment. For an overall view of stream habitat evaluation methods and techniques, the reader is directed to the manuals developed by Bovee and Milhous (1978), Bovee (1982) and Platts et al. (1983). The following brief discussion outlines specific techniques for measuring the three model variables.

The trout cover rating variable (TCRL) as published by Wesche (1980) should be computed as follows:

$$CR = \frac{L_{obc}}{T} PF_{(obc)} + \frac{A_{r-b}}{SA} (PF_{r-b}) + \frac{Ad}{SA}$$

where L_{obc} = length of overhead bank cover in the study section having a water depth of at least 0.50 feet and a width of 0.3 feet or greater;

T = length of the thalweg line through the section;

PF_{obc} = preference factor for overhead bank cover (Value = 0.75 for fish $\geq$ 6.0" and 0.05 for fish < 6.0");

A_{r-b} = surface area of the study section having water depths greater than 0.50 feet and substrate size 3.0 inches in diameter or greater (i.e., rubble and boulder) or a substrate covered with aquatic vegetation;

SA = total surface area of the study section at the average discharge, or at the flow worked;

PF_{r-b} = preference factor for instream rubble-boulder-aquatic vegetation areas; (Value = 0.75 for fish ≥ 6.0" and 0.25 for fish < 6.0");

Ad = surface area of the study section having a water depth of 1.5 feet or greater regardless of substrate or adjacent bankside cover;

CR = cover rating value for the study section at the discharge worked. Cover ratings should be calculated for fish less than 6.0" in size and for fish greater than or equal to 6.0" in size. The two should then be averaged to derive a mean trout cover rating for the stream study section.

The TCRL variable can be used for any size stream when incorporating it into the proposed regression model. Measurements should be made at late summer low-flow.

Several accurate, yet efficient, methods can be used to determine RCSVEL, rated cross-sectional velocity. If a current meter is available, a discharge measurement can be made at one of the study site transects following standard U.S. Geological Survey procedures as described by Buchanan and Somers (1969). Once discharge, Q, for the study site is known and width and depth measurements have been taken at all other transects to determine cross-sectional area, A, the following equation can be used to determine cross-sectional velocity (CSVEL) for each transect:

$$CSVEL = \frac{Q}{A}$$

CSVEL values can then be averaged to determine the mean CSVEL. This value can then be rated as poor, moderate or optimum using the rating system presented earlier in this report.

A second quicker and less equipment-intensive method for determining RCSVEL would be to apply the float method developed by Wesche et al. (1983). Developed for use in steep, rough, low-order tributary streams, this method requires simply that a pencil be floated through the study site. The site length is then divided by the travel time to determine float velocity (V_F). This value is then entered into the following regression equation to determine mean CSVEL:

$$\text{Mean CSVEL} = 0.20 + 0.46\ V_F$$

Mean CSVEL is then rated as described above.

To derive variable V_{14}, either late summer or winter low streamflow values should be derived from gaging station records. Whichever value is lowest should be expressed as a percent of average annual daily flow (ADF) and used to derive a rating based on the suitability index curve for variable V_{14} as published by Raleigh et al. (1984). Should gage records for the study stream not exist, records from an adjacent, similar watershed could be used or estimation procedures could be followed as outlined by standard hydrology texts.

<u>Variable Significance</u>

The multiple regression model developed is basically a hybrid of the Trout Cover Rating Model (Wesche, 1980), the Habitat Quality Index Model (Binns, 1979) and the Habitat Suitability Index Model for brown trout (Raleigh et al., 1984). There can be little doubt, as discussed below, that the three variables in the model, cover, water velocity and baseflow, are critical physical parameters which can influence brown trout production. Also, through inclusion of the TCRL method, not only is available cover quantified, but other important habitat characteristics are integrated into the model as well. These include water depth, substrate characteristics, presence of aquatic vegetation, stream width, surface area, and streambank characteristics.

The importance of cover as a habitat variable is stressed by its inclusion in the three published habitat evaluation models listed above as well as in the PHABSIM model of the CIFSG (Bovee, 1982). As stated by Raleigh (1984):

> "Cover is recognized as one of the essential components of trout streams. Adult brown trout seek cover more than any other trout species. Boussu (1954) was able to increase the number and weight of brown trout in stream sections by adding artificial brush cover. Numbers and weight, particularly of adult trout, were decreased when brush cover and undercut banks were eliminated. Lewis (1969) reported that the amount of cover was important in determining the number of trout in sections of a Montana stream. Cover for adult brown trout consists of areas of obscured stream bottom where the velocity is low and depths are at least 15 cm. Wesche (1980) reported that, in larger streams, the abundance of brown trout _ 15 cm in length increased with depth; most were at depths _ 15 cm. In the Au Sable River, Michigan, adult brown trout preferred

cover at lower water column depth to cover nearer the surface, cover with tactile stimulus, and cover with the least light (DeVore and White 1978).

Escape cover is provided by overhanging and submerged vegetation; undercut banks; instream objects, such as debris piles, logs, and large rocks; and pool depth or surface turbulence. A cover area of $\geq$ 35 percent of the total stream area provides adequate cover for adult brown trout. The main use of summer cover is probably for predator avoidance and resting."

When regressed individually against brown trout standing stock for the southeast Wyoming study sites, TCRL was found to explain 32.5 percent of the variation in population size. A component of the TCRL, WAT45 (surface area having depths greater than 45 cm divided by total surface area) accounted for 14 percent of the variation, thus indicating the importance of water depth as cover in the regulation of brown trout populations.

The role of water velocity in the stream environment has been well documented (Haynes, 1970). According to Scott (1958) and Allen (1959), velocity is the most important parameter determining distributional patterns of aquatic invertebrates, an important food source for brown trout. The influence of current is also manifested in the quantities of organisms produced per unit area (Ruttner, 1953). Increased water velocities increase the exchange rate between the organism and its water supply, thereby promoting respiration and food acquisition (Giger, 1973). Numerous studies have been conducted which relate water velocity to the number of invertebrates produced (e.g. Kennedy, 1967; Needham and Usinger, 1956; Kimbel and Wesche, 1975). Velocity and aquatic insects are also closely related in another way, that being in the delivery of food to the fish by the mechanism of "drift". According to Waters (1969), Chapman (1966), and Good (1974), a positive correlation exists between velocity and the quantity of the drift.

Water velocity serves an important role in the provision and maintenance of spawning and egg incubation habitat for brown trout (Smith, 1973; Hooper, 1973; Reiser and Wesche, 1977). Sufficient velocity is needed to prevent the accumulation of fine sediment within the spawning gravels as well as to provide a suitable supply of oxygen to the eggs. Also, water velocity can play a critical function in terms of temperature regulation in the stream environment, ice formation processes, and the transport of contaminants through the system (Hynes, 1970).

Water velocity, as measured by RCSVEL, accounted for 26 percent of brown trout population variation among the study sites when regressed individually against standing stock.

The increasing concern over the past 15 to 20 years for maintaining suitable instream flow levels for fisheries purposes lends credence to the inclusion of V_{14} (baseflow expressed as a percent of average annual daily flow) in the developed model (Stalnaker and Arnette, 1976; Wesche and Rechard, 1980). Numerous investigators have described the habitat losses that can occur as baseflow levels are reduced (e.g., Wesche, 1973 and 1974; Tennant, 1976), while Burton and Wesche (1974) studied the duration of various baseflow levels in a variety of brown trout streams and found that those streams with higher baseflows present for longer durations during the summer supported significantly greater brown trout populations. Also, both Binns (1979) and Raleigh et al. (1984) considered baseflow of sufficient importance to include it in their habitat models.

Regressed individually against brown trout standing stock, V_{14} accounted for 42 percent of the variation in study site populations.

Application of Developed Model

It is recommended that a two stage approach be utilized for the modelling of brown trout habitat quality in riverine systems. The first stage would be to assess water quality-related limiting factors such as dissolved oxygen, pH, temperature and other parameters deemed important (e.g., heavy metals and other possible contaminants) to determine if brown trout can survive in the study stream(s). These parameters can be evaluated according to guidelines established by the Environmental Protection Agency (EPA, 1973) or the appropriate State water quality agency.

The second stage of the evaluation process would be to assess the physical habitat and streamflow regime using the three parameter regression model presented in this report. While this model has been developed using physical and biological data from southeastern Wyoming streams, we feel that the variables involved (cover, water velocity, and baseflow regime) are of such universal importance for brown trout populations that the model will be applicable to other regions for the comparative assessment of habitat quality. Should absolute estimates of brown trout carrying capacity be required for other regions, the development of new model coefficients may be required.

