TFW-AM9-91-002

STATUS AND TRENDS OF IN STREAM HABITAT IN FORESTED LANDS OF WASHINGTON: THE, TIMBER-FISH-WILDLIFE AMBIENT MONITORING PROJECT

1989-.91 BIENNIAl_. PROGRESS REPORT

By

Center for Stream side Studies
University of Washington

December 16, 1991

Ambient Monitoring Project Biennial Progress Report

1989-91 Biennial Period

Stephen C. Ralph

Tamre Cardoso

Geoffrey C. Poole

Loveday L. Conquest

Robert J. Naiman

Center for Stream side Studies
University of Washington
Seattle, Washington 98195

TABLE OF CONTENTS

ACKNOWLEDGMENTS

The development and implementation of a monitoring project such as this relies heavily upon the vision and resources of a large number of people. The original concept came from the recognition that a way was needed to evaluate existing stream habitat and riparian conditions in watersheds where forest land management is the predominant land use practice. Individuals from the forest products industry, state resource management agencies, environmental groups and treaty tribes participated in this effort. Funding was provided by a combination of tribal and state contributions. The forest products industry cooperated by providing information on access and watershed history.

The Ambient Monitoring Steering Committee, especially under the chairmanship of Dave Somers and Mike Parton, provided thoughtful opinions and guidance on project development. The 28 treaty tribes provided substantial financial support and field assistance through the able and cooperative staff of the Northwest Indian Fisheries Commission. Mike Parton during his tenure as monitoring field coordinator for tribal involvement (NWIFC) provided numerous insights and substantial energy and field expertise during the first year of the project. David Alexis, following in that capacity during the second year of the project field season, offered substantial ideas for clarifying aspects of the field methods. Other tribal technical staff worked diligently to integrate aspects of this project into their respective habitat management programs.

Dr. John F. Orsborn (Washington State University) gave generously of his limited time in reviewing and providing much needed refinement of the field methods manual and implementation. Phil Peterson (CSS) offered, through many hours of discussion and field trips, his unique insight to furthering our understanding of the complex interactions of physical stream habitat and life history requirements of salmon and trout. The project further benefited from the opportune association with Dr. Lee MacDonald (Colorado State University) during his brief tenure at CSