MODELING TROUT STANDING STOCK IN SMALL WYOMING STREAMS BASED UPON EASILY MEASURED HABITAT AND GEOMORPHOLOGICAL CHARACTERISTICS

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Abstract

The need to assess fishery quality in mountain streams is associated with development of water resources, timber harvest, and recreational use. Available methods to estimate trout standing stocks in streams are labor intensive. A goal in stream habitat assessment is to develop a method that requires little field work, but accurately predicts trout abundance. This report presents regression modes which predict trout abundance in forested mountain areas and in rangeland areas of Wyoming. Independent variables include easily measured instream habitat and geomorphological variables. The models have been validated using field data. The best forest model accounted for 51 percent of the trout standing stock, while the best rangeland model accounted for 64 percent of the variation. A multivariate link was established between instream habitat and geomorphology. Rapid data collection and a mechanism for quick, reliable preliminary decision making should make these models attractive to managers.

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INTRODUCTION

Trout standing stock in unexploited stream systems is a function of habitat qulality. Habitat quality for trout is dependent upon the interaction between food producing areas, water quality, instream cover and spawning sites (Wesche and Rechard 1980). As few stream systems are totally unexploited, it is recognized that harvesting of fish may bias studies of the relation between measured features of habitat and trout standing stock.

Despite the impact of recreational fishing, measurable components of stream habitat have been shown to be related to trout standing stock and methods to evaluate habitat quality have been developed. Most methods are field intensive, requiring large expenditures of time and money. A logical step in stream habitat assessment is to develop a technique that measures the habitat needs of trout, but requires minimal field work.

Habitat Variables and Trout Standing Stock

Numerous investigators have reported relations between measurable components of habitat and standing stock of trout. Usually stream habitat evaluations have been limited to studies of the "water column" and channel morphology (Platts et al. 1983).

The water column provides fish and other aquatic organisms with physical support and a medium in which movement can occur (Platts et al. 1983). Characteristics of the water column such as water temperature, especially maximum summer water temperature (Hynes 1970; Binns 1979), water velocity (Lewis 1969; Wesche 1973; Nickleson 1976; Binns 1979), stream depth (Eifert and Wesche 1982) and pool quality (Schuck 1943; Shetter et al. 1946; Lewis 1969; Binns 1979) have been found to influence trout standing stock in streams.

The stream zone, consisting of the stream channel (banks and stream bottom), channel morphology and flood plain characteristics along the riparian zone, also has been related to standing stock of trout in streams. Average annual stream flow and peak stream flow can be estimated for ungaged channels from channel measurements taken during periods of low flow (Lowham 1976). These estimates can be used to determine annual stream flow variation. Stream flow variation results in poor habitat quality for trout when highly variable (Binns 1979). Instream and bank cover have also been shown to influence trout standing stock in streams (Boussu 1954; Lewis 1969; Binns 1979; Wesche 1974, 1980; Eifert and Wesche 1982).

Stable stream banks enhance habitat quality for trout in streams. When undercut, they have been shown to be an important component of trout cover (Boussu 1954; Hunt 1971; Wesche 1973, 1980). Stream bank and bottom stability were positively related to trout standing stock in two small Wyoming streams (Eifert and Wesche 1982). Overhanging bank vegetation, besides providing allochthonous input to the stream (Hickman and Raleigh 1982) and cover (Wesche 1980) can also regulate summer stream temperatures (Brocksen et al. 1968; Raleigh et al. 1984a).

Composition of the stream channel substrate has a greater influence on trout standing stock in streams than any other single factor (Cummins 1966). Fine sediment ($\leq$ 0.25 cm. diameter) has been associated with decreased trout standing stock due to it's negative effect on aquatic macroinvertebrate production (Tarzwell 1936; Kimble and Wesche 1975) and trout reproductive success (Saunders 1965; Reiser and Wesche 1976). Rubble substrate (7.6-30 cm.) is optimal for production of aquatic macroinvertebrates (Pennak and Van Gerpen 1947; Sprules 1947; Kimble and Wesche 1975) used by trout as food (Behnke and Zarn 1976). Gravel substrates (0.26-7.5 cm.) are prefered by salmonids for spawning (Bovee 1974; Reiser and Wesche 1976).

Channel gradient influences trout habitat quality by it's effect on water velocity and stream sediment transport (Platts et al. 1983). When two salmonid species occur in the same stream system, they may segregate into differing channel gradients (Bachman 1958; MacPhee 1966; Kennedy and Strange 1982). In brook trout (<u>Salvelinus fontinalis</u>) streams in the Snowy Range of Wyoming, standing stock decreased with increasing gradient (Chisholm and

Hubert, In Press).

Species Variation in Habitat Selection

Brook trout, brown trout (*Salmo trutta*), rainbow trout (*S. gairdneri*) and cutthroat trout (*S. clarki*) have similar habitat requirements (Behnke and Zarn 1976; Hickman and Raleigh 1982; Raleigh 1982; Raleigh et al. 1984a; Raleigh et al. 1984b). Cover, or refuge areas in streams that provide protection from predators and high current velocities, is important to these trout species and may govern the carrying capacity of trout streams (Saunders and Smith 1962; Wesche 1980).

Certain generalities can be made about habitat selection by the four common trout species found in the central Rocky Mountains. Brown trout tend to be the most cover oriented species (Boussu 1954; Lewis 1969; Wesche 1980) with overhead bank cover being especally important (Wesche et al., In press). Cutthroat trout are generally found at the highest elevations, in the highest gradient channels (Platts 1974) and in association with rubble-boulder habitat (Wesche 1980). Brook trout are found at higher elevations than rainbow trout (Newman 1956; Platts 1974; Eifert and Wesche 1982), in meadow sections with low channel gradients (Platts 1974) and associated with instream cover (Boussu 1954; Hunt 1971). Rainbow trout are found at higher elevations than brown trout (Eifert and Wesche 1982), in middle gradient stream sections (Platts 1974) and in more open parts of the stream channel with faster water velocities

(Butler and Hawthorne 1968; Lewis 1969; Platts 1974).

Competition among species, rather than species habitat preference, may account for observed differences in habitat relations between trout species (Newman 1956; Moore et al. 1983). Mixing of salmonid species in stream systems by management actions has generated trout communities where the natural mechanisms of spatial partitioning may not have evolved. Often the result is the biggest fish are associated with the best habitat (Newmann 1956).

Habitat Models and Trout Standing Stock in Rocky Mountain Streams

Mathematical modeling of trout standing stock in streams offers a method to assess components of habitat, and provide insight into standing stock and habitat relations. When refined and tested, these models can offer an alternative to direct measurements of trout standing stock by removal or mark recapture methods. Such models may provide a mechanism to test specific habitat components and a system to evaluate management decisions.

In recent years several habitat models have been developed. Lewis (1969) developed a model to predict brown trout and rainbow trout standing stocks based on measures of surface area, volume, depth, current velocity and cover in pools. He found that a combination of current velocity and cover variables were important for brown trout, while current velocity was most important for rainbow trout.

A widely recognized model is the Wyoming Habitat Quality Index (HQI; Binns 1979). During the first phase of model development, Binns (1979) rated 10 habitat variables and combined them in an index of habitat quality which correlated with trout standing stock. The fish food abundance and fish food diversity attributes used in the model were difficult and time consuming to assess, so these attributes were replaced with an index of macroinvertebrate production. The resulting model accounted for 97 percent of the variation in trout standing stock for 36 Wyoming streams. Testing of this model with eight additional streams resulted in 93 percent of the variation in trout standing stock explained and low prediction error between actual and predicted standing stock.

Wesche (1973, 1976) developed the Wyoming Trout Cover Rating (TCR) method which incorporated measures of overhead bank cover, instream rubble-boulder cover and the preference for these two habitat features by adult ($\geq$ 15.25 and juvenile (< 15.25 cm) trout. The TCR was initially developed to quantify changes in cover at different flow regimes. Subsequently, Wesche (1980) modified the cover rating to include a deep water factor for large streams (average discharge $\geq$ 2.83 cubic meters per second). Regressing the TCR against standing stock of trout resulted in a statistically significant ($P < 0.05$) relation for brown trout, but no statistically significant relations were found between the TCR and brook trout or cutthroat trout standing stocks (Wesche 1980). However, Eifert and Wesche (1982) found that the TCR was significantly correlated ($R = 0.43$; $P < 0.10$) to trout standing stock in two small Wyoming streams predominated by brook trout.

Another method of predicting habitat quality is the Habitat Evaluation Procedure (HEP) of the United States Fish and Wildlife Service (1980, 1981). Habitat quality for fish species is determined via Habitat Suitability Index models (HSI). To date HSI models have been developed for cutthroat trout (Hickman and Raleigh 1982), brook trout (Raleigh 1982), brown trout (Raleigh et al. 1984a) and rainbow trout (Raleigh et al. 1984b). Specific habitat variables are rated from zero (worst habitat quality) to 1 (best habitat quality) based upon HSI curves developed from the literature. Models have as yet not been tested in the field except for a test of the brown trout HSI model currently being undertaken by the University of Wyoming (Wayne A. Hubert, University of Wyoming, Wyoming Cooperative Fishery and Wildlife Research Unit, Personal Communication).

Drainage Basin Geomorphology and Trout Standing Stock

Streams and their watersheds develop together, with 95 percent of all landforms being shaped by streams (Strahler 1964). As a result of stream-watershed interactions, streams reflect the hydrology and biology of their watersheds (Platts 1974, 1979). Ziemer (1973) stated that in addition to channel characteristics, instream habitat, and thereby the stream potential to produce fish, may be the result of geomorphic processes in the drainage basin.

Thus, measures of drainage basin geomorphology may be useful tools in predicting trout standing stock in streams.

Fausch and Parsons (1984) reviewed 26 models that predicted standing stock of salmonids in stream systems. Of these, 21 were based solely on measures of instream habitat and channel morphology. Five models used drainage basin geomorphology to predict salmonid standing stock (Ziemer 1973; Burton and Wesche 1974; Platts 1974; Wesche et al. 1977; Oswood and Barber 1982). Ziemer (1973) used drainage basin geomorphology to predict pink salmon (*Oncorhynchus gorbuscha*) escapement in Alaska, while Burton and Wesche (1974) developed an index to trout abundance in southeast Wyoming streams. Using variables from Ziemer (1973) and Burton and Wesche (1974), Wesche et al. (1977) developed an index for cutthroat trout standing stock in the Sierra Madre Range of Wyoming. Platts (1974) in Idaho and Oswood and Barber (1982) combined drainage basin geomorphology and measures of instream habitat to predict salmonid standing stocks.

In addition to these five models, Swanston et al. (1977) and Heller et al. (1983) used drainage basin geomorphology to model salmonid habitat quality. Swanston et al. (1977) analyzed drainage basin geomorphology through multivariate analysis and were able to differentiate between "very good" and "very poor" salmon streams in southeast Alaska. Heller et al. (1983) used geomorphology to estimate fish habitat quality on the Siuslaw National Forest in

Oregon. All of these studies indicate that drainage basin geomorphology, measured from United States Geological Survey topographic maps, can be used as reliable predictors of trout habitat quality.

Stream Reach Inventory Channel Stability Evaluation and Trout Standing Stock

Stream Reach Inventory Channel Stability Evaluation (SRICSE; Pfankuch 1975) is a visual assessment of channel and streambank stability. It's main application is in second to fourth order mountain streams for the evaluation of stream bank and channel substrate material resistance to detachment (Pfankuch 1975). Eifert and Wesche (1982) stated that insight into the entire watershed may be gained by evaluation of SRICSE scores averaged over a stream.

Several investigators have used SRICSE to assess habitat quality in streams. Brouha (1981) found that SRICSE scores between 77 and 83 were associated with the highest trout standing stock and that scores between 58 and 100 reflected acceptable habitat conditions in the Shasta-Trinity National Forest of California. The highest number of catchable trout were associated with SRICSE scores between 70 and 85 (Robert Rainville, United States Forest Service, Couer D'Alene, Idaho, Personal Communication). Eifert and Wesche (1982) working on small streams in southeastern Wyoming found that SRICSE scores between 65 and 91 corresponded to the best fishery habitat. In addition, Eifert and Wesche (1982) compared results of

Duff and Cooper's (1978) stream survey methodology and trout standing stock. Results showed that five variables; average width, average reach depth, pool rating score, bank cover and stream velocity had significant relations with trout standing stock. Inclusion of these variables into the SRICSE rating could increase the biological sensitivity of SRICSE and provide a rapid method to predict trout habitat quality (Eifert and Wesche 1982).

Lanka et al. (1984) developed multiple-linear regression models for small Wyoming trout streams. Preliminary analysis indicated different relations between SRICSE and trout standing stock in forest (those stream reaches within National Forest boundaries) and nonforest streams (those outside). Subsequently two models were developed which accounted for 56 percent and 62 percent of the variation in trout standing stock in forest streams and nonforest streams, respectively.

Study Objectives

Many methods have been developed to assess stream habitat quality. These methods provide means to assess trout standing stock in streams and to predict the effects of management decisions. Most methods to assess stream habitat quality are dependent upon extensive measures of instream habitat, consequently these methods are often time consuming and costly. Studies of drainage basin geomorphology indicate that geomorphic characterisitcs may be valuable predictors of habitat quality, while at the same time being inexpensive data to collect. Previous work has suggested a relation exists between drainage basin geomorphology and instream habitat. This study addresses the statistical relation among selected variables of both types to provide insight into their relation with each other and with trout standing stock.

The objectives of this study were:

1) Evaluate by use of simple-linear regression, the relationship between drainage basin geomorphology and instream habitat variables with trout standing stock.

2) Develop predictive multiple-linear regression models for small Wyoming trout streams based on variables shown to be significantly ($P \leq 0.10$) correlated to trout standing stock.

3) Test these models with independent data.

4) Choosing only those variables significantly related to trout standing stock, determine the correlation between instream habitat variables and measures of drainage basin geomorphology.

5) Determine if there is a multivariate relation between those instream habitat and geomorphological variables significantly related to trout standing stock.

METHODS

Baxter and Simon (1970) divided Wyoming into four major drainage systems: Missouri River Basin; Colorado River Basin; Great Basin; and Columbia River Basin. They further divided these main basins by their major tributary rivers. During this study data were gathered from the Colorado and Missouri River systems within Wyoming.

Sources of Instream Habitat Data and Standing Stock Estimates

Data used for model development were compiled from two basic sources. First, during 1983, phone contact with Bureau of Land Management and University of Wyoming personnel enabled utilization of existing agency file data. Second, data were gathered from additional streams by field measurements during the summer of 1984.

Agency file data were accepted only if the following criteria were met: 1) instream habitat data and standing stock estimates were collected over the same reach within one month of each other 2) a SRICSE rating (Pfankuch 1975) had been conducted as well as measurements of nine other instream habitat variables (Table 1); and 3) a minimum two-pass depletion estimate following DeLury (1947, 1951) or Zippin (1958) for each reach was made so that a reliable

Table 1. Instream habitat variables used in data analysis.

Stream Reach Inventory and Channel Stability Evaluation Composite Score
Average Wetted Reach Width in meters
Average Reach Depth in meters
Average Reach Velocity in meters per second
Width-Depth Ratio[a]
Percent Bedrock and Boulder Substrate $\geq$ 30.1 centimeters diameter
Percent Rubble Substrate 7.6 - 30.0 centimeters diameter
Percent Gravel Substrate 0.26 - 7.5 centimeters diameter
Percent Silt-Sand Substrate $\leq$ 0.25 centimeters diameter
Reach Gradient in percent

[a]Computed as average wetted reach width divided by average reach depth.

estimate of standing stock was available. Sources of file data are listed in Appendix A.

Field Data Collection Methods

In the summer of 1984, data were collected on small (< 10 meters average wetted width during summer low flow), perennial streams with known populations of brown trout, rainbow trout, cutthroat trout or brook trout. It was assumed that if trout were present in a stream reach, the stream above the reach point was within acceptable water chemistry and temperature limits for trout survival. At least one pool-riffle sequence was included in each 75-meter study reach. Because of the difficulty in effectively collecting accurate data in stream segments excessively cluttered with debris or overhanging vegetation, such reaches were avoided. This may have introduced some bias, but avoided situations where the efficiency of data collection was greatly influenced by stream obstructions.

Within each 75-meter reach, 10 cross channel transects were established at 7.5-meter intervals. At each transect, wetted stream width was measured perpendicular to flow (Duff and Cooper 1978; Platts et al. 1983), and mean wetted stream width was computed for the reach. Depth measurements were taken at 0.25, 0.50 and 0.75 of the wetted stream width. The three depth measurements for each transect were summed and divided by four to compute mean transect depth. Division is by four to account for zero depths at the banks

(Duff and Cooper 1978; Platts et al. 1983). The mean depth for each of the 10 transects was then averaged to obtain average reach depth. Width-depth ratio was computed as the average wetted width divided by the average reach depth. Concurrent with each depth measuremen substrate class was visually determined (Table 1; Duff and Cooper 1978). The sum for each substrate class was divided by the total number of measurements to obtain the percent of each substrate class over the reach.

Channel stability can be visually estimated using SRICSE (Pfankuch 1975). Fifteen stability indicators were numerically rated over an entire stream reach. Three stream zones were examined; upper bank, lower bank and channel bottom. Each indicator was rated excellent, good, fair or poor. Total reach score, the sum of the individual ratings, was then grouped into one of four stability classes, from excellent to poor. Total reach SRICSE score was used in data analyses.

Water velocity estimates were made using the float method (Buchanan and Somers 1969; Duff and Cooper 1978; Orth 1983). A pencil was floated three times over a relatively straight, unobstructed subsection of the reach for approximately 20 seconds. Distance traveled and float duration were recorded. The subsection velocity (meters per second) was computed as the sum of the float lengths in meters divided by the sum of the float durations in seconds. Within the reach subsection where velocity measurements were taken, three equally spaced transects were measured to determine average width and depth. Discharge through the subsection was computed using the equation giver by Buchanan and Somers (1969), Duff and Cooper (1978) and Orth (1983):

(average subsection width x average subsection depth x average subsection velocity x 0.85) = discharge in cubic meters per second.

The correction factor of 0.85 was used to adjust for faster than average water velocities on the water surface. It is the average of the 0.8 (rough stream bottom) and 0.9 (smooth stream bottom) correction factors recommended by Duff and Cooper (1978) and Orth (1983), and was used to avoid bias associated with deciding what was smooth-or-rough bottom streambeds.

Average reach velocity was computed assuming that discharge was constant through the reach. For this computation a rearrangement of the equation presented for discharge was used, but incorporating average reach values for stream width and depth:

(discharge / average reach wetted width x average reach depth) = average reach velocity.

Reach gradient was estimated with a clinometer following Duff and Cooper (1978).

Standing Stock Estimates

Estimates of trout standing stock were obtained at each site using the removal method (DeLury 1947, 1951). Each reach was blocked at the upper and lower end with a minnow seine (6.35 square millimeter mesh) to prevent emigration or immigration. Three depletion passes were made over the reach with a battery-powered Coffelt Model BP-2 backpack electro-shocker. At the end of each pass fish were weighed to the nearest gram and natural total length (Anderson and Gutreuter 1983) was measured to the nearest millimeter. Only trout $\geq$ 100 millimeters were measured and weighed. Those < 100 millimeters were counted in young-of-the-year estimates. Estimates of trout population in each reach were computed with program CAPTURE (White et al. 1982). Model M(bh) was chosen because it allowed for capture variability among animals and for behavioral responses to the first capture attempt (Reynolds 1983). Trout standing stock (kilograms per hectare) was then determined as:

(estimated number of trout of each species in the reach x average weight of that species captured and weighed in the reach) = trout standing stock.

Geomorphological Variables

Eleven geomorphological variables were measured from United States Geologic Survey, 1:24,000 scale topographic maps (Table 2). When 1:24,000 scale maps were not available, 1:62,500 scale maps were used. Variables shown to be correlated to trout standing stock in previous studies (Ziemer 1973; Burton and Wesche 1974; Heller et al. 1983) initially were chosen for measurement, but were thought to be too time consuming in their measurement for management purposes.

Table 2. Characteristics of drainage basin geomorphology analyzed for relations to trout standing stock in this study.

Variable	Units
Reach Elevation	Meters
Mid-Range Basin Elevation	Meters
Stream Order	
Basin Area	Hectares
Basin Perimeter	Kilometers
Basin Relief	Meters
Compactness Coefficient	
Stream Length	Kilometers
Relief Ratio	Meters/Kilometer
Channel Slope	Meters/Kilometer
Drainage Density	Kilometers/Kilometer ^{2}

Therefore, geomorphological characteristics were used that measured similar drainage basin processes, but could be obtained more quickly.

Each study site was located on a topographic map and it's drainage divide was drawn. Study reach elevation was read directly from the map. Mid-range basin elevation was used to approximate mean basin elevation. It was calculated as:

[(highest elevation on the headwater divide +

reach elevation) / 2] = mid-range basin elevation.

Stream order was determined by counting only those stream channels shown in blue on topographic maps (Horton 1945 as modified by Strahler 1952, 1957). Basin area (Horton 1945) was measured using a compensating polar planimeter while basin perimeter (Horton 1945), was measured using a map measurer. Basin relief (Schumm 1956) was calculated as:

(highest elevation on the headwater divide -

reach elevation) = basin relief.

Compactness coefficient (CC) was a component variable of the Fish Habitat Index natural quality number developed for the Siuslaw National Forest by Heller et al. (1983) and was calculated by the equation:

$$(\text{basin perimeter} \ / \ [2 \times (3.14 \times \text{basin area})^{\frac{1}{2}}]) =$$

compactness coefficient.

Stream length (Horton 1945) was measured by following the longest watercourse shown in blue on the map with a map measurer. Relief ratio (Schumm 1956) was calculated as the basin relief divided by the stream length. Channel slope was calculated using the equation given by Craig and Rankl (1978):

(elevation at 85% of stream length -
elevation at 10% of stream length) /
(85% of stream length - 10% of stream length) = channel slope.

Drainage density (Horton 1945) was calculated as the kilometers of all stream channels shown in blue in a drainage basin divided by the drainage area in square kilometers.

Data Analysis

Due to the proposed land exchange between the Bureau of Land Management and the United States Forest Service, separating stream reaches by political boundary (Lanka et al. 1984) was abandoned. Instead a latitudinal-elevation gradient, demarcating high-elevation coniferous forest dominated watersheds from lower elevation sagebrush-grassland dominated rangeland watersheds was used (Table 3). The boundary elevation between forest and rangeland streams approximately follows the low-elevation coniferous forest timber line in Wyoming. This system allowed placement of high elevation streams not on National Forest Lands into the forest stream data set. Separate analyses was performed on each data subset.

Statistical data analysis employed BMDP (Dixon et al. 1981) and The Statistical Package for the Social Sciences (SPSS) (Nie et al. 1975) statistical computer programs. Simple-linear regression

Table 3. Elevation at which forest streams were separated from rangeland streams at different minutes of latitude.

Minutes of Latitude	Elevation (Meters)
41-42	2287
42-43	2135
43-44	1982
44-45	1830

was used to determine the correlation, significance level and direction of the relation between each independent variable and trout standing stock. Normal probability plots and standardized residual plots were inspected to detect violations of regression assumptions and to justify log transformations of independent variables (Zar 1974). Those variables significantly correlated ($P \leq 0.10$) to trout standing stock were analyzed using BMDP all-subsets multiple-linear regression. If log transformations increased accounted for variance at least 5 percent, the transformed variable was chosen over the untransformed one for further statistical analyses. All-subsets multiple-linear regression was used to pick the set of variables with the highest adjusted coefficient of determination (R_a^2).

Adding variables can only increase the unadjusted coefficient of determination (R^2; Neter and Wasserman 1974). A more conservative estimate of statistical fit than R^2 is R_a^2 , since R_a^2 may decrease as more variables are added to a regression equation. Only if an additional variable adds information to the resulting model, will R_a^2 increase (Neter and Wasserman 1974).

Due to the effects of colinearity, a positive relationship between one independent variable and trout standing stock may change to a negative relation with multiple-linear regression. All-subsets multiple-linear regression does not report regression coefficients for every possible subset. Therefore, the model chosen as best based upon all-subsets regression (one with relatively few variables yet a high R_a^2 value), was reanalyzed using SPSS multiple-linear regression. Inspection of the regression coefficients and their significance level enabled evaluation of the biological relation of each variable in the equation with trout standing stock.

The relationship between those instream and geomorphic variables that were significantly correlated to trout standing stock was investigated using canonical correlation. With canonical correlation, variable coefficients were chosen such that the linear combination of instream variables (u) was maximally correlated with the linear combination of geomorphic variables (v). The correlation between these canonical variables, u and v, was the canonical correlation (Rc; Levine 1977). If a pair of instream or geomorphic variables were highly multicolinear ($R \leq 0.75$) one was excluded from analysis. The remaining variables were used to generate a canonical model for both forest and rangeland stream types.

RESULTS

A common problem in collecting data from different sources is the bias introduced by variability in methods used to collect the data. Seven of the instream habitat variables, and trout standing stock data obtained from agency files were estimated using different methods (Table 4). Despite the variation in methods used to collect these data, they were used in this study for two reasons. First, the range of precision between methods was probably no greater than that between data collectors. Second, the potential bias in the data was recognized apriori, and since these data met selection criteria for data acceptance and were available, they were used.

Study stream reaches were located in ten of Wyoming's 23 counties (Table 5) and two of Wyoming's 4 major river drainages (Table 6). Reach township, range, section and elevation are listed in Appendix B along with the United States Geologic Survey topographic map on which each site was found.

Variable Characteristics and Relations with Trout Standing Stock

Study reaches for both forest and rangeland streams varied widely in their characteristics (Tables 7 and 8). Data from the 91 study reaches used in this study for model development are presented

Table 4. Methods used by Bureau of Land Management and University of Wyoming sources to gather data used in this study.

Variable	Collection Method	Number of Reaches
Standing Stock	Removal	
	Delury (1947, 1951)	32
	Zippen (1956)	13
Velocity	Price AA Meter[a]	21
	Time of Travel Dye[a]	22
	Gauging Station[a]	1
	Float[b]	1
Gradient	Surveying Method[c]	34
	Topographic Map[c]	11
Substrate	Transect[c]	41
	Visual[b]	4
Elevation	Field Measured	32
	Topographic Map[b]	14

[a]Buchanan and Somers 1969

[b]Duff and Cooper 1978

[c]Platts et al. 1983

Table 5. Number of study stream reaches by Wyoming County used in model development. N = 91.

County	Number of Reaches
Albany	8
Big Horn	3
Carbon	51
Fremont	9
Hot Springs	3
Johnson	4
Laramie	6
Park	1
Sheridan	3
Washakie	3

Table 6. Number of study stream reaches in each major drainage basin of Wyoming used in model development. N = 91.

MISSOURI RIVER BASIN	Number of Reaches
Bighorn River	10
Tongue River	3
Powder River	4
Platte River	21
Laramie River	5
Encampment River	4
Sweetwater River	15
Medicine Bow River	10
COLORADO RIVER BASIN	
Little Snake River	19
GREAT BASIN	
None	
COLUMBIA RIVER BASIN	
None	

Table 7. Range of values for the forest stream variables used in this study. N = 65.

Variable Name	Lowest Value	Highest Value
Trout Standing Crop	1.0 Kg/Ha	604.2 Kg/Ha
SRICSE Reach Score	51	141
Average Wetted Reach Width	0.78 M	9.14 M
Average Reach Depth	0.04 M	0.40 M
Average Reach Velocity	0.06 M/S	0.81 M/S
Width Depth Ratio	5.0	88.83
Percent Bedrock Boulder Substrate	0	74
Percent Rubble Substrate	0	70
Percent Gravel Substrate	0	70
Percent Silt-Sand Substrate	0	46
Percent Reach Gradient	1	9
Reach Elevation	2097 M	3158 M
Mid-Range Basin Elevation	2426 M	3362 M
Stream Order	1	5
Basin Area	95 Ha	39290 Ha
Basin Perimeter	5 Km	96 Km
Basin Relief	165 M	1601 M
Compactness Coefficient	0.08	0.36
Stream Length	1.7 Km	29.3 Km
Relief Ratio	23.5 M/Km	262.3 M/Km
Channel Slope	8.4 M/Km	116.1 M/Km
Drainage Density	0.40 Km/Km^2	4.2 Km/Km^2

Table 8. Range of values for the rangeland stream variables used in this study. N = 26.

Variable Name	Lowest Value	Highest Value
Trout Standing Crop	8.5 Kg/Ha	393.9 Kg/Ha
SRICSE Reach Score	61	128
Average Wetted Reach Width	1.52 M	7.47 M
Average Reach Depth	0.05 M	0.46 M
Average Reach Velocity	0.07 M/S	0.74 M/S
Width Depth Ratio	6.63	48.80
Percent Bedrock Boulder Substrate	0	53
Percent Rubble Substrate	0	67
Percent Gravel Substrate	3	56
Percent Silt-Sand Substrate	6	77
Percent Reach Gradient	1	4
Reach Elevation	1329 M	2245 M
Mid-Range Basin Elevation	1987 M	2841 M
Stream Order	2	6
Basin Area	1348 Ha	48918 Ha
Basin Perimeter	23 Km	173 Km
Basin Relief	267 M	3024 M
Compactness Coefficient	0.14	0.26
Stream Length	8.3 Km	72.4 Km
Relief Ratio	14.8 M/Km	116.3 M/Km
Channel Slope	10.1 M/Km	70.0 M/Km
Drainage Density	0.8 Km/Km^2	5.5 Km/Km^2

in Appendix C.

About one-half of the variables analyzed in both forest and rangeland streams were significantly ($P \leq 0.10$) related to trout standing stock. Five of the 10 instream variables and five of the 11 geomorphological variables were significantly related to trout standing stock in forest streams (Table 9). In rangeland streams, five of the 10 instream variables and six of the 11 geomorphological variables were significantly related to trout standing stock (Table 10). Normality and residual plots indicated possible violations of regression assumptions. Log transformations were used to correct for these violations. The effects of these transformations on significance level and R_a^2 are presented in Tables 9 and 10 for forest and rangeland streams, respectively.

Upon inspection of X,Y plots for each independent variable and trout standing stock, three independent variables showed the peak range of standing stock spread over a narrow range of predictor variable values. These three variables, reach elevation (RE) in forest streams, mid-range basin elevation (MRE) and width-depth ratio (WD) in rangeland streams, were rated from 1 (low standing stock range) to 3 (high standing stock range) to yield a more linear relation between the rated predictor variable and trout standing stock. A rating system was chosen over polynomial regression (raising predictor variables to increasing powers) due to the ease of interpretation and the applicability of rating systems to

Table 9. Adjusted R^2 values for those variables significantly ($P \leq 0.10$) correlated to trout standing stock (Kg/Ha) and the influence of log transformations used to correct for violations of regression assumptions in forest streams. X = Nonsignificiant relation. N = 65.

Variable	Raw Data	Log Transformed
SRICSE Reach Score	X	X
Average Wetted Reach Width	-0.12	-0.18[a]
Average Reach Depth	X	X
Average Reach Velocity	X	X
Width Depth Ratio	-0.09	-0.21[a]
Percent Bedrock Boulder Substrate	X	X
Percent Rubble Substrate	-0.05[a]	-0.08
Percent Gravel Substrate	0.05[a]	X
Percent Silt-Sand Substrate	X	X
Percent Reach Gradient	-0.03[a]	-0.03
Reach Elevation	-0.03[b]	-0.04
Mid-Range Basin Elevation	-0.14[a]	-0.17
Stream Order	X	X
Basin Area	X	X
Basin Perimeter	X	X
Basin Relief	-0.07	-0.14[a]
Compactness Coefficient	X	X
Stream Length	X	X
Relief Ratio	X	-0.12[a]
Channel Slope	X	X
Drainage Density	-0.05[a]	-0.05

[a]Variable forms used in model development.

[b]Rated form of this variable used ($R_a^2 = 0.25$)

Table 10. Adjusted R^2 values for those variables significantly ($P \leq 0.10$) correlated to trout standing stock (Kg/Ha) and the influence of log transformations used to correct for violations of regression assumptions in rangeland streams. X = Nonsignificant relations. N = 26.

Variable	Raw Data	Log Transformed
SRICSE Reach Score	X	X
Average Wetted Reach Width	-0.22	-0.27[a]
Average Reach Depth	X	X
Average Reach Velocity	-0.25[a]	-0.27
Width Depth Ratio	-0.23[b]	-0.16
Percent Bedrock Boulder Substrate	X	X
Percent Rubble Substrate	-0.23[a]	-0.20
Percent Gravel Substrate	X	X
Percent Silt-Sand Substrate	0.13[a]	0.14
Percent Reach Gradient	X	X
Reach Elevation	0.27[a]	0.25
Mid-Range Basin Elevation	X[b]	X
Stream Order	-0.31[a]	-0.32
Basin Area	-0.08[a]	X
Basin Perimeter	-0.05[a,c]	X
Basin Relief	-0.30	-0.43[a]
Compactness Coefficient	X	X
Stream Length	-0.07[a,d]	X
Relief Ratio	-0.08	-0.16[a]
Channel Slope	-0.07	-0.14[a]
Drainage Density	X	X

[a]Variable forms used in model development.

[b]Rated form of this variable:
Mid-Range Basin Elevation $R^2 = 0.40$
Width Depth Ratio $R_a^2 = 0.45$[a]

[c]$P = 0.1330$

[d]$P = 0.1014$

management situations. The ratings were:

reach elevation

1 = RE < 2150 meters,

2 = RE > 2355 meters,

3 = 2150 $\leq$ RE $\leq$ 2355 meters;

mid-range basin elevation

1 = MRE $\leq$ 2000 meters or MRE $\geq$ 2600 meters,

2 = 2000 < MRE < 2325 meters or 2475 < MRE < 2600 meters,

3 = 2325 $\leq$ MRE $\leq$ 2475 meters;

width-depth ratio

1 = WD $\leq$ 10 or WD > 33,

2 = 23 $\leq$ WD $\leq$ 33,

3 = 10 < WD < 23.

The effects of rating these three variables are presented in tables 9 and 10 for forest and rangeland streams, respectively.

In rangeland streams, basin perimeter (P = 0.1330) and stream length (P = 0.1014) did not meet the criteria for significance ($P \leq 0.10$) used in this study. However, the negative relation to trout standing stock shown by both these variables (Table 10) was logical and because both variables were near the significance level used in this study, they were included in regression analyses for model development.

Models

Three multiple-linear regression models were developed for both forest and rangeland streams. For each stream type, those geomorphological and instream habitat variables indicated in Tables 9 and 10 were used to develop the first model. In both stream types this model gave the highest adjusted coefficient of determination and was called the "best model". The second model was based only on those instream habitat variables and the third only on those geomorphological variables indicated in Tables 9 and 10.

The best model for forest streams (N = 65) was:

$$Y = 447.75 + 67.49(RRE) - 153.67[\log(RR+1)] - 35.73(DD) - 263.09[\log(ARW+1)].$$

Where: Y = predicted kilograms per hectare trout; RRE = rated reach elevation; RR = relief ratio; DD = drainage density; ARW = average wetted reach width.

This model was significantly correlated with trout standing stock ($F = 17.42$; $P < 0.001$; $R_a^2 = 0.51$; $R = 0.73$). Prediction error for this model, or the difference between actual standing stock and predicted standing stock (residual) divided by actual standing stock, was 119 percent. All regression coefficients were significantly different from zero ($P = 0.01$; Table 11).

The instream habitat model for forest streams (N = 65) was:

$$Y = 408.22 - 189.66[\log(ARW+1)] - 113.92[\log(WD+1)] - 12.41(G).$$

Where: Y = predicted kilograms per hectare trout; ARW = average wetted reach width; WD = width-depth ratio; G = percent reach

Table 11. Standard error and probability level of the regression coefficients for the best forest stream model.

Variable	Coefficient	SE	T	Probability
Rated Elevation	67.49	25.03	2.70	0.009
Relief Ratio	-153.67	45.76	-3.36	0.001
Drainage Density	-35.73	9.55	-3.74	0.000
Average Reach Width	-263.09	55.39	-4.75	0.000
Constant	447.75	129.15	3.47	0.001

gradient.

This model was significantly correlated with trout standing stock ($F = 10.51$; $P < 0.001$; $R_a^2 = 0.31$; $R = 0.58$). Prediction error for this model was 139 percent. All regression coefficients were significantly different from zero ($P = 0.08$; Table 12).

The geomorphological variable model for forest streams ($N = 65$) was:

$$Y = 471.54 + 99.38(RRE) - 138.17[\log(BR+1)] - 123.60[\log(RR+1)].$$

Where: Y = predicted kilograms per hectare trout; RRE = rated reach elevation; BR = basin relief; RR = relief ratio.

This model was significantly correlated with trout standing stock ($F = 12.98$; $P < 0.001$; $R_a^2 = 0.36$; $R = 0.62$). Prediction error for this model was 307 percent. However, one reach had an 11,020 percent prediction error (actual standing stock = 1.0, predicted standing stock = 110.2). When this one stream was excluded, prediction error decreased to 139 percent. All regression coefficients were significantly different from zero ($P = 0.03$; Table 13). Figure 1 shows the scatter of points about the regression line for each of the forest stream models.

The best model for rangeland streams ($N = 26$) was:

$$Y = 200.25 + 36.05(RMRE) - 0.85(BP) - 138.73[\log(CS+1)] + 50.45(RWD).$$

Where: Y = predicted kilograms per hectare trout; RMRE = rated mid-

Table 12. Standard error and probability level of the regression coefficients for the instream habitat model in forest streams.

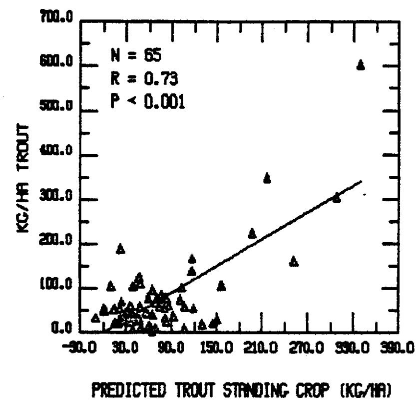
Variable	Coefficient	SE	T	Probability
Average Reach Width	-189.66	85.79	-2.21	0.031
Width Depth Ratio	-113.92	62.04	-1.84	0.071
Reach Gradient	-12.41	4.15	-2.99	0.004
Constant	408.22	67.68	6.03	0.000

Table 13. Standard error and probability level of the regression coefficients for the geomorphological variable model in forest streams.

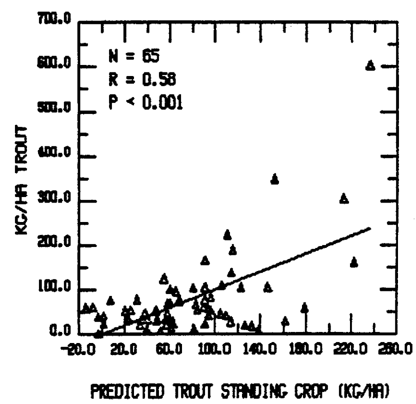
Variable	Coefficient	SE	T	Probability
Rated Elevation	99.38	27.25	3.65	0.001
Basin Relief	-138.17	53.96	-2.56	0.013
Relief Ratio	-123.60	52.02	-2.38	0.021
Constant	471.54	195.64	2.41	0.019

Figure 1. Actual standing stock versus predicted standing stock for the three forest stream models. A = best model, B = instream habitat model, C = geomorphological variable model.

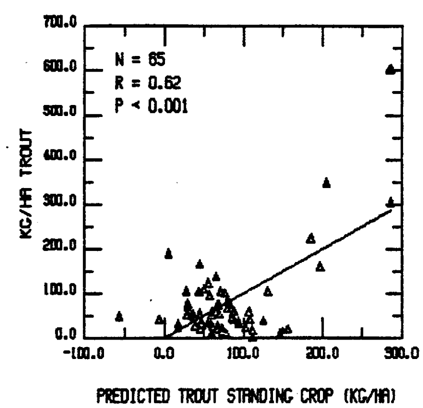
A.


N = 65
R = 0.73
P < 0.001
KG/HA TROUT
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
-30.0 30.0 90.0 150.0 210.0 270.0 330.0 390.0
PREDICTED TROUT STANDING CROP (KG/HA)

B.


N = 65
R = 0.58
P < 0.001
KG/HA TROUT
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
-20.0 20.0 60.0 100.0 140.0 180.0 220.0 260.0
PREDICTED TROUT STANDING CROP (KG/HA)

C.


N = 65
R = 0.62
P < 0.001
KG/HA TROUT
0.0
100.0
200.0
300.0
400.0
500.0
600.0
700.0
-100.0 0.0 100.0 200.0 300.0
PREDICTED TROUT STANDING CROP (KG/HA)

range basin elevation; BP = basin perimeter; CS = channel slope; RWD = rated width-depth ratio.

This model was significantly correlated with trout standing stock ($F = 11.99$; $P < 0.001$; $R_a^2 = 0.64$; $R = 0.83$). Prediction error for this model was 39 percent. All regression coefficients except rated mid-range basin elevation ($P = 0.112$), were significantly different from zero ($P = 0.07$; Table 14).

The instream habitat model for rangeland streams ($N = 26$) was:

$$Y = 39.20 + 70.95(RWD) - 197.10(ARV).$$

Where: Y = predicted kilograms per hectare trout; RWD = rated width-depth ratio; ARV = average reach velocity.

This model was significantly correlated with trout standing stock ($F = 17.31$; $P < 0.001$; $R_a^2 = 0.57$; $R = 0.78$). Prediction error for this model was 56 percent. All regression coefficients were significantly different from zero ($P = 0.02$; Table 15).

The geomorphological variable model for rangeland streams ($N = 26$) was:

$$Y = 487.59 + 53.30(RMRE) - 160.12[\log(BR+1)].$$

Where: Y = predicted kilograms per hectare trout; RMRE = rated mid-range basin elevation; BR = basin relief.

This model was significantly correlated with trout standing stock ($F = 14.29$; $P < 0.001$; $R_a^2 = 0.52$; $R = 0.74$). Prediction error for this model was 55 percent. All regression coefficients were significantly different from zero ($P = 0.03$; Table 16). Figure 2

Table 14. Standard error and probability level of the regression coefficients for the best rangeland stream model.

Variable	Coefficient	SE	T	Probability
Rated Mid-Range Basin Elevation	36.05	21.73	1.66	0.112
Basin Perimeter	-0.85	0.45	-1.88	0.073
Channel Slope	-138.73	52.59	-2.64	0.015
Rated Width Depth Ratio	50.45	17.48	2.89	0.009
Constant	200.25	122.38	1.64	0.117

Table 15. Standard error and probability level of the regression coefficients for the instream habitat model in rangeland streams.

Variable	Coefficient	SE	T	Probability
Rated Width Depth Ratio	70.95	16.46	16.46	0.000
Average Reach Velocity	-197.10	71.44	-2.76	0.011
Constant	39.20	46.92	0.84	0.412

Table 16. Standard error and probability level of the regression coefficients for the geomorphological variable model in rangeland streams.

Variable	Coefficient	SE	T	Probability
Rated Mid-Range Basin Elevation	53.30	22.90	2.33	0.029
Basin Relief	-160.12	59.07	-2.71	0.012
Constant	487.59	209.45	2.33	0.029

shows the scatter of points about the regression line for each of the rangeland stream models.

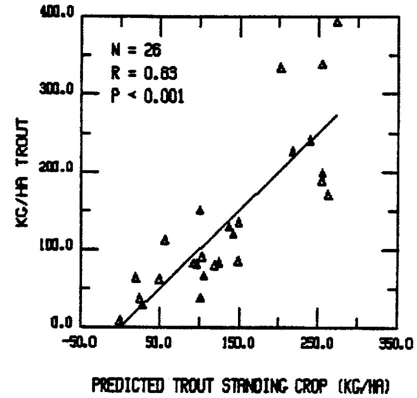
Relation Between Instream Habitat and Drainage Basin Geomorphology

Due to the functional relation between drainage basin geomorphology and stream channel formation, one would expect significant statistical relations to exist between measures of instream habitat and drainage basin geomorphology. For forest streams, 14 statistically significant ($P \leq 0.10$) relations exsisted between those instream habitat and geomorphological variables used for model development (Table 17). In rangeland streams 24 statistically significant relations were found (Table 18).

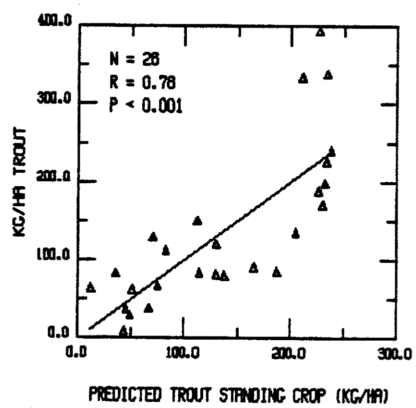
Canonical correlation analysis indicated significant functional relations exsisted between instream habitat variables and geomorphological variables. In forest streams the correlation between the canonical variables for the first function was highly significant ($Rc = 0.79$; $P < 0.001$; Figure 3). Canonical variate v reflected drainage basin size while canonical variate u reflected stream size. The second function also was highly significant ($Rc = 0.67$; $P < 0.001$; Figure 3). Canonical variate v may have reflected drainage basin features that indicate decreased response time to rainfall events, while canonical variate u may have reflected stream channel adjustments to this decrease in drainage basin response time. The redundancy index indicated that for forest streams the first two functions employ about 27 percent of the variance in the

Figure 2. Actual standing stock versus predicted standing stock for the three rangeland stream models. A = best model, B = instream habitat model, C = geomorphological variable model.

A.


N = 26
R = 0.83
P < 0.001
KG/HA TROUT
400.0
300.0
200.0
100.0
0.0
-50.0
50.0
150.0
250.0
350.0
PREDICTED TROUT STANDING CROP (KG/HA)

B.


N = 26
R = 0.78
P < 0.001
KG/HA TROUT
400.0
300.0
200.0
100.0
0.0
0.0
100.0
200.0
300.0
PREDICTED TROUT STANDING CROP (KG/HA)

C.

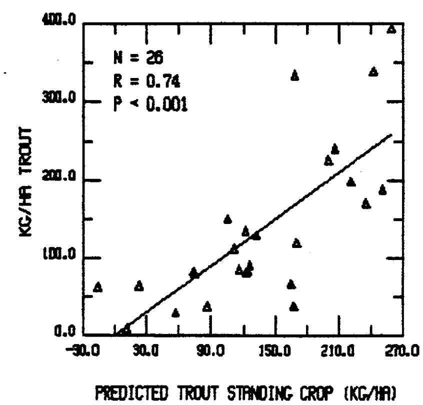

N = 26
R = 0.74
P < 0.001
KG/HA TROUT
400.0
300.0
200.0
100.0
0.0
-30.0
30.0
90.0
150.0
210.0
270.0
PREDICTED TROUT STANDING CROP (KG/HA)

Table 17. Correlations between the raw form of those instream habitat and geomorphological variables that were significantly ($P \leq 0.10$) correlated to trout standing stock in forest streams (Critical R value = 0.206 for N = 65; d.f. = 63; $P \leq 0.10$).

	Reach Elevation	Mid-Range Basin Elevation	Basin Relief	Relief Ratio	Drainage Density
Average Reach Width	0.07	0.36[a]	0.56[a]	-0.12	-0.28[a]
Percent Rubble Substrate	0.29[a]	0.43[a]	0.28[a]	0.10	-0.22[a]
Percent Gravel Substrate	-0.47[a]	-0.45[a]	0.08	0.28[a]	0.10
Reach Gradient	0.06	0.05	0.02	0.10	0.54[a]
Width-Depth Ratio	0.41[a]	0.44[a]	0.01	0.09	0.28[a]

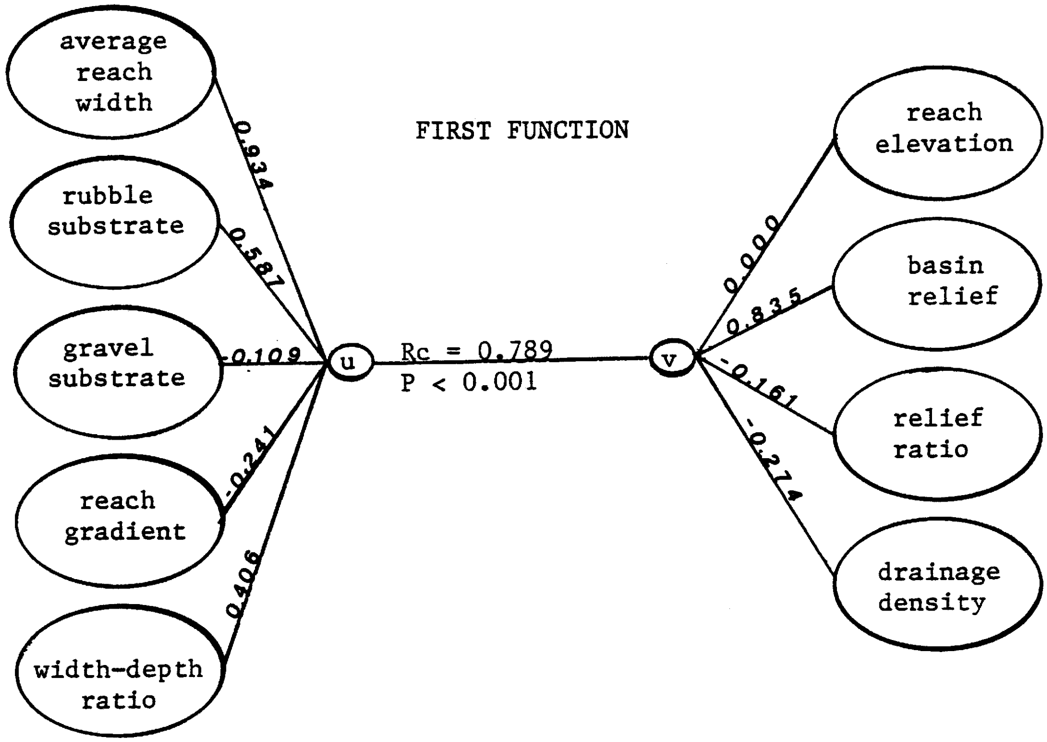
[a]A significant relationship at the $P \leq 0.10$ level.

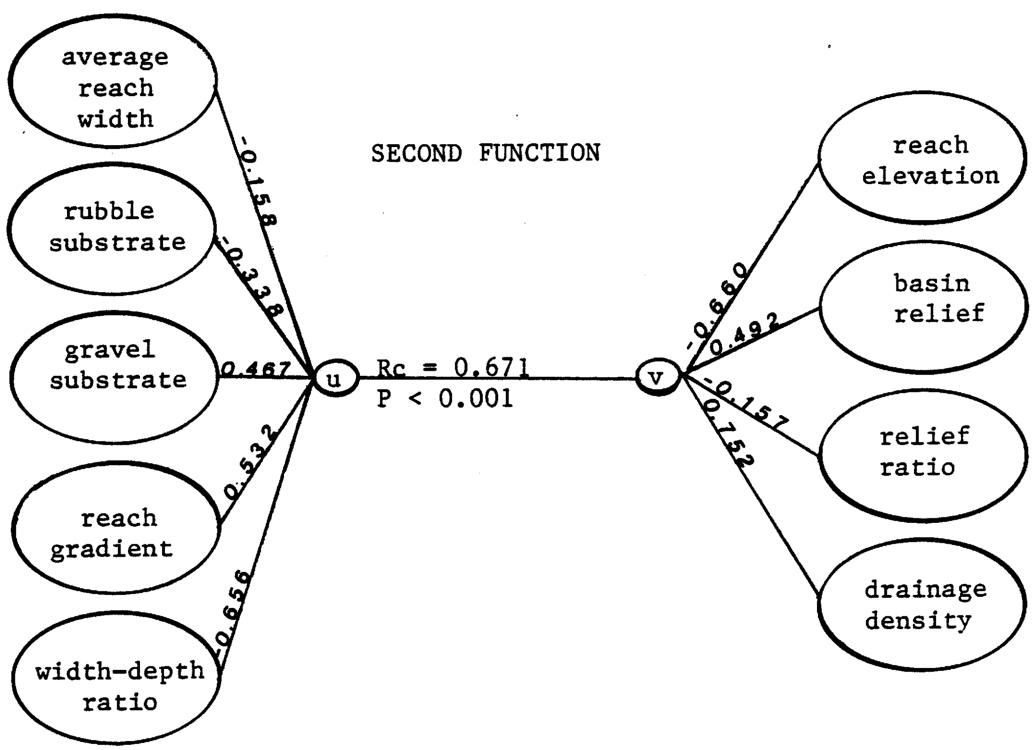
Table 18. Correlations between the raw form of those instream habitat and geomorphological variables that were used in rangeland stream model development (Critical R value = 0.33 for N = 26; d.f. = 24; $P \leq 0.10$).

	Reach Elevation	Mid-Range Basin Elevation	Stream Order	Basin Area	Basin Perimeter	Basin Relief	Stream Length	Relief Ratio	Channel Slope
Average Reach Width	-0.67[a]	0.00	0.62[a]	0.60[a]	0.55[a]	0.62[a]	0.63[a]	0.02	0.11
Average Reach Velocity	-0.60[a]	0.16	0.71[a]	0.55[a]	0.46[a]	0.56[a]	0.52[a]	0.15	0.15
Percent Rubble Substrate	-0.44[a]	0.09	0.50[a]	0.18[a]	0.08	0.53[a]	0.11	0.46[a]	0.58[a]
Percent Silt-Sand Substrate	0.32	-0.09	-0.17	-0.44[a]	-0.48[a]	-0.35[a]	-0.48[a]	0.05	-0.07
Width-Depth Ratio	-0.50[a]	-0.19	0.33[a]	0.08	0.12	0.17	0.11	0.04	0.26

[a]Significant relation at the $P \leq 0.10$ level.

Figure 3. Results of canonical correlation analysis between measures of instream habitat (canonical variate u) and drainage basin geomorphology (canonical variate v) in forest streams. Coefficients on the lines between an individual variable and it's canonical variable are structure coefficients which represent the correlation between each variable and the canonical variate.


FIRST FUNCTION
average reach width
rubble substrate
gravel substrate
reach gradient
width-depth ratio
0.934
0.587
-0.109
-0.241
0.406
u
Rc = 0.789
P < 0.001
v
0.000
0.835
-0.161
-0.274
reach elevation
basin relief
relief ratio
drainage density


SECOND FUNCTION
average reach width
rubble substrate
gravel substrate
reach gradient
width-depth ratio
-0.158
-0.338
0.467
0.532
-0.656
u
Rc = 0.671
P < 0.001
v
-0.660
0.492
-0.157
0.752
reach elevation
basin relief
relief ratio
drainage density

instream habitat and in the geomorphological variables used in this analysis.

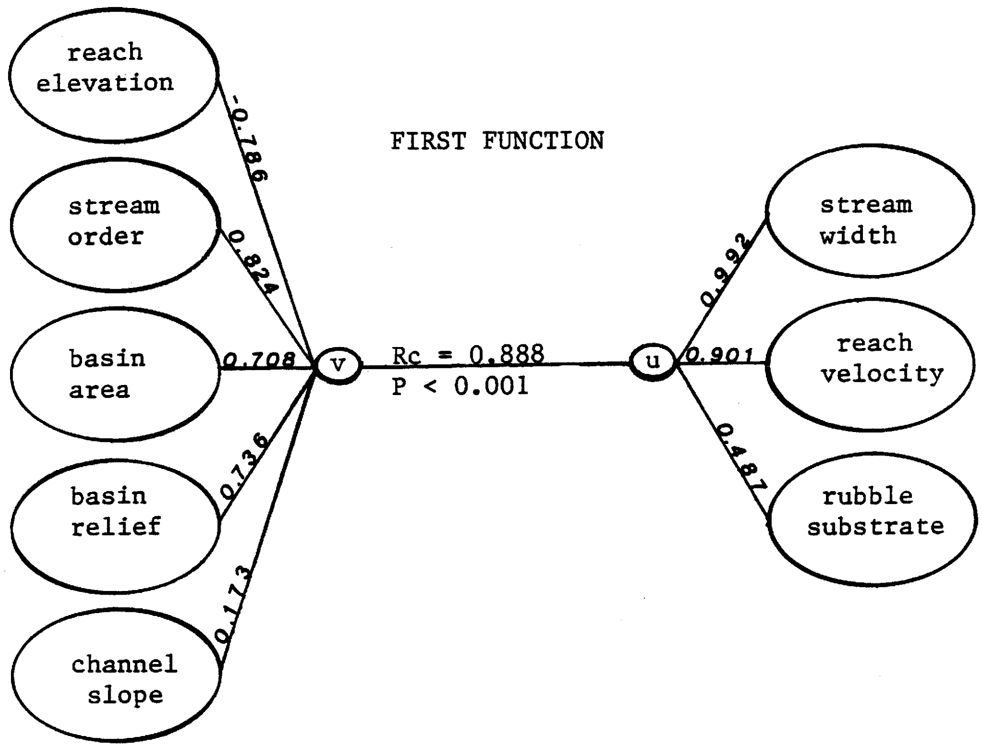
A highly significant relation between the canonical variables for the first function also was found in rangeland streams ($Rc = 0.89$; $P < 0.001$; Figure 4). Canonical variate v reflected drainage basin size while canonical variate u reflected stream size. The second function was also significant ($Rc = 0.69$; $P = 0.064$; Figure 4). Canonical variate v reflected basin gradient, while canonical variate u may have reflected food producing areas and instream cover. The redundancy index indicated that for rangeland streams, the first two functions employ about 60 percent of the variance in the instream habitat variables and 50 percent of the variance in the geomorphological variables used in this study.

Model Testing

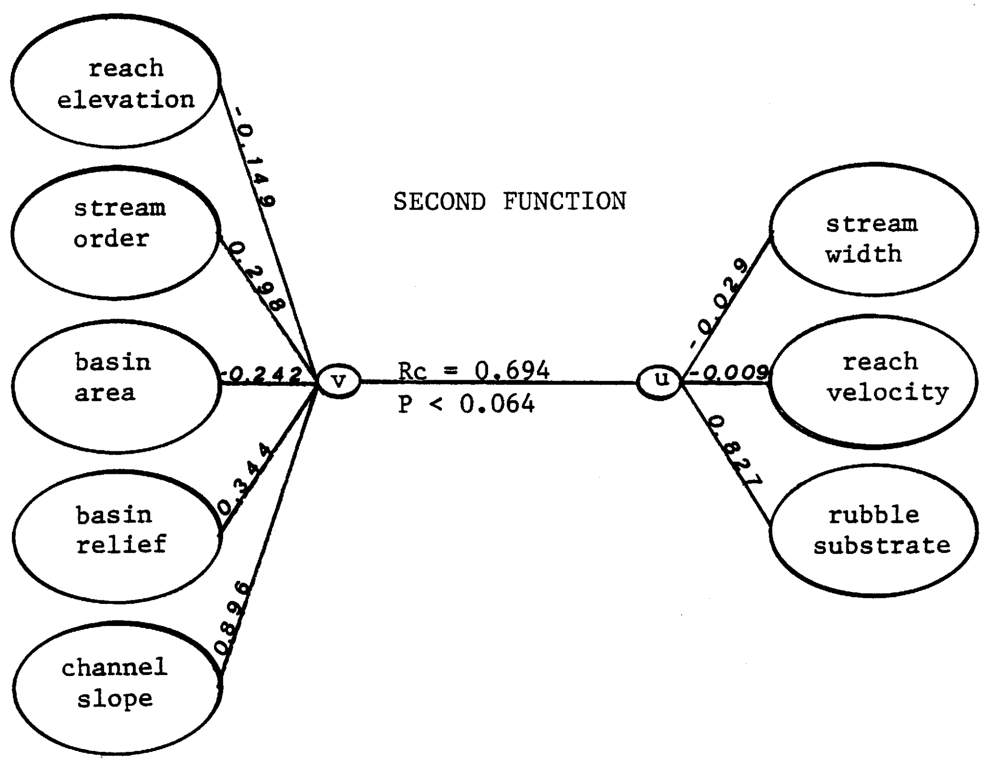
Each model was tested using an independent data set. Township, range, section, elevation and the United States Geologic Survey topographic map on which each test reach was located are listed in Appendix D. Data from the test reaches are presented in Appendicies E and F.

In all models, except the forest instream model, higher correlations between model output and actual standing stock were observed for model testing than in model development. All model tests had lower prediction error than those associated with model

Figure 4. Results of canonical correlation analysis between measures of instream habitat (canonical variate u) and drainage basin geomorphology (canonical variate v) in rangeland streams. Coefficients on the lines between an individual variable and it's canonical variable are structure coefficients which represent the correlation between each variable and the canonical variate.



reach elevation
stream order
basin area
basin relief
channel slope
FIRST FUNCTION
-0.786
0.824
0.708
0.736
0.173
v
Rc = 0.888
P < 0.001
u
0.992
0.901
0.487
stream width
reach velocity
rubble substrate



reach elevation
stream order
basin area
basin relief
channel slope
SECOND FUNCTION
-0.149
0.298
-0.242
0.344
0.896
v
Rc = 0.694
P < 0.064
u
-0.029
-0.009
0.827
stream width
reach velocity
rubble substrate

development. Percent prediction error and coefficient of correlation are presented in Table 19 (forest streams) and Table 20 (rangeland streams) for each model. Rangeland stream tests resulted in higher correlation and lower prediction error than those associated with forest streams. The "best model" in each stream type, as with model development, gave the best test results.

In initial testing of the forest stream models, three outliers were identified. Two reaches of Pelton Creek were located just off a main United States Forest Service access road in the Snowy Range southwest of Laramie, Wyoming. Heavy fishing pressure is known to occur on these stream reaches. A third reach, North Fork Savery Creek, had little fishing presure, but for an unknown reason always has had low trout standing stock (Donald Miller, Wyoming Game and Fish, Laramie, Personal Communication). When these three streams were eliminated from model testing the scatter of points about the regression lines was substantially reduced (Figure 5). No outliers were identified in the streams used to test the rangeland models. Again, the scatter of points about the regression line for these models indicated a close fit (Figure 6).

Table 19. Correlation coefficient and percent prediction error for the 11 streams used to test the forest stream models.

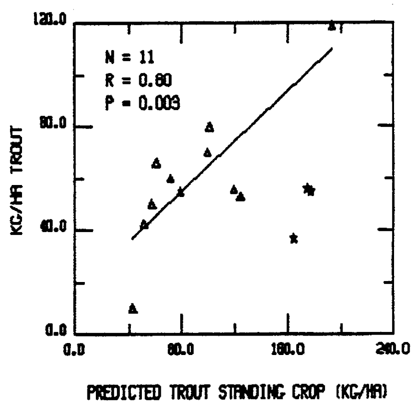
	Best Model	Instream Model	Geomorphic Model
Correlation Coefficient	0.80	0.32	0.75
Percent Prediction Error	73	103	101

Table 20. Correlation coefficient and percent prediction error for the 8 streams used to test the rangeland stream models.

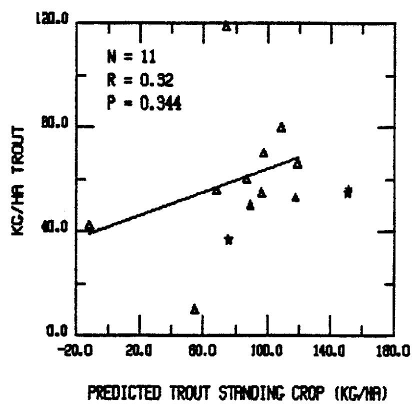
	Best Model	Instream Model	Geomorphic Model
Correlation Coefficient	0.96	0.90	0.69
Percent Prediction Error	18	29	50

Figure 5. Actual standing stock versus predicted standing stock for the forest stream model tests. A = best model test, B = instream habitat model test, C = geomorphological variable model test. The * identifies where the three streams identified as outliers fall on each plot.

A.


N = 11
R = 0.80
P = 0.003
KG/HA TROUT
120.0
80.0
40.0
0.0
80.0
160.0
240.0
PREDICTED TROUT STANDING CROP (KG/HA)

B.


N = 11
R = 0.32
P = 0.344
KG/HA TROUT
120.0
80.0
40.0
0.0
-20.0
20.0
60.0
100.0
140.0
180.0
PREDICTED TROUT STANDING CROP (KG/HA)

C.

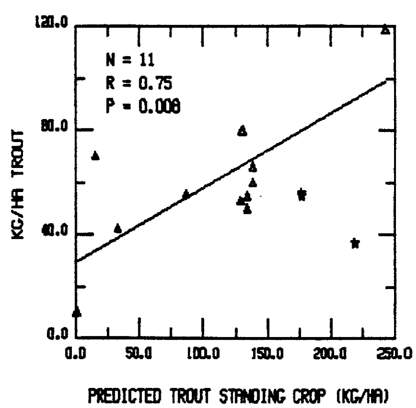
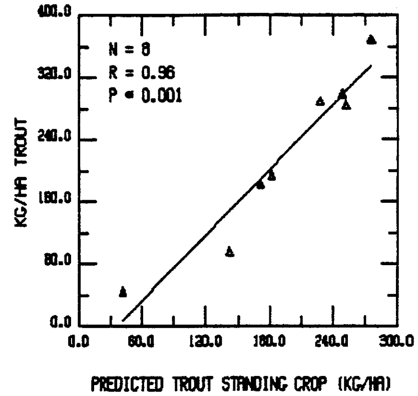
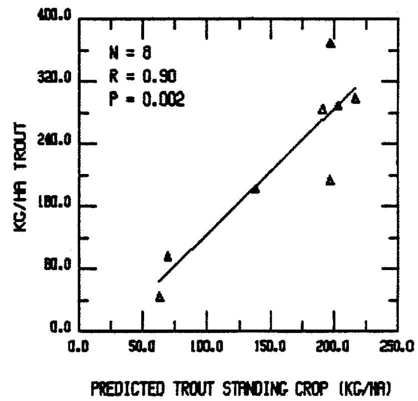

N = 11
R = 0.75
P = 0.008
KG/HA TROUT
120.0
80.0
40.0
0.0
50.0
100.0
150.0
200.0
250.0
PREDICTED TROUT STANDING CROP (KG/HA)

Figure 6. Actual standing stock versus predicted standing stock for the rangeland stream model tests. A = best model test, B = instream habitat model test, C = geomorphological variable model test.

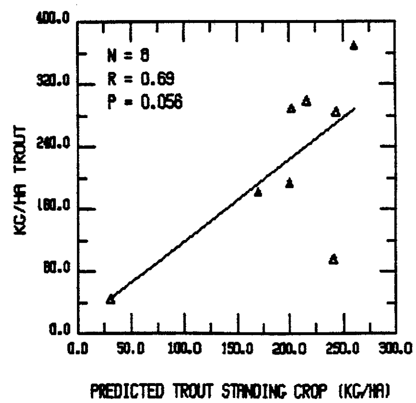
A.


N = 8
R = 0.96
P < 0.001
KG/HA TROUT
PREDICTED TROUT STANDING CROP (KG/HA)
0.0
80.0
160.0
240.0
320.0
400.0
60.0
120.0
180.0
240.0
300.0

B.


N = 8
R = 0.90
P = 0.002
KG/HA TROUT
PREDICTED TROUT STANDING CROP (KG/HA)
0.0
80.0
160.0
240.0
320.0
400.0
50.0
100.0
150.0
200.0
250.0

C.


N = 8
R = 0.69
P = 0.056
KG/HA TROUT
PREDICTED TROUT STANDING CROP (KG/HA)
0.0
80.0
160.0
240.0
320.0
400.0
50.0
100.0
150.0
200.0
250.0
300.0

DISCUSSION

This discussion has been divided into three parts. First, the biological significance of the statistical relations found between trout standing stock and predictor variables was discussed. Second, model reliability and applicability to management situations was considered. Finally, a discussion of the relations found between instream habitat and drainage basin geomorphology and how these relations affect trout was presented.

Instream Habitat Variables and Trout Standing Stock

In the following paragraphs those instream habitat variables significantly relate to trout standing stock have been discussed. Special emphasis was placed on those variables used in the models presented.

In small Wyoming streams, increasing stream width may negatively effect trout standing stock (Platts and Wagstaff 1984). As stream width increased beyond 3 meters, trout standing stock decreased in this study. With increasing stream width, the area of bank cover relative to stream area decreases. Cover oriented species such as trout, prefer streams with abundant overhead bank cover (Baldes and Vincent 1969; Lewis 1969; Hunt 1971; Wesche 1980). Boussu (1954) found that removal of overhead bank cover resulted in reduced trout standing stock. By having less of the stream channel influenced by overhead bank cover, increasing stream width may negatively affect trout standing stock (Hunt 1971).

Binns (1979) in contrast with results of this study, found that optimal trout habitat occurred at stream widths between 5.4 and 6.6 meters. However, the streams used by Binns (1979) were larger (maximum width 44 meters) than the small streams used in this study. The wider range of stream widths and the larger streams used by Binns (1979) probably account for the larger optimal stream width found by Binns (1979).

Width-depth ratio also was related negatively to trout standing stock. At width-depth ratios greater than 20, trout standing stock decreased. Eifert and Wesche (1982) found similar results in southeast Wyoming. Increasing width-depth ratios, similar to increasing widths, probably reflected less overhead bank cover per unit of stream area available to trout. In addition, with increasing width and decreasing depth, pool area tends to decrease (Platts 1974), limiting the quantity of this habitat that has been shown to be important to trout (Shuck 1943; Lewis 1969; Binns 1979).

Increasing stream width and width-depth ratios expose more water surface to solar insolation. Results presented by Conder (1982) showed that on the west slope of the Bighorn Mountains, as streams move downslope and become larger, water temperatures increase. In rangeland stream types, increasing stream temperatures may have limited trout standing stocks.

The negative relations found between the variables, channel gradient and percent rubble substrate, and trout standing stock probably have their influence on trout via a relation with water velocity. Numerous investigators have related higher water velocities with increasing channel gradient (Richards 1982; Kennedy and Strange 1982; Platts et al. 1983). Water velocity in this study was negatively related to trout standing stock. Suitable trout habitat was characterized by water velocities greater than 0.3 meters per second but less than 0.92 meters per second (Wesche 1973). Water velocities > 1.0 meter per second, result in poor habitat quality (Binns 1979) and have been shown to limit carrying capacity of trout in streams (Eifert and Wesche 1982).

Pool abundance in streams may be reflected by the quantity of silt-sand and gravel substrates. In this study, silt-sand substrate in rangeland streams and gravel substrate in forest streams ranged from less than ten percent to more than 75 percent of the channel substrate. Both were positively correlated to trout standing stock. These results were similar to those found by Platts (1974). Deep water with lower than average current velocity and silt-sand or fine gravel substrates characterize pool habitat (Wesche and Reiser 1976). In constrast to other studies showing negative relations between fine substrate material and trout food abundance (Tarzwell 1936; Saunders 1965) the positive relation between fine substrate material and trout standing stock seen in this study probably reflects the relation between fine substrate and reduced water velocities and higher quality pool habitat as seen by Platts (1974).

In stream systems habitat quality is dependent upon habitat diversity. None of the instream habitat variables analyzed in this study by themselves would generate habitat quality. Rather the combination of many habitat features is necessary for quality habitat.

Geomorphological Variables and Trout Standing Stock

Those geomorphic variables significantly related to trout standing stock have been discussed in the following paragraphs. Special emphasis again was placed on those variables used in the models developed in this study.

The relations observed between drainage basin geomorphology and trout standing stock (Tables 9 and 10) suggested that small, gently sloping drainage basins produced the best trout habitat. By their negative relation to trout standing stock, basin relief and relief ratio indicate that a large drop in elevation over the drainage basin and high stream gradient resulted in reduced trout habitat quality. Branson et al. (1981) stated that high basin relief resuled in greater channel slope and increased drainage density both of which were negatively related to trout standing stock in this study. The combined effects of these three watershed features [1) increased basin slope (basin relief and relief ratio), 2) increased channel slope, and 3) a more dendritic drainage pattern (drainage density)], may have tended to decrease stream response time to rainfall events. As a result, more water was concentrated faster in the channel system. Such drainage basins, when subjected to high intensity storms, as in much of Wyoming, often would have greater flow variability, reduced depression and groundwater storage and decreased base flows (Viessman et al. 1977). Low base flows and high stream flow variability both result in poor habitat quality for trout (White et al. 1976; Binns 1979). This combination of drainage basin features probably limit the carrying capacity of a trout stream.

In my study, highest trout biomass was associated with the transition zone between forest and rangeland stream types. Elevation was significantly related to trout in both stream types. Both forest and rangeland streams showed greatest trout standing stock at similar elevations: forest streams between 2100 and 2355 meters, and rangeland streams between 2100 and 2245 meters. The overlap in elevation between stream types may be due to the latitudinal-elevation gradient used to separate the two classes of streams. The negative relation between elevation, mid-range basin elevation and trout standing stock in forest streams suggested that lower forest streams have higher trout habitat quality. Conversely, the positive relation between elevation and trout standing stock in rangeland streams suggested that higher elevation rangeland streams have better habitat quality. Platts (1974) found a similar situation in forest streams in Idaho. He felt that width-depth relations and water temperature conditions in forest streams were more favorable at lower elevations. The best habitat quality for trout was found at the transition between high gradient boulder substrate habitat and lower gradient gravel substrate habitat (Elser 1968). This transition zone is located at the ecotone between forest and rangeland vegetation types Bowers et al. 1979). Elser (1968) felt that in this transition zone optimal water temperature and pool riffle ratios for trout were found. That the highest trout standing stock occurred at similar elevations for both stream types indicates that, in Wyoming, the ecotone between forest and rangeland vegetation types tends to have the best habitat quality for trout.

As with stream width and width-depth ratio, increasing stream size as reflected by geomorphic variables in this study, resulted in poor habitat quality for trout. Stream order, basin area, basin perimeter and stream length, all negatively related to trout standing stock in this study, are indicies of stream size (Viessman 1977; Platts 1974). Windell (1984) found that as stream order increased on the east slope of the Rocky Mountains, human impacts on the aquatic and riparian resources increased. Data presented by Conder (1982) indicated a similar situation existed in the Bighorn Basin of Wyoming. In my study, the negative influence of increasing stream size on trout standing stock as reflected by measures of drainage basin geomorphology and instream habitat probably was a result of decreasing overhead bank cover and increasing human impacts in the stream zone.

Variation in Model Performance

The models developed for forest streams did not predict trout standing stock as well as rangeland stream models. One reason may be the greater diversity of physical habitat conditions that support trout in forest streams. In rangeland streams, predictor variables such as stream width, may better reflect critical factors of habitat that limit trout such as maximum summer water temperature.

Another explanation for decreased model precision in forest streams may have been greater fishing pressure and exploitation. Rangeland streams in the Bighorn Basin were subject to low fishing pressure (Richards and Holden 1980; Conder 1982). In the Powder River Basin, rangeland streams were on private land with trespass fees charged to fish. Streams in the Platte River Basin were on private land with little public fishing allowed (Eifert and Wesche 1982). In the Sweetwater River drainage the two rangeland streams were located on land managed by Bureau of Land Management, but they were remote brook trout fisheries, 70 kilometers north of Rawlins, Wyoming. Forest streams were all located on public lands, had fair to good access and presumably received substantial fishing pressure with the exception of streams in the Little Snake River Basin.

Model Reliability and Application to Management

The models presented are a rapid way to evaluate trout habitat quality. The "best model" for both forest and rangeland stream types incorporated three geomorphological variables and one instream habitat variable. The drainage basin variables used in the "best model" and the geomorphic variable model take one person approximately one hour to measure from topographic maps. Average wetted reach width (forest streams) and width-depth ratio (rangeland streams) were the instream habitat variables used in the "best models". These variables collected over a reach using stream transects are easily and accurately measured (Platts et al. 1983).

The variables necessary for the instream habitat models also are easily collected. Average width and width-depth ratio are collected using stream transects. Reach gradient can be measured with a clinometer (Platts et al. 1983). Average reach velocity, necessary for the rangeland stream model, took two people about 45 minutes to estimate in the field. If flourescent dye is available, the leading edge velocity technique as recommended by Binns (1979) and Eifert and Wesche (1982) is more accurate and takes less time. In contrast to HQI (Binns 1979) and HSI models (Hickman and Raleigh 1982; Raleigh 1982; Raleigh et al. 1984a; Raleigh et al. 1984b) which are field intensive, the models presented in this study require 1 - 4 man-hours to collect necessary data.

Besides being quick, testing indicated the models to be reliable predictors of trout standing stock in small Wyoming streams. The prediction error associated with the forest stream models was about 130 percent, while that for rangeland streams was

50 percent. Binns (1979) had 23 percent prediction error during model development. While this value is much lower than that for models developed in this study, the time necessary to collect model data for Binns (1979) is substantially longer. Average prediction error for the forest stream model tests was about 90 percent (Table 19) while for rangeland streams it averaged about 30 percent (Table 20). When testing his model Binns (1979) found only a 12.5 percent prediction error. The 18 percent prediction error associated with the "best model" in rangeland streams (Table 20) compared favorably with that of Binns (1979).

The model universe is an important consideration for future model users (Johnson 1981). Application of models to areas where they do not apply is a common problem (Fausch and Parsons 1984). The area of applicability for the models from this study is bounded on the east by the eastern foothills of the Laramie and Bighorn Mountain ranges and on the west by the Continental Divide. The models are applicable to Wyoming except the extreme west and the northeast corner of the state.

Each model is applicable to management situations depending upon the specific question to be answered. Restricted by law, or limited by equipment and personnel from generating standing stock estimates, land management organizations could use the "best model" to obtain rapid preliminary standing stock estimates for large numbers of streams. The instream habitat model could be used apriori, to determine the effects of proposed management activities, such as stream improvements or water removal on trout standing stock. Potential trout standing stock in streams, with man's influence on the watershed minimized could be estimated by using the geomorphic variable model. Comparisons between this estimate and actual standing stock could provide the necessary data to enable mitigation of habitat loses due to activities in the watershed. So, for baseline assessment or for preliminary management information, all three models have potential application to management situations.

Instream Habitat and Drainage Basin Geomorphology

The high number of significant relations found between measured instream habitat variables and drainage basin geomorphological variables (Tables 17 and 18) suggested a functional link between the two variable types. While several investigators have used drainage basin geomorphology to predict salmonid standing stock or abundance (Ziemer 1973; Burton and Wesche 1974; Swanston et al. 1977), only Platts (1974) and Heller et al. (1983) have looked at the actual relation between drainage basin geomorphology and measures of instream habitat. Platts (1974) found that as stream order increased so did stream width, depth and the percent rubble substrate, but percent of the stream in pools, channel gradient and percent gravel substrate decreased. Heller et al. (1983) correlated a habitat condition score generated from measured instream habitat to four measures of drainage basin geomorphology. In my study, a statistical link between instream habitat and drainage basin geomorphology was established statistically between the two variable types.

Results of canonical correlation analysis provided further statistical evidence that a functional link existed between drainage basin features and instream habitat. In both forest and rangeland stream types, a strong link existed between measures of drainage basin size and stream size. Platts (1974) found similar results when comparing stream order with stream width and depth. Canonical correlation analysis selects variable information from each variable set to maximize the relation between the two resultant canonical variates (Levine 1977). The redundancy index for both stream types, but especially forest streams, indicates that the total percentage of measured variables being used to create the canonical variables is relatively small. Consequently, in my study, not all factors governing instream habitat can be explained by the geomorphic variables analyzed.

A statistical link between drainage basin geomorphology and; 1) trout standing stock instream habitat has been demonstrated in this study. Trout standing stock is a function of instream habitat quality (Binns 1979; Heller et al. 1983; Raleigh et al. 1984a). Instream habitat, based on results of this study, as well as Platts (1974) and Heller et al. (1983) is at least partially related to drainage basin features measured from topographic maps. Statistical evidence leads me to the conclusion that the relation between drainage basin geomorphology and trout standing stock is the result of a functional link between geomorphology and instream habitat.

SUMMARY

Predictive multiple regression models were developed for a wide variety of small Wyoming streams. The data set was divided into two subsets, forest streams and rangeland streams, based on a latitudinal-elevation gradient. Within each stream type, three models were developed that accounted for a significant amount of the variation in trout standing stock. One model used only measures of drainage basin geomorphology as predictor variables, while a second used only measures of instream habitat. A third model was developed that combined both measures of instream habitat and geomorphology to create a "best model". All models were tested with independent data. Tests resulted in high correlations with moderate prediction error. The models have applicability for baseline studies or preliminary analysis of habitat quality by management agencies. A statistical relation was found to exist between several instream habitat variables and drainage basin geomorphology. Measures of drainage basin size and stream size were highly correlated. This study demonstrated statistically that drainage basin geomorphology influences trout standing stock. I feel that the influence on trout standing stock shown by drainage basin characteristics is due to a functional relation between geomorphology and instream habitat.

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APPENDICES

APPENDIX A

Sources of File Data used in this Study:

United States Department of the Interior,

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APPENDIX B

Range, Township, Section, Elevation and United States Geologic Survey Topographic Quad for each Study Site sampled in 1984.