LITERATURE CITED

Allen, K.R. 1959. The distribution of stream bottom faunas. Proc. New Zealand Ecol. Soc. 6:5-8.

Binns, N.A. 1971. A habitat quality index for Wyoming trout streams. Wyoming Game and Fish Department. Fishery Report Number 2, Cheyenne, WY. 75 pp.

Boussu, M.F. 1954. Relationships between trout populations and cover on a small stream. J. Wildl. Mgmt., Vol. 18. pp. 229-239.

Bovee, K.D. and R. Milhous. 1978. Hydraulic simulation in instream flow studies. Instream Flow Information Paper No. 5, FWS/OBS-78/33. 131 pp.

_____. 1982. A guide to stream habitat analysis using the instream flow incremental methodology. Instream Flow Information Paper No. 12, FWS/OBS-82-26. 248 pp.

Buchanan, T.J. and W.P. Somers. 1969. Discharge Measurements at Gaging Stations. Book 3, Chapter A8 of Techniques of Water Resources Investigations of the U.S. Geological Survey. U.S. Government Printing Office, Washington, D.C. 65 pp.

Burton, R.A., and T.A. Wesche. 1974. Relationship of duration of flows and selected watershed parameters to the standing crop estimates of trout populations. Water Resources Series Number 52, Water Resources Research Institute, University of Wyoming, Laramie. 86 pp.

Chapman, D.W. 1966. Food and space as regulators of salmonid populations in streams. Amer. Natur. 100:345-357.

DeLury, D.B. 1947. On the Estimation of Biological Populations. Biometrics 3:145-167.

Devere, P.W. and R.J. White. 1978. Daytime responses of brown trout (Salmo trutta) to cover stimuli in stream channels. Trans. Am. Fish. Soc. 107(6):763-771.

_____. 1951. On the Planning of Experiments for the Estimation of Fish Populations. J. Fish. Res. Bd. Canada 8:281-307.

Eifert, W.H. and T.A. Wesche. 1982. Evaluation of the Stream Reach Inventory and Channel Stability Index for Instream Habitat Analysis. Water Resources Series Number 82, Water Resources Research Institute, University of Wyoming, Laramie, WY. 106 pp.

Fausch, K.D. and M.G. Parsons. 1984. A review of models that predict standing crop of stream fish from habitat variables. U.S. Department of Agriculture Forest Service, Wildlife and Fishery Ecology Unit, Fort Collins, CO. 45 pp.

Giger, R.D. 1973. Streamflow requirements of salmonids. Oregon Wildlife Commission, Job Final Report, Project AFS 62-1. 117 pp.

Good, W.R. 1974. Some effects of spring snowmelt runoff on aquatic invertebrate populations in a high mountain stream. Water Resources Series No. 50. Water Resources Research Institute, University of Wyoming, Laramie. 103 pp.

Hermansen H. and C. Kreg. 1984. Influence of physical factors on density of stocked brown trout (Salmo trutta fario L.) in a Danish lowland stream. Fisheries Management 15(3):107-110.

Hooper, D.R. 1973. Evaluation of the effects of flows on trout stream ecology. Pacific Gas and Electric Company, Emeryville, CA.

Hynes, H.B.N. 1970. The ecology of running water. University of Toronto Press. 555 pp.

Kennedy, Harry D. 1967. Seasonal abundance of aquatic invertebrates and their utilization by hatchery reared rainbow trout. Technical Paper No. 12, U.S. Fish and Wildlife Service, Bureau of Sport Fisheries and Wildlife, Washington, D.C.

Kimbel, L.A. and T.A. Wesche. 1975. Relationships between selected physical parameters and benthic community structure in a small mountain stream. Water Resources Series No. 55. Water Resources Research Institute, University of Wyoming, Laramie. 65 pp.

Lanka, R.P. In press. Modeling trout standing stock in small Wyoming streams based upon easily measured habitat and geomorphological characteristics. Master Thesis. Department of Zoology and Physiology, University of Wyoming, Laramie.

Layher, W.G. and O.E. Maughan. 1984. Analysis and refinement of habitat suitability index models for eight warm water fish species. Report to U.S. Department of the Interior, Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO.

Lewis, S.L. 1969. Physical factors influencing fish populations in pools of a trout stream. Transactions American Fisheries Society 98:14-22.

Li, H.W., C.B. Schreck and K.J. Rodnick. 1984. Assessment of habitat quality models for cutthroat trout (Salmo clarki clarki) and coho salmon (Oncorhynchus kisutch) for Oregon's coastal streams. Report to U.S. Department of the Interior, Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO.

Needham, P.R. and R. Usinger. 1956. Variability in the macrofauna of a single riffle in Prosser Creek, California as indicated by a Surber sampler. Hilgardia 24:383-409.

Platts, W.S. 1979. Relationships among stream order, fish populations and aquatic geomorphology in an Idaho river drainage. Fisheries 4:5-9.

_____, Megahan, W.F. and G.W. Minshall. 1983. Methods for evaluating stream, riparian, and biotic conditions. U.S. Department of Agriculture Forest Service, General Technical Report INT-138, Intermountain Forest and Range Experimentation Station, Ogden, UT. 70 pp.

Raleigh, R.F., L.D. Zuckerman and P.C. Nelson. 1984. Habitat suitability index models and instream flow suitability curves: Brown trout. U.S. Department of the Interior Fish and Wildlife Service, FWS/OBS-82/10.71. 71 pp.

Reiser, D.W. and T.A. Wesche. 1977. Determination of physical and hydraulic preferences of brown and brook trout in the selection of spawning locations. Water Resources Series No. 64. Water Resources Research Institute, University of Wyoming, Laramie. 112 pp.

Ruttner, F. 1953. Fundamentals of limnology (translation by D.G. Frey and F.E.J. Fry). Univ. Toronto Press. xi + 242 pp.

Scott, D. 1958. Ecological studies on the Trichoptera of the River Dean, Cheshire. Arch. Hydrobiol. 54:340-392.

Smith, A.K. 1973. Development and application of spawning velocity and depth criteria for Oregon salmonids. Trans. Amer. Fish. Soc. 102:312-316.

Stalnaker, C.B. and J.L. Arnette, eds. 1976. Methodologies for the determination of stream resource flow requirements: an assessment. U.S. Fish and Wildlife Service, Office of Biological Services, Western Water Allocation, Washington, D.C.

Tennant, D.L. 1976. Instream flow regimens for fish, wildlife, recreation, and related environmental resources. In Proc. Symp. and Spec. Conf. on Instream Flow Needs, ed., J.F. Orsborn and C.H. Allman. Vol. II, pp. 359-373. Amer. Fish. Soc., Bethesda, MD.

Terrell, J.W. 1984. Proceedings of a workshop on fish habitat suitability index models. Western Energy and Land Use Team, Fish and Wildlife Service, Biological Report 85(6) Ft. Collins, CO. 393 pp.

U.S. Environmental Protection Agency. 1973. Water Quality Criteria. National Academy of Science--National Academy of Engineering, EPA R3-73-0333, Washington, D.C.

U.S. Fish and Wildlife Service. 1980. Ecological services manual-habitat evaluation procedures (HEP). ESM102. U.S. Department of the Interior Fish and Wildlife Service, Division of Ecological Services, Washington, D.C.

Waters, T.F. 1969. Invertebrate drift-ecology and significance to stream fishes. In Symposium on Salmon and Trout in Streams, H.R. MacMillan Lectures in Fisheries, Univ. British Columbia, Vancouver, B.C. pp. 121-134.

Wesche, Thomas A. 1973. Parametric Determination of Minimum Stream Flow for Trout. Water Resources Series No. 37, University of Wyoming, Laramie. 102 pp.

_____. 1974. Relationship of Discharge Reductions to Available Trout Habitat for Recommending Suitable Streamflows. Water Resources Series No. 53, University of Wyoming, Laramie. 71 pp.

_____. 1980. The WRRI Trout cover rating method. Water Resources Series No. 78, Water Resources Research Institute, University of Wyoming, Laramie. 46 pp.

_____ and P.A. Rechard. 1980. A summary of instream flow methods for fisheries and related research needs. Eisenhower Consortium Bulletin No. 9. U.S. Government Printing Office: 1980-0-679-417/509, Washington, D.C. 122 pp.

_____, W.T. Hill, Jr., and V.R. Hasfurther. 1983. Two approaches for estimation of Manning's n in mountain streams. Wyoming Water Research Center Report, University of Wyoming, Laramie. 42 pp.