STREAM NAME	LEGAL LOCATION	ELEVATION (M)	UNITED STATES GEOLOGIC SURVEY TOPOGRAPHIC MAP
MISSOURI RIVER BASIN			
Bighorn River			
001 White Creek	53N 90W S19	1329 R[1]	Black Mountain
021 Trapper Creek	52N 90W S5	1451 R	Black Mountain
031 Medicine Lodge Creek	50N 89W S10	1585 R	Hyatt Ranch
041 Canyon Creek	47N 88W S12	1433 R	Ten Sleep
051 North Fork Otter Creek	45N 87W S15	1451 R	Big Trails
061 South Fork Otter Creek	45N 87W S15	1455 R	Big Trails
071 South Fork Owl Creek	43N 102W S3	1631 R	Arapaho Ranch
072 South Fork Owl Creek	43N 100W S28	1975 R	Anchor Reservoir
081 Wood River	46N 102W S21	2164 F[2]	Noon Point
091 Rock Creek	43N 102W S16	2600 F	Willow Creek
Tongue River			
101 Prospect Creek	54N 88W S17	2694 F	Woodrock
111 South Fork West Fork Tongue River	54N 88W S17	2694 F	Woodrock
121 Little Tongue River	56N 87W S28	2097 F	Dayton South

STREAM NAME	LEGAL LOCATION	ELEVATION (M)	UNITED STATES GEOLOGIC SURVEY TOPOGRAPHIC MAP
Powder River			
131 Doyle Creek	47N 84W S5	2469 F	Hazelton
141 Little North Fork Crazy Woman Creek	49N 82W S19	1621 R	Klondike Ranch
151 North Fork Crazy Woman Creek	49N 82W S19	1634 R	Klondike Ranch
161 South Fork Red Fork Powder River	44N 84W S29	1756 R	Mayoworth
Platte River			
171 North Fork Horse Creek	17N 70W S9	2045 R	Horse Creek
172 North Fork Horse Creek	17N 70W S8	2083 R	Ragged Top
173 North Fork Horse Creek	17N 70W S18	2121 R	Ragged Top
174 North Fork Horse Creek	17N 71W S13	2205 R	Ragged Top
175 North Fork Horse Creek	17N 71W S14	2245 R	Ragged Top
181 Horse Creek	17N 70W S22	2015 R	Horse Creek
182 Horse Creek	17N 70W S28	2082 R	Horse Creek
183 Horse Creek	17N 70W S28	2144 R	Horse Creek
184 Horse Creek	17N 71W S25	2234 R	Ragged Top
201 South Fork Sage Creek	26N 82W S17	2173 F	Beaver Creek
211 Saylor Creek	25N 82W S17	2271 F	Beaver Creek
221 Lost Creek	25N 82W S6	2307 F	Beaver Creek
231 East Fork Pass Creek	18N 81W S25	2548 F	Turpin Reservoir
241 Pass Creek	18N 81W S26	2533 F	Turpin Reservoir
251 Jack Creek	15N 87W S1	2603 F	Sharp Hill
252 Jack Creek	15N 86W S20	2533 F	Sharp Hill
261 North Fork Spring Creek	15N 86W S21	2676 F	Sharp Hill
262 North Fork Spring Creek	15N 86W S17	2655 F	Sharp Hill
271 South Fork Spring Creek	14N 86W S1	2755 F	Bridger Peak

STREAM NAME	LEGAL LOCATION	ELEVATION (M)	UNITED STATES GEOLOGIC SURVEY TOPOGRAPHIC MAP
272 South Fork Spring Creek	15N 86W S36	2700 F	Bridger Peak
281 Tributary Nugget Creek	15N 86W S15	2694 F	Sharp Hill
<u>Laramie River</u>			
291 Telephone Creek	16N 79W S15	3158 F	Centennial
301 Nash Fork Creek	16N 79W S14	3121 F	Centennial
302 Nash Fork Creek	16N 79W S13	2993 F	Centennial
311 South Fork Trail Creek	17N 78W S30	3045 F	Morgan
321 Trail Creek	17N 78W S19	2972 F	Morgan
<u>Encampment River</u>			
331 South Fork Hog Park Creek	12N 84W S9	2493 F	Dudley Creek
332 South Fork Hog Park Creek	12N 84W S9	2493 F	Dudley Creek
341 Hog Park Creek	12N 84W S10	2512 F	Dudley Creek
342 Hog Park Creek	12N 84W S10	2512 F	Dudley Creek
<u>Sweetwater River</u>			
351 Cherry Creek	27N 88W S12	2063 R	Youngs Pass
352 Cherry Creek	27N 88W S12	2054 R	Youngs Pass
353 Cherry Creek	27N 88W S2	1984 R	Youngs Pass
361 Pete Creek	27N 87W S28	2371 F	Spanish Mine
362 Pete Creek	28N 87W S32	1969 R	Youngs Pass
363 Pete Creek	28N 87W S33	1957 R	Spanish Mine
371 Middle Fork Cottonwood Creek	28N 91W S29	2402 F	Split Rock
381 Willow Creek	27N 90W S7	2298 F	Split Rock
382 Willow Creek	27N 91W S12	2332 F	Split Rock

STREAM NAME	LEGAL LOCATION	ELEVATION (M)	UNITED STATES GEOLOGIC SURVEY TOPOGRAPHIC MAP
391 East Fork Sweetwater River	29N 102W S14	2441 F	Anderson Ridge
392 East Fork Sweetwater River	19N 102W S25	2371 F	Anderson Ridge
401 Pine Creek	29N 101W S26	2432 F	South Pass City
402 Pine Creek	29N 101W S26	2438 F	South Pass City
411 Fish Creek	28N 101W S10	2335 F	South Pass City
412 Fish Creek	28N 101W S3	2353 F	South Pass City
Medicine Bow River			
421 Carlson Creek	17N 79W S4	2959 F	Sand Lake
422 Carlson Creek	18N 79W S33	2935 F	Sand Lake
431 East Fork Medicine Bow River	18N 80W S25	2688 F	White Rock Canyon
432 East Fork Medicine Bow River	18N 80W S36	2719 F	Sand Lake
441 Wagonhound Creek	18N 79W S18	2699 F	White Rock Canyon
451 Johnson Park Creek	17N 80W S13	2905 F	Sand Lake
452 Johnson Park Creek	17N 80W S14	2889 F	Sand Lake
461 Deep Creek	17N 80W S9	3071 F	Sand Lake
471 Middle Fork Rock Creek	17N 78W S18	2975 F	Morgan
472 North Fork Rock Creek	17N 79W S12	2950 F	Morgan
COLORADO RIVER BASIN			
Little Snake River			
481 Solomon Creek	13N 85W S32	2670 F	Solomon Creek
482 Solomon Creek	13N 85W S32	2646 F	Solomon Creek
483 Solomon Creek	13N 85W S32	2621 F	Solomon Creek
491 Roaring Fork Little Snake	13N 86W S14	2768 F	Solomon Creek
492 Roaring Fork Little Snake	13N 86W S22	2646 F	Solomon Creek

STREAM NAME	LEGAL LOCATION	ELEVATION (M)	UNITED STATES GEOLOGIC SURVEY TOPOGRAPHIC MAP
493 Roaring Fork Little Snake	17N 86W S22	2609 F	Solomon Creek
501 Dead Man Creek	13N 85W S28	2667 F	Solomon Creek
502 Dead Man Creek	13N 85W S33	2661 F	Solomon Creek
503 Dead Man Creek	13N 85W S33	2646 F	Solomon Creek
511 North Fork Little Snake	13N 85W S33	2633 F	Solomon Creek
512 North Fork Little Snake	13N 85W S33	2606 F	Solomon Creek
513 North Fork Little Snake	13N 85W S32	2594 F	Solomon Creek
521 Harrison Creek	13N 85W S32	2637 F	Solomon Creek
522 Harrison Creek	13N 85W S33	2695 F	Solomon Creek
523 Harrison Creek	12N 85W S4	2524 F	Solomon Creek
531 West Branch Little Snake	13N 86W S24	2667 F	Fletcher Peak
532 West Branch Little Snake	13N 86W S25	2646 F	Fletcher Peak
533 West Branch Little Snake	13N 86W S26	2560 F	Fletcher Peak
191 Big Sandstone Creek	14N 82W S29	2105 R	Tullis

[1]R=Rangeland Stream

[2]F=Forest Stream

APPENDIX C

Data from the 91 Stream Study Sites

used for Development of Models

Abbreviations are as follows:

STR - Stream name (see Appendix B)
LS - Landform slope
MWP - Mass wasting potential
DJP - Debris jam potential
VBP - Vegetative bank protection
CC - Channel capacity
BRC - Bank rock content
OFS - Obstructions flow deflectors and sediment traps
CUT - Cutting
DEP - Deposition
RA - Rock angularity
RB - Rock brightness
PP - Particle packing
%SM - Percent stable materials
SD - Scouring and deposition
CAV - Clinging aquatic vegetation
SRI - Stream reach inventory channel stability evaluation score for the reach
ARW - Average reach width in meters
ARV - Average reach velocity in meters per second
ARD - Average reach depth in meters
RF - Reach discharge in cubic meters per second
SIN - Channel sinuosity ratio over the reach
APC - Average pool class rating
%BB - Percent bedrock and boulder substrate
%R - Percent rubble substrate
%G - Percent gravel substrate
%SS - Percent silt sand substrate
%RG - Reach gradient in percent
RE - Reach elevation in meters
MRE - Mid-range basin elevation in meters
SO - Stream order
BA - Basin area in hectares
BP - Basin perimeter in kilometers
BR - Basin relief in meters
CC - Compactness coefficient
SL - Stream length in kilometers
CS - Channel slope in meters per kilometer
RR - Relief ratio in meters per kilometer
DD - Drainage density in kilometers per square kilometer

TRH - Kilograms per hectare all trout
BRH - Kilograms per hectare brook trout
BNH - Kilograms per hectare brown trout
RBH - Kilograms per hectare rainbow trout
CTH - Kilograms per hectare cutthroat trout
TRK - Kilograms per kilometer all trout
BRK - Kilograms per kilometer brook trout
BNK - Kilograms per kilometer brown trout
RBK - Kilograms per kilometer rainbow trout
CTK - Kilograms per kilometer cutthroat trout
NGF - Non-game species present
Y = Yes
N = No
STT - Stream type
R = Rangeland stream
F = Forest stream

STR	LS	MWP	DJP	VBP	CC	BRC	OFS	CUT	DEP	RA	RB	PP	%SM	SD	CAV	SRI	ARW	ARV	ARD	RF	SIN	APC	%BB	%R	%G	%SS	%RG	RE	MRE	SO	BA	BP
011	2	04	6	06	2	3	3	04	05	3	4	5	08	08	4	067	2.44	0.33	0.05	0.04	1.1	4	02	37	37	24	2	1329	2082	4	07718	071
021	7	05	7	05	3	4	3	05	05	3	2	4	05	07	2	067	5.03	0.34	0.18	0.31	1.2	3	08	47	30	15	2	1451	2363	3	10852	051
031	8	05	8	04	2	3	2	06	04	3	3	5	05	06	2	066	7.47	0.14	0.19	0.20	1.2	3	06	67	20	07	2	1585	2359	4	09628	069
041	8	08	6	04	2	5	4	06	12	1	1	3	08	15	1	084	5.58	0.58	0.27	0.88	1.5	2	52	29	13	06	2	1433	2309	4	20616	116
051	8	06	5	06	2	3	2	06	12	3	2	4	08	12	3	084	4.11	0.35	0.14	0.20	1.4	3	19	34	28	19	2	1451	2028	3	11966	063
061	8	05	5	08	3	4	2	12	13	3	2	5	08	18	2	093	5.97	0.31	0.16	0.30	1.4	3	16	32	15	37	2	1445	1987	5	09583	056
071	5	06	6	06	2	5	3	06	06	2	2	3	05	08	3	068	6.86	0.70	0.29	1.39	1.3	2	37	43	12	08	2	1631	2683	6	48918	173
072	2	03	4	11	2	5	4	06	06	3	4	3	06	10	4	073	4.57	0.50	0.10	0.23	1.2	3	05	40	45	10	2	1975	2841	4	21386	107
081	3	06	4	07	1	5	4	10	08	3	3	4	06	09	3	076	9.14	0.41	0.30	1.13	1.2	3	05	60	30	05	4	2164	2965	5	39290	096
091	2	06	4	05	2	6	4	08	08	3	2	4	08	10	3	075	3.05	0.30	0.10	0.09	1.2	2	00	44	38	18	1	2600	3132	4	05088	039
101	2	06	2	03	1	6	2	08	04	2	2	4	08	12	1	063	2.15	0.42	0.10	0.09	1.6	1	17	63	17	03	3	2694	2816	2	00695	013
111	2	09	2	06	3	8	2	12	08	3	3	6	12	12	2	090	3.59	0.31	0.16	0.18	3.8	3	07	27	66	00	3	2694	2917	3	01455	019
121	2	09	8	09	3	4	6	08	08	3	3	6	12	12	4	097	4.37	0.23	0.13	0.13	1.1	4	33	00	57	10	3	2097	2495	3	02738	031
131	2	03	6	03	1	6	8	08	16	4	3	8	16	12	4	100	3.37	0.24	0.15	0.12	1.6	3	27	10	46	17	3	2469	2840	3	02580	028
141	6	12	6	12	3	4	4	16	12	2	3	4	08	12	4	108	2.84	0.33	0.16	0.15	1.4	2	30	37	03	30	2	1621	2109	3	01474	035
151	4	09	4	06	2	2	2	16	12	3	4	6	04	18	4	096	5.88	0.74	0.24	1.04	1.0	2	53	27	10	10	4	1634	2534	4	12026	071
161	6	03	8	06	1	2	6	04	08	2	3	2	08	12	4	075	5.77	0.56	0.24	0.77	1.2	1	46	27	10	17	3	1756	2142	4	09521	070
171	2	09	4	09	2	4	6	08	16	2	4	8	12	24	2	110	2.44	0.18	0.07	0.03		4	10	22	45	23	2	2045	2282	2	05035	062
172	2	09	4	06	2	8	6	12	12	2	4	8	16	24	3	118	1.83	0.11	0.10	0.02		3	00	00	42	58	1	2083	2334	2	04526	055
173	4	06	4	06	2	4	4	08	12	2	3	6	12	18	3	094	2.13	0.09	0.11	0.02		3	24	17	27	32	2	2121	2352	2	04072	047
174	4	06	4	06	2	2	2	08	04	2	2	4	04	12	2	064	2.13	0.13	0.11	0.03		3	35	21	21	23	4	2205	2370	2	03719	045
175	4	06	4	06	2	4	6	12	04	2	3	4	08	12	2	079	1.52	0.13	0.10	0.02		4	09	24	40	27	1	2245	2389	2	03385	040
181	4	03	4	03	2	4	6	08	12	2	2	6	12	18	3	089	2.44	0.08	0.10	0.02		4	15	18	53	14	2	2015	2278	2	14436	094
182	4	06	4	06	2	2	4	04	08	2	1	4	08	12	2	061	3.05	0.09	0.22	0.06		3	19	23	39	19	2	2082	2388	2	14298	091
183	4	06	4	06	2	6	4	04	08	2	1	6	12	12	2	067	3.35	0.07	0.16	0.04		2	04	10	56	30	1	2144	2414	2	13861	086
184	4	03	4	03	2	4	4	04	04	2	1	4	12	12	2	065	2.44	0.10	0.13	0.03		3	09	27	27	37	1	2234	2469	2	11177	071
201	4	12	6	12	2	8	6	16	16	3	4	8	16	24	4	141	2.68	0.23	0.18	0.11	1.2	4	13	03	61	23	1	2173	2440	3	04614	039
211	6	09	6	06	1	6	6	06	12	2	3	6	12	24	3	118	2.18	0.34	0.08	0.06	1.5	2	20	07	63	10	3	2271	2449	2	00963	017
221	4	06	8	09	3	8	4	08	08	2	4	8	08	18	4	102	0.87	0.29	0.08	0.02	1.3	2	00	00	70	30	1	2307	2437	1	00382	008
231	2	09	8	06	2	4	6	12	12	2	3	4	08	12	2	092	6.11	0.35	0.12	0.26	1.1		64	27	09	00	4	2548	2734	3	01362	021
241	2	09	4	06	2	4	4	08	08	3	2	4	08	12	2	080	4.86	0.46	0.13	0.29	1.1		44	44	06	06	5	2533	2879	3	02031	025

STR	LS	MWP	DJP	VBP	CC	BRC	OFS	CUT	DEP	RA	RB	PP	%SM	SD	CAV	SRI	ARW	ARV	ARD	RF	SIN	APC	%BB	%R	%G	%SS	%RG	RE	MRE	SO	BA	BP
251	2	06	2	07	1	4	2	08	12	3	3	6	16	12	3	083	5.45	0.23	0.18	0.23	1.6		03	41	53	03	2	2603	2929	2	01535	019
252	2	03	2	03	1	6	2	12	08	2	1	4	12	12	3	073	5.17	0.19	0.23	0.23	2.5		20	44	23	13	3	2533	2894	3	03483	033
261	2	06	2	05	3	4	4	08	12	1	2	4	16	12	3	084	6.52	0.31	0.13	0.26	1.1		09	43	24	24	2	2676	2978	3	01919	022
262	2	09	6	03	1	4	2	12	08	2	2	6	12	09	2	084	5.65	0.34	0.11	0.21	1.5		07	33	50	10	1	2655	2968	3	02049	025
271	2	03	8	09	2	4	6	10	08	1	1	4	08	12	3	073	4.15	0.81	0.16	0.54	1.2		36	61	03	00	5	2755	3055	1	01016	015
272	4	06	4	06	1	2	2	04	04	2	2	4	08	06	3	058	4.95	0.47	0.12	0.28	1.0		55	27	15	03	6	2700	3027	1	01171	016
281	2	09	6	06	2	4	2	12	04	1	1	4	08	06	3	070	2.02	0.37	0.04	0.03	1.2		37	22	41	00	4	2694	2841	1	00095	005
291	2	09	4	03	2	4	4	08	08	3	2	8	12	18	1	086	4.05	0.17	0.13	0.09	1.1	4	45	40	13	02	1	3158	3362	2	00466	012
301	2	09	4	03	1	4	2	04	04	3	4	8	12	06	3	067	3.03	0.21	0.11	0.07	1.3	4	45	20	35	00	1	3121	3350	1	00448	010
302	2	09	8	03	2	8	4	08	04	2	4	8	08	12	3	085	5.13	0.32	0.18	0.30	1.2	3	10	70	15	05	3	2993	3283	3	01481	019
311	6	06	4	09	2	4	2	04	04	1	1	2	04	06	3	058	4.30	0.58	0.10	0.25	1.1		74	26	00	00	4	3045	3238	2	00736	016
321	2	03	4	03	3	6	4	12	20	4	4	8	12	18	3	096	4.35	0.55	0.13	1.31	1.1		25	55	17	03	3	2972	3181	3	01160	018
331	2	04	3	07	2	6	4	06	08	1	2	4	07	10	3	069	4.73	0.17	0.16	0.13	1.2		05	20	61	14	1	2493	2844	4	03137	034
332	2	04	3	06	2	6	4	06	08	2	2	4	07	10	3	069	4.43	0.15	0.18	0.12	1.7		01	14	57	28	1	2493	2841	4	03149	034
341	2	03	3	06	3	4	4	06	06	2	1	3	04	08	3	058	7.16	0.25	0.17	0.31	1.0		27	30	27	16	1	2512	2848	4	04331	084
342	2	09	3	06	3	4	4	06	06	1	2	4	04	08	3	065	6.57	0.27	0.17	0.30	1.0		27	28	32	13	1	2512	2845	4	04355	085
351	4	12	6	06	2	6	2	12	12	2	3	6	08	12	4	097	2.70	0.26	0.10	0.07	2.5	3	14	50	27	13	2	2063	2505	4	01348	023
352	8	09	8	09	2	6	6	08	08	2	3	4	08	12	4	097	2.40	0.24	0.14	0.08	1.3	3	21	49	09	21	3	2054	2501	4	01363	025
353	6	09	6	09	3	6	6	16	16	3	4	8	16	18	2	120	2.57	0.26	0.09	0.06	1.9	2	27	30	20	23	2	1984	2466	4	01480	027
361	2	03	8	09	1	2	2	04	04	1	3	2	04	06	4	055	2.43	0.24	0.07	0.04	1.1	3	23	64	13	00	8	2371	2669	2	00297	009
362	2	09	6	09	1	8	4	12	16	3	3	8	12	18	4	115	2.00	0.21	0.12	0.05	1.4	1	03	00	20	77	4	1969	2460	4	02731	027
363	2	09	2	09	1	6	2	08	12	2	2	4	08	18	4	087	3.10	0.22	0.09	0.06	2.0	5	03	27	20	50	3	1957	2454	4	02752	028
371	4	06	2	06	1	2	2	04	04	2	2	4	04	06	2	051	2.61	0.21	0.09	0.05	1.0	2	67	20	13	00	6	2402	2585	2	00788	013
381	4	09	6	09	1	6	4	12	12	2	3	8	12	18	4	110	2.95	0.30	0.17	0.15	2.2	1	13	54	13	20	2	2298	2528	3	01333	017
382	2	06	4	03	1	4	2	08	08	2	3	4	08	12	4	071	2.64	0.56	0.17	0.25	1.8	2	70	10	00	20	2	2332	2544	3	00588	011
391	2	12	2	06	3	6	2	12	12	3	3	6	08	12	3	092	5.68	0.39	0.21	0.46	2.0	2	07	33	43	17	2	2441	2874	3	04430	037
392	2	12	2	09	3	6	2	16	12	3	3	4	08	12	3	097	4.71	0.35	0.21	0.35	3.2	2	16	40	37	07	2	2371	2839	3	06284	043
401	2	06	2	03	1	6	2	12	08	2	4	6	12	12	3	081	1.93	0.21	0.10	0.04	1.6	1	07	20	70	03	2	2432	2748	2	01864	029
402	4	09	4	03	2	8	4	08	08	2	2	4	08	18	2	086	1.96	0.14	0.11	0.03	1.4	2	07	50	33	10	1	2438	2751	2	01766	027
411	2	03	2	03	2	6	2	04	04	2	1	4	12	12	1	060	0.78	0.43	0.12	0.04	1.4	1	36	17	30	17	2	2335	2426	2	01504	021

STR	LS	MWP	DJP	VBP	CC	BRC	OFS	CUT	DEP	RA	RB	PP	%SM	SD	CAV	SRI	ARW	ARV	ARD	RF	SIN	APC	%BB	%R	%G	%SS	%RG	RE	MRE	SO	BA	BP
412	2	03	2	03	2	6	6	04	04	3	1	6	08	06	1	057	1.20	0.10	0.16	0.02	1.7	1	07	07	66	20	2	2353	2436	2	01148	018
421	6	09	8	09	2	4	6	08	08	2	1	4	12	18	1	098	1.85	0.15	0.07	0.02	1.0		36	28	08	28	5	2959	3080	1	00377	010
422	2	06	2	03	1	2	2	08	08	1	2	4	08	06	2	057	3.54	0.33	0.06	0.07	1.1		52	25	17	06	2	2935	3092	1	00660	012
431	4	06	4	09	1	2	4	04	04	1	2	4	04	12	3	068	4.86	0.58	0.06	0.17	1.1		67	33	00	00	3	2688	2957	3	01991	022
432	2	06	2	03	2	4	2	08	04	1	2	4	04	06	3	051	6.38	0.60	0.11	0.42	1.0		56	44	00	00	4	2719	2972	3	01816	020
441	2	03	2	03	1	4	2	16	12	3	3	6	16	06	3	082	2.24	0.06	0.08	0.01	1.3		05	22	49	24	1	2699	2813	2	00713	012
451	2	03	4	06	3	6	4	08	04	1	2	4	04	08	2	069	3.98	0.33	0.13	0.17	1.1		42	39	17	03	2	2905	3115	2	00720	013
452	4	08	4	06	2	8	6	12	08	3	2	6	16	18	1	104	4.07	0.16	0.18	0.12	1.6		03	23	28	46	1	2889	3107	2	00803	014
461	2	06	4	06	1	4	2	08	04	3	1	2	08	12	1	064	5.33	0.32	0.06	0.08	1.1		44	42	08	06	3	3071	3198	2	00880	014
471	2	03	4	06	2	4	4	08	04	2	1	4	08	06	1	059	2.80	0.71	0.04	0.08	1.1		48	52	00	00	2	2975	3100	1	00210	008
472	2	06	2	06	1	2	2	08	04	1	2	4	08	06	2	056	5.83	0.57	0.10	0.33	1.1		67	25	08	00	5	2950	3138	2	01459	019
481	3	04	3	07	2	3	3	08	08	1	1	4	06	09	3	065	1.40	0.18	0.08	0.02	1.2		17	24	48	16	7	2670	2880	2	00242	006
482	4	06	4	06	2	4	3	06	08	1	2	4	06	09	3	068	1.52	0.28	0.07	0.03	1.1		18	19	46	17	7	2640	2856	2	00341	008
483	3	09	3	06	2	4	4	08	04	1	2	3	05	08	3	065	1.78	0.21	0.08	0.03	1.2		13	22	40	25	6	2621	2844	2	00347	009
491	2	04	5	09	2	4	4	08	08	2	2	4	08	08	4	074	1.27	0.30	0.08	0.03	1.1		32	25	21	22	7	2768	2982	2	00591	011
492	2	04	5	06	2	4	4	06	08	2	2	4	06	08	3	066	2.65	0.07	0.11	0.02	1.4		35	04	29	32	6	2646	2931	2	00901	014
493	4	04	4	06	2	3	3	05	06	2	1	4	05	06	2	057	1.96	0.26	0.12	0.06	1.2		57	16	10	17	7	2609	2896	2	01057	017
501	4	03	4	05	3	2	3	04	06	1	2	3	04	08	3	055	2.43	0.22	0.13	0.07	1.0		42	24	17	17	9	2667	2929	2	00490	009
502	2	03	4	06	2	4	4	04	08	1	2	4	06	08	3	061	2.61	0.38	0.11	0.11	1.0		34	25	24	17	7	2661	2920	2	00495	012
503	2	03	4	06	2	4	4	04	08	2	1	4	06	08	3	061	3.00	0.25	0.12	0.09	1.0		34	24	21	21	8	2646	2911	2	00502	012
511	2	03	4	06	2	2	3	04	04	2	2	3	04	08	3	052	3.42	0.17	0.14	0.08	1.2		43	17	27	13	6	2633	2983	2	00604	012
512	3	05	3	06	2	6	5	08	06	1	2	4	08	12	3	074	3.96	0.17	0.13	0.09	1.1		21	23	39	17	3	2606	2893	3	01870	021
513	3	04	4	06	2	3	4	06	06	2	2	4	08	09	3	066	4.23	0.16	0.13	0.09	1.2		29	23	31	17	3	2594	2890	3	01984	021
521	3	04	3	08	2	3	2	04	04	2	1	3	04	08	3	054	2.04	0.19	0.10	0.04	1.1		20	18	33	29	6	2637	2841	2	00233	006
522	3	03	5	09	2	4	2	05	04	1	2	3	05	08	3	059	2.06	0.22	0.11	0.05	1.2		32	17	26	25	9	2615	2835	2	00257	006
523	2	07	4	09	2	4	2	06	06	1	2	4	06	09	3	067	2.41	0.15	0.14	0.05	1.3		14	14	48	24	4	2524	2789	2	00385	008
531	6	06	5	06	2	2	4	05	06	3	1	5	06	07	3	067	3.28	0.21	0.13	0.09	1.0		51	19	14	16	7	2667	2994	3	01279	016
532	5	04	5	06	2	2	5	05	06	3	2	5	06	06	3	065	2.85	0.21	0.15	0.09	1.0		48	20	17	15	9	2646	2934	3	01310	017
533	4	05	3	05	2	3	3	06	05	3	1	5	05	06	3	059	3.75	0.29	0.13	0.14	1.1		35	27	19	19	7	2560	2893	3	01912	018
191	4	08	5	06	2	4	4	10	12	2	2	4	08	12	1	084	3.05	0.30	0.46	0.42	1.4	1	27	30	11	32	3	2105	2703	4	10916	058

BR	CC	SL	CS	RR	DD	TRH	BRH	BNH	RBH	CTH	TRK	BRK	BNK	RBK	CTK	NGF	STT
1487	0.23	23.7	050.9	062.7	2.0	073.2	006.3	055.9	000.0	000.0	017.5	001.4	016.1	000.0	000.0	N	R
1860	0.14	29.7	054.0	062.6	1.4	083.3	000.0	082.5	000.8	000.0	044.8	000.0	044.3	000.5	000.0	N	R
2255	0.20	31.0	056.1	072.7	1.3	111.4	000.0	104.8	006.6	000.0	076.1	000.0	071.7	004.4	000.0	N	R
1778	0.23	46.7	029.8	038.1	1.7	080.3	000.0	080.3	000.0	000.0	044.2	000.0	044.2	000.0	000.0	Y	R
1141	0.14	24.3	037.3	047.0	2.4	149.9	000.0	103.6	046.3	000.0	084.6	000.0	067.4	017.2	000.0	Y	R
1057	0.16	26.7	032.3	039.6	1.9	029.2	000.0	019.0	010.2	000.0	019.2	000.0	012.5	006.7	000.0	N	R
2049	0.22	72.4	022.8	028.3	2.0	008.5	000.0	000.0	008.5	000.0	006.1	000.0	000.0	006.1	000.0	N	R
1732	0.21	44.0	017.6	039.4	1.8	063.9	000.0	000.0	042.1	021.8	029.1	000.0	000.0	019.6	009.5	N	R
1601	0.14	29.3	031.9	054.6	1.5	001.0	000.0	000.0	000.0	001.0	000.9	000.0	000.0	000.0	000.9	Y	F
1095	0.15	09.0	096.8	121.7	1.8	042.2	000.0	000.0	000.0	042.2	013.2	000.0	000.0	000.0	013.2	Y	F
0244	0.14	05.0	026.6	048.8	1.0	105.4	072.3	013.7	000.0	017.4	022.6	016.0	002.9	000.0	003.7	N	F
0445	0.14	08.0	021.8	055.6	1.5	061.0	060.0	000.0	000.0	001.0	021.9	021.5	000.0	000.0	000.4	N	F
0795	0.17	11.7	039.6	067.9	1.1	049.8	038.2	000.0	011.6	000.0	021.8	016.7	000.0	005.1	000.0	N	F
0741	0.16	14.3	016.1	051.8	1.2	058.4	000.5	057.9	000.0	000.0	019.7	000.2	019.5	000.0	000.0	N	F
0976	0.26	16.8	058.3	058.1	3.2	085.8	000.0	069.7	01611	000.0	024.3	000.0	019.8	004.5	000.0	Y	R
1800	0.18	32.0	037.6	056.2	1.0	082.9	000.0	042.9	040.0	000.0	048.8	000.0	025.3	023.5	000.0	N	R
0773	0.20	30.3	017.9	025.5	1.5	128.6	000.0	038.9	089.7	000.0	074.6	000.0	022.8	051.8	000.0	N	R
0480	0.25	27.0	014.4	017.8	5.5	066.6	026.4	000.0	040.2	000.0	016.2	006.4	000.0	009.8	000.0	N	R
0377	0.23	25.0	011.3	015.1	4.4	170.4	097.7	000.0	072.7	000.0	031.2	017.9	000.0	013.3	000.0	N	R
0340	0.21	22.0	014.8	015.5	3.8	338.8	278.8	000.0	055.0	000.0	071.1	059.4	000.0	011.7	000.0	N	R
0303	0.21	20.0	015.2	015.2	2.4	188.6	188.6	000.0	000.0	000.0	040.2	040.2	000.0	000.0	000.0	N	R
0267	0.19	18.0	011.8	014.8	1.5	393.9	393.9	000.0	000.0	000.0	059.9	059.9	000.0	000.0	000.0	N	R
0844	0.22	36.0	022.4	023.4	1.6	090.6	045.1	045.5	000.0	000.0	022.2	011.0	011.2	000.0	000.0	Y	R
0623	0.21	34.0	014.7	018.3	1.3	225.9	146.7	079.2	000.0	000.0	068.9	044.7	024.2	000.0	000.0	N	R
0573	0.21	31.0	010.7	018.5	0.9	239.5	042.5	166.4	030.6	000.0	080.0	014.2	055.6	010.2	000.0	N	R
0463	0.19	25.0	010.1	018.5	0.8	198.0	198.0	000.0	000.0	000.0	048.3	048.3	000.0	000.0	000.0	N	R
0533	0.16	16.3	018.9	032.7	1.4	349.0	000.0	349.0	000.0	000.0	093.6	000.0	093.6	000.0	000.0	N	F
0355	0.15	04.7	059.2	075.5	0.9	224.8	224.8	000.0	000.0	000.0	049.0	049.0	000.0	000.0	000.0	N	F
0259	0.13	03.0	048.7	086.3	0.8	160.8	160.8	000.0	000.0	000.0	014.0	014.0	000.0	000.0	000.0	N	F
0372	0.16	08.0	042.7	046.5	1.2	042.0	028.9	000.0	013.1	000.0	025.6	017.5	000.0	000.0	000.0	N	F
0762	0.16	08.3	044.6	091.8	1.8	053.0	053.0	000.0	000.0	000.0	025.8	025.8	000.0	000.0	000.0	N	F