_____, D.W. Reiser, W. Wichers and D. Wichers. 1977. Fishery Resources and Instream Flow Recommendations for Streams to be Impacted by Cheyenne's Proposed Phase II Development. Report to Wyoming Game and Fish Department. 62 pp. and appendices.

Zar, J.H. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, NJ. 620 pp.

Ziemer, G.L. 1971. Quantitative geomorphology of drainage basins related to fish production. Information Leaflet No. 162, Alaska Department of Fish and Game, Juneau, AL. 26 pp.

APPENDIX 1

APPENDIX I
DESCRIPTION OF STUDY SITES

Study Area	Location	Elevation Above MSL feet (meters)	Average Daily Flow cfs (Cum/sec)	Date Sampled	Flow Sampled cfs (Cum/sec)	Channel Length feet (meters)	Channel Width feet (meters)	Surface Area Sampled sq. ft. (sq. m.)	Fish Species Sampled
Douglas Creek #1	S9,T14N,R77W 0.5 miles below Rob Roy Reservoir	9300 (2835)	31 (0.88)	Aug. 23, 1973	4 (0.11)	680 (207)	10-33 (3-10)	10,800 (1003)	Brown Trout (90%) Brook Trout (7%) Rainbow Trout (3%) Longnose Suckers
Douglas Creek #2	S15,T13N,R79W 1.5 miles below mouth of Lake Creek	8460 (2579)	50 (estimated) (1.42)	July 8, 1974	30 (0.85)	260 (79)	22-40 (7-12)	8,365 (777)	Brown Trout (89%) Brook Trout (11%) Longnose Dace
Douglas Creek #3	S15,T13N,R79W 1.5 miles below mouth of Lake Creek	8445 (2574)	50 (estimated) (1.42)	July 9, 1974	23 (0.65)	720 (219)	29-56 (9-17)	28,753 (2,671)	Brown Trout (87%) Brook Trout (11%) Rainbow Trout (2%) Longnose & White Suckers Longnose Dace
Douglas Creek #4	Same as above	8445 (2574)	Unknown	July 10, 1974	7 (0.20)	660 (0.20)	12-23 (4-7)	11,530 (1071)	Brown Trout (70%) Brook Trout (30%) Longnose Dace
Douglas Creek #5	S16,T13N,R79W 0.3 miles below Douglas Creek #3	8430 (2569)	50 (estimated) (1.42)	July 8, 1974	30 (0.85)	250 (76)	24-45 (7-12)	9,672 (893)	Brown Trout (95%) Brook Trout (5%)
Douglas Creek #6	S19,T13N,R79W 0.7 miles below mouth of Felton Ck.	8220 (2505)	78.7 (2.23)	Aug. 17, 1973	9 (0.25)	480 (146)	18-42 (5-13)	13,600 (1263)	Brown Trout (97%) Rainbow Trout (2%) Brown Trout (1%)
Douglas Creek #7	S19,T13N,R79W 0.8 miles below mouth of Felton Ck.	8200 (2499)	78.7 (2.23)	Aug. 13, 1973	21 (0.59)	830 (253)	20-75 (6-23)	29,602 (2750)	Brown Trout (90%) Brook Trout (3%) Rainbow Trout (7%)

APPENDIX I
DESCRIPTION OF STUDY SITES (cont.)