BR	CC	SL	CS	RR	DD	TRH	BRH	BNH	RBH	CTH	TRK	BRK	BNK	RBK	CTK	NGF	STT
0652	0.14	06.0	055.6	108.7	0.9	070.1	004.5	065.6	000.0	000.0	038.1	002.4	035.7	000.0	000.0	N	F
0722	0.11	12.7	021.2	056.9	1.1	096.2	000.0	096.2	000.0	000.0	049.7	000.0	049.7	000.0	000.0	N	F
0604	0.14	02.3	039.2	072.8	1.0	035.6	006.3	029.3	000.0	000.0	023.2	004.1	019.1	000.0	000.0	N	F
0625	0.16	09.8	033.4	063.8	1.1	010.5	007.7	002.8	000.0	000.0	005.9	004.3	001.6	000.0	000.0	N	F
0599	0.13	04.0	073.3	149.8	0.4	032.9	020.4	000.0	012.5	000.0	013.7	008.5	000.0	005.2	000.0	N	F
0654	0.13	04.8	052.5	136.3	0.4	025.4	020.1	000.0	005.3	000.0	012.6	010.0	000.0	002.6	000.0	Y	F
0293	0.14	02.0	094.0	146.5	2.1	059.3	025.4	033.9	000.0	000.0	011.9	005.1	006.8	000.0	000.0	N	F
0421	0.16	02.3	061.0	183.0	1.1	105.7	105.7	000.0	000.0	000.0	040.8	040.8	000.0	000.0	000.0	N	F
0446	0.13	01.7	109.2	262.3	0.8	189.4	189.4	000.0	000.0	000.0	047.9	047.9	000.0	000.0	000.0	N	F
0578	0.14	07.7	040.1	075.1	1.1	124.8	066.9	057.9	000.0	000.0	067.6	036.2	031.4	000.0	000.0	N	F
0387	0.17	06.7	040.0	057.8	1.1	033.1	033.1	000.0	000.0	000.0	014.3	014.3	000.0	000.0	000.0	N	F
0419	0.15	06.7	050.9	062.5	1.1	068.8	060.8	000.0	000.0	008.0	029.8	026.4	000.0	000.0	003.4	N	F
0628	0.17	14.3	022.6	043.9	1.7	069.2	011.3	055.8	002.1	000.0	032.9	005.4	026.4	001.1	000.0	N	F
0634	0.17	14.7	022.0	043.1	1.7	083.8	018.2	065.6	000.0	000.0	036.3	007.9	028.4	000.0	000.0	N	F
0674	0.36	11.3	008.6	059.6	2.2	033.3	001.0	032.3	000.0	000.0	023.9	000.8	023.1	000.0	000.0	N	F
0680	0.35	11.7	008.4	058.1	2.2	052.4	001.1	047.0	004.3	000.0	034.4	000.7	030.9	002.8	000.0	N	F
0884	0.18	08.3	070.0	106.5	2.5	082.0	082.0	000.0	000.0	000.0	022.1	022.1	000.0	000.0	000.0	N	R
0893	0.19	08.7	066.6	102.7	2.5	134.6	134.6	000.0	000.0	000.0	032.3	032.3	000.0	000.0	000.0	N	R
0963	0.20	10.7	057.2	090.0	2.5	120.1	110.7	000.4	000.0	000.0	030.9	030.8	000.1	000.0	000.0	N	R
0594	0.15	03.3	104.1	118.8	1.8	078.8	078.8	000.0	000.0	000.0	019.1	019.1	000.0	000.0	000.0	N	F
0982	0.15	12.3	048.8	079.8	3.1	334.0	334.0	000.0	000.0	000.0	066.8	066.8	000.0	000.0	000.0	N	R
0994	0.15	12.7	047.5	078.3	3.1	038.0	038.0	000.0	000.0	000.0	011.8	011.8	000.0	000.0	000.0	Y	R
0367	0.13	04.3	087.0	085.3	1.0	101.3	101.3	000.0	000.0	000.0	026.4	026.4	000.0	000.0	000.0	N	F
0459	0.13	04.7	044.9	097.7	1.2	020.2	020.2	000.0	000.0	000.0	005.9	005.9	000.0	000.0	000.0	N	F
0425	0.13	03.3	051.8	128.8	2.0	008.5	008.5	000.0	000.0	000.0	002.3	002.3	000.0	000.0	000.0	N	F
0865	0.16	13.2	024.2	065.5	1.1	028.4	016.6	008.0	003.8	000.0	016.1	009.4	004.5	002.2	000.0	N	F
0935	0.15	17.3	021.3	054.0	1.0	056.8	025.6	027.4	003.8	000.0	026.7	012.2	012.7	001.8	000.0	Y	F
0632	0.19	12.3	026.4	051.4	1.1	105.9	015.9	000.0	000.0	000.0	020.5	020.5	000.0	000.0	000.0	N	F
0626	0.18	11.3	026.2	055.4	1.1	029.5	029.5	000.0	000.0	000.0	005.8	005.8	000.0	000.0	000.0	N	F
0183	0.15	07.8	017.6	023.5	0.9	604.2	604.2	000.0	000.0	000.0	047.1	047.1	000.0	000.0	000.0	N	F

BR	CC	SL	CS	RR	DD	TRH	BRH	BNH	RBH	CTH	TRK	BRK	BNK	RBK	CTK	NGF	STT
0165	0.15	06.3	019.0	026.2	0.9	304.9	304.9	000.0	000.0	000.0	036.6	036.6	000.0	000.0	000.0	N	F
0290	0.14	02.3	054.2	126.1	0.6	054.2	054.2	000.0	000.0	000.0	010.0	010.0	000.0	000.0	000.0	N	F
0266	0.13	03.0	045.4	088.7	0.5	037.5	037.5	000.0	000.0	000.0	013.3	013.3	000.0	000.0	000.0	N	F
0528	0.14	08.3	046.9	064.8	0.9	076.6	076.6	000.0	000.0	000.0	037.2	037.2	000.0	000.0	000.0	N	F
0507	0.13	07.0	061.0	072.4	0.9	060.8	060.8	000.0	000.0	000.0	038.8	038.8	000.0	000.0	000.0	N	F
0227	0.13	03.0	033.9	075.7	0.8	018.9	018.9	000.0	000.0	000.0	004.2	004.2	000.0	000.0	000.0	N	F
0420	0.14	03.1	101.7	135.5	0.9	102.4	101.4	000.0	000.0	000.0	040.8	040.8	000.0	000.0	000.0	N	F
0436	0.14	03.8	088.1	114.7	0.9	110.4	110.4	000.0	000.0	000.0	044.9	044.9	000.0	000.0	000.0	N	F
0254	0.13	04.9	019.8	051.8	1.2	039.2	032.8	000.0	006.4	000.0	020.9	017.5	000.0	003.4	000.0	N	F
0250	0.16	03.1	063.5	080.6	1.5	023.4	023.4	000.0	000.0	000.0	006.5	006.5	000.0	000.0	000.0	N	F
0375	0.14	08.0	038.2	046.9	0.9	058.4	058.4	000.0	000.0	000.0	034.0	034.0	000.0	000.0	000.0	N	F
0396	0.08	06.0	045.4	066.0	4.1	045.6	000.0	000.0	000.0	045.6	007.6	000.0	000.0	000.0	007.6	N	F
0420	0.08	06.4	042.8	065.6	3.2	078.1	000.0	000.0	000.0	078.1	013.7	000.0	000.0	000.0	013.7	N	F
0439	0.09	07.8	032.6	056.2	3.7	041.9	000.0	000.0	000.0	041.9	007.6	000.0	000.0	000.0	007.6	N	F
0416	0.13	04.6	071.3	090.4	2.0	138.0	132.0	000.0	000.0	006.0	023.7	022.9	000.0	000.0	000.8	N	F
0446	0.13	05.7	088.4	078.3	1.2	074.4	074.4	000.0	000.0	000.0	018.6	018.6	000.0	000.0	000.0	N	F
0580	0.15	06.3	090.8	092.1	1.1	166.9	166.9	000.0	000.0	000.0	036.5	036.5	000.0	000.0	000.0	N	F
0530	0.11	05.5	072.8	096.4	2.6	030.4	000.0	000.0	000.0	030.4	007.1	000.0	000.0	000.0	007.1	N	F
0549	0.15	05.7	071.9	096.3	2.7	032.9	000.0	000.0	000.0	032.9	008.7	000.0	000.0	000.0	008.7	N	F
0561	0.15	05.9	065.2	095.1	2.8	020.4	000.0	000.0	000.0	020.4	006.6	000.0	000.0	000.0	006.6	N	F
0411	0114	04.0	116.1	102.8	1.8	007.8	000.0	000.0	000.0	007.8	002.9	000.0	000.0	000.0	002.9	Y	F
0440	0.14	06.6	085.6	066.7	1.4	010.4	000.0	000.0	000.0	010.4	004.5	000.0	000.0	000.0	004.5	Y	F
0488	0.13	07.4	083.8	065.9	1.5	015.6	000.0	000.0	000.0	015.6	007.8	000.0	000.0	000.0	007.8	Y	F
0427	0.11	05.6	052.1	076.3	4.2	022.8	000.0	000.0	000.0	022.8	005.3	000.0	000.0	000.0	005.3	N	F
0457	0.12	05.8	054.9	078.8	4.0	021.7	000.0	000.0	000.0	021.7	005.4	000.0	000.0	000.0	005.4	N	F
0524	0.11	06.9	049.3	075.9	3.6	028.2	000.0	000.0	000.0	028.2	007.3	000.0	000.0	000.0	007.3	N	F
0553	0.13	05.8	080.8	095.3	2.5	033.8	000.0	000.0	000.0	033.8	012.2	000.0	000.0	000.0	012.2	N	F
0608	0.13	06.0	079.2	101.3	2.5	048.5	000.0	000.0	000.0	048.5	014.9	000.0	000.0	000.0	014.9	N	F
0663	0.12	07.0	082.3	094.7	2.2	054.7	000.0	000.0	000.0	054.7	021.2	000.0	000.0	000.0	021.2	N	F
3024	0.16	26.0	021.6	116.3	1.6	061.7	000.0	000.0	061.7	000.0	021.7	000.0	000.0	021.7	000.0	Y	R

APPENDIX D

Range, Township, Section, Elevation and United States Geologic Survey

Topographic Quad for each Study Site used in Model Testing

STREAM NAME	LEGAL LOCATION	ELEVATION (M)	UNITED STATES GEOLOGIC SURVEY TOPOGRAPHIC MAP
FOREST STREAMS			
01 North Fork Savery Creek[a]	16N 88W S13	2341	Divide Peak
02 Pelton Creek[a]	13N 79W S29	2530	Horatio Rock
03 Pelton Creek[a]	13N 79W S29	2530	Horatio Rock
04 Dirtyman Creek	15N 87W S29	2467	Singer Peak
05 Rose Creek	12N 85W S17	2405	Solomon Creek
06 Big Sandstone Creek	14N 87W S12	2694	Singer Peak
07 Deadman Creek	13N 85W S33	2652	Solomon Creek
08 Sheep Creek	27N 75W S14	2291	Marshall
09 Lake Creek	13N 79W S11	2603	Foxpark
10 Lake Creek	13N 79W S11	2603	Foxpark
11 Douglas Creek	15N 79W S21	2957	Medicine Bow Peak
12 Douglas Creek	15N 79W S21	2957	Medicine Bow Peak
13 North Fork Little Laramie River	16N 78W S8	2865	Centennial
14 North Fork Little Laramie River	16N 78W S8	2865	Centennial

STREAM NAME	LEGAL LOCATION	ELEVATION (M)	UNITED STATES GEOLOGIC SURVEY TOPOGRAPHIC MAP
RANGELAND STREAMS			
15 North Fork Horse Creek	17N 70W S8	2076	Horse Creek
16 North Fork Horse Creek	17N 70W S7	2108	Ragged Top
17 North Fork Horse Creek	17N 70W S18	2176	Ragged Top
18 North Fork Horse Creek	17N 71W S12	2239	Ragged Top
19 Horse Creek	17N 70W S22	2030	Horse Creek
20 Horse Creek	17N 70W S28	2128	Horse Creek
21 Horse Creek	17N 71W S25	2195	Ragged Top
22 Willow Creek	56N 94W S15	1128	Kane

[a]Identified as outliers

APPENDIX E

Data from the Study Sites used in Model Testing
Forest Streams

STREAM	AVERAGE REACH WIDTH	WIDTH DEPTH RATIO	REACH GRADIENT	RELIEF RATIO	DRAINAGE DENSITY	BASIN RELIEF	RATED REACH ELEVATION	Kg/Ha TROUT	PREDICTED Kg/Ha BEST EQUATION	PREDICTED Kg/Ha GEOMORPHIC EQUATION	PREDICTED Kg/Ha INSTREAM EQUATION
01	4.9	33.3	00.95	030.5	1.5	442.6	3	036.8	163.6	218.7	075.3
02	2.9	17.1	00.37	016.0	1.8	296.9	2	056.0	173.8	176.5	151.1
03	2.8	15.6	00.95	016.0	1.8	296.9	2	055.0	177.1	176.5	150.5
04	1.4	32.9	05.21	192.3	0.9	499.9	2	070.2	099.2	074.6	097.1
05	2.2	20.0	07.58	091.4	0.8	292.6	2	055.8	119.2	086.3	067.7
06	2.9	39.2	04.73	206.0	0.8	597.4	2	070.0	042.7	000.3	054.6
07	3.5	28.3	10.42	134.8	0.9	512.1	2	042.4	050.9	032.1	-012.2
08	5.2	28.2	01.42	014.0	1.9	578.8	3	118.9	193.1	242.5	073.4
09	3.6	21.2	01.13	030.8	1.5	375.8	2	053.0	123.9	128.8	117.7
10	4.8	20.0	00.56	030.8	1.4	366.8	2	080.0	101.0	130.2	108.3
11	4.8	25.3	00.60	054.1	1.0	210.9	2	055.0	078.6	133.8	096.1
12	6.0	22.2	00.46	054.1	1.0	210.9	2	050.0	057.1	133.8	088.8
13	5.2	27.4	00.61	041.0	1.5	249.9	2	060.0	071.2	138.2	086.6
14	5.8	15.3	00.28	041.0	1.5	249.9	2	066.0	060.6	138.2	118.9

APPENDIX F

Data from the Study Sites used in Model Testing
Rangeland Streams

STREAM	RATED WIDTH DEPTH RATIO	CHANNEL SLOPE	BASIN PERIMETER	RATED MID-RANGE BASIN ELEVATION	BASIN RELIEF	AVERAGE REACH VELOCITY	Kg/Ha TROUT	PREDICTED Kg/Ha BEST EQUATION	PREDICTED Kg/Ha GEOMORPHIC EQUATION	PREDICTED Kg/Ha INSTREAM EQUATION
15	2	11.6	058	2	0447	0.22	182.1	171.2	169.7	137.7
16	1	16.9	051	3	0346	0.21	095.7	141.6	240.7	068.8
17	3	15.4	046	3	0334	0.31	284.5	252.0	243.2	109.9
18	3	11.1	040	3	0260	0.28	368.6	275.5	260.6	196.9
19	3	22.9	102	3	0628	0.28	194.0	181.6	199.4	196.9
20	3	12.0	091	3	0607	0.25	288.9	227.7	201.7	202.8
21	3	10.2	077	3	0494	0.18	298.9	248.6	216.0	216.6
22	1	32.1	041	1	1545	0.24	044.1	041.0	030.2	062.8