Study Area	Location	Elevation Above MSL feet (meters)	Average Daily Flow cfs (Cum/sec)	Date Sampled	Flow Sampled cfs (Cum/sec)	Channel Length feet (meters)	Channel Width feet (meters)	Surface Area Sampled sq. ft. (sq. m.)	Fish Species Sampled
Hog Park Creek #1	S9,T12N,R84W 1.4 miles below Hog Park Reservoir	8310 (2533)	27 (0.76)	Aug. 29, 1973	3.5 (0.10)	620 (189)	8-31 (2-9)	12,622 (1173)	Brown Trout (61%) Brook Trout (37%) Rainbow Trout (7%)
Hog Park Creek #2	S9,T12N,R84W 1.5 miles below Hog Park Reservoir	8280 (2524)	27 (0.76)	Aug. 1, 1975	27 (0.76)	356 (109)	15-35 (5-11)	8,308 (772)	Brown Trout (92%) Brook Trout (8%)
Hog Park Creek #3	S9,T12N,R84W 1.5 miles below Hog Park Reservoir	8270 (2521)	27 (0.76)	Aug. 4, 1975	19 (0.54)	304 (93)	17-32 (5-10)	7,196 (669)	Brown Trout (90%) Brook Trout (3%) Rainbow Trout (7%)
Hog Park Creek #4	S10,T12N,R84W Just above Mouth	8250 (2515)	45 (est.) (1.27)	Aug. 25, 1976	11 (0.31)	396 (121)	17-36 (5-11)	10,300 (957)	Brown Trout (97%) Brook Trout (3%)
Hog Park Creek #5	S10,T12N,R84W Just above Mouth	8245 (2513)	45 (est.) (1.27)	Aug. 25, 1976	10 (0.28)	383 (117)	13-33 (4-10)	7,812 (726)	Brown Trout (92%) Brook Trout (3%) Rainbow Trout (5%)
South Fork Hog Park Creek #1	S9,T12N,R84W Just above Mouth	8280 (2524)	15 to 20 (est.) (0.4-0.6)	Sept. 8, 1976	5 (0.15)	476 (145)	8-25 (2-8)	7,114 (661)	Brown Trout (62%) Brook Trout (37%) Rainbow Trout (1%)
South Fork Hog Park #2	S9,T12N,R84W Just above Mouth	8275 (2522)	15 to 20 (est.) (0.4-0.6)	Sept. 8, 1976	4 (0.11)	515 (157)	7-20 (2-6)	7,111 (661)	Brown Trout (66%) Brook Trout (34%)
Lake Creek #1	S16,T13N,R79W near Mouth	8540 (2603)	10 (est.) (0.28)	June 30, 1975	8 (0.23)	404 (123)	10-15 (3-5)	5,067 (471)	Brown Trout (82%) Brook Trout (18%) Longnose Suckers

APPENDIX I
DESCRIPTION OF STUDY SITES (cont.)

Study Area	Location	Elevation Above MSL feet (meters)	Average Daily Flow cfs (Cum/sec)	Date Sampled	Flow Sampled cfs (Cum/sec)	Channel Length feet (meters)	Channel Width feet (meters)	Surface Area Sampled sq. ft. (sq. m.)	Fish Species Sampled
Lake Creek #2	S16,T13N,R79W near Mouth	8520 (2597)	10 (est.) (0.28)	July 1, 1980	8 (0.23)	348 (106)	7-25 (2-8)	5,958 (553)	Brown Trout (79%) Brook Trout (20%) Rainbow Trout (1%) Longnose Suckers Longnose Dace Creek Chub
Deer Creek #1	S12,T31N,R77W 19 miles upstream from town of Glenrock, WY	6500 (1981)	44 (125)	Oct. 2, 1973	10 (0.28)	600 183)	34-68 (10-21)	27,000 (2508)	Brown Trout (67%) Rainbow Trout (33%) White Suckers Creek Chub Longnose Dace
Deer Creek #2	S7,T32N,R76W 11 miles above town of Glenrock, WY at Field's Campgrounds	5300 (1615)	Unknown	Oct. 3, 1973	18 (0.51)	650 (198)	30-43 (9-13)	24,500 (2276)	Brown Trout (67%) Rainbow Trout (33%) Longnose & White Suckers Creek Chubs Longnose Dace
Little Laramie River #1	S1 and 2 T15N,R77W	7580 (2310)	103 (2.91)	Sept. 4, 1975	28 (0.79)	308 (94)	25-48 (8-15)	11,420 (1061)	Brown Trout (100%) Longnose Suckers Longnose Dace
Little Laramie River #2	S1 and 2 T15N,R77W	7580 (231)	103 (2.91)	Sept. 5, 1975	28 (0.79)	240 (73)	24-48 (7-15)	8,110 (753)	Brown Trout (100%) Longnose Suckers White Suckers
Laramie River #1	S15,T12N,R77W At Boswell Ranch near Jelm, WY	7680 (2341)	159 (4.50)	Sept. 27, 1975	47 (1.33)	395 (120)	40-54 (12-16)	18,000 (1672)	Brown Trout (100%) Longnose Suckers
Laramie River #2	S15,T12N,R77W At Boswell Ranch near Jelm, WY	7675 (2339)	159 (4.50)	Sept. 10, 1975	66 (1.87)	456 (139)	45-66 (14-20)	23,230 (2344)	Brown Trout (100%) Longnose Dace Longnose Suckers

APPENDIX I
DESCRIPTION OF STUDY SITES (cont.)

Study Area	Location	Elevation Above MSL feet (meters)	Average Daily Flow cfs (Cum/sec)	Date Sampled	Flow Sampled cfs (Cum/sec)	Channel Length feet (meters)	Channel Width feet (meters)	Surface Area Sampled sq. ft. (sq. m.)	Fish Species Sampled
Laramie River #3	S15,T12N,R77W At Boswell Ranch near Jelm, WY	7670 (2338)	159 (4.50)	Sept. 27, 1975	55 (1.56)	396 (121)	40-72 (12-72)	23,088 (2145)	Brown Trout (98%) Rainbow Trout (2%) Longnose Dace Longnose Suckers
Laramie River #4	S36,T14N,R77W Just below Pioneer Canal	7380 (2249)	Unknown	Aug. 8, 1975	18 (0.51)	440 (134)	21-51 (6-16)	13,798 (1282)	Brown Trout (100%) Longnose Dace Longnose Suckers White Suckers
Laramie River #5	S28,T15N,R74W Approx. 7 miles west of Laramie, WY	7170 (2185)	Unknown	Aug. 11, 1975	29 (0.82)	455 (139)	38-46 (12-14)	21,591 (2007)	Brown Trout (100%) Longnose Dace Creek Chubs Common Shiners Sand Shiners White Suckers Longnose Suckers Fatheads
Laramie River #6	S28,T15N,R74W Approx. 7 miles west of Laramie, WY	7170 (2185)	Unknown	Aug. 12, 1975	28 (0.79)	324 (99)	34-51 (10-16)	13,766 (1280)	Brown Trout (100%)
Encampment River #1	S3,T12N,R84W Just above Olson Creek	8180 (2493)	160 (est.) (4.53)	Sept. 16, 1976	45 (1.27)	335 (102)	40-72 (12-22)	17,621 (1637)	Brown Trout (98%) Rainbow Trout (2%)
Encampment River #2	S3,T12N,R84W Just above Olson Creek	8175 (2492)	160 (est.) (4.53)	Sept. 14, 1976	40 (1.13)	461 (141)	34-68 (10-21)	20,679 (1921)	Brown Trout (95%) Brook Trout (4%) Rainbow Trout (1%)
Encampment River #3	S3,T12N,R84W Just above Olson Creek	8170 (2490)	160 (est.) (4.53)	Sept. 15, 1976	38 (1.08)	274 (84)	19-50 (6-15)	8,562 (795)	Brown Trout (99%) Rainbow Trout (1%)

APPENDIX I
DESCRIPTION OF STUDY SITES (cont.)

Study Area	Location	Elevation Above MSL feet (meters)	Average Daily Flow cfs (Cum/sec)	Date Sampled	Flow Sampled cfs (Cum/sec)	Channel Length feet (meters)	Channel Width feet (meters)	Surface Area Sampled sq. ft. (sq. m.)	Fish Species Sampled
Pelton Creek #1	S29,T13N,R79W 1 mile above Mouth	8300 (2530)	10 (est.) (0.28)	July 7, 1975	4 (0.11)	360 (110)	6-18 (2-5)	3445 (320)	Brook Trout (52%) Brown Trout (48%) Creek Chub White Suckers Longnose Suckers
Pelton Creek #2	S29,T13N,R79W 1 mile above Mouth	8300 (2530)	10 (est.) (0.28)	July 8, 1975	6 (0.17)	376 (112)	6-14 (2-4)	3552 (330)	Brook Trout (54%) Brown Trout (46%) White Suckers
Horse Creek #1	S28,T17N,R70W	6990 (2130)	Unknown	June 3, 1981	2 (0.05) 7/20/81	300 (91)	4-19 (1-6)	2728 (254)	Brown Trout (83%) Brook Trout (17%)
Horse Creek #2	S28,T17N,R70W	7040 (2145)	Unknown	June 4, 1981	2 (0.05) 7/21/81	300 (91)	7-18 (2-5)	3437 (319)	Brown Trout (58%) Brook Trout (29%) Rainbow Trout (13%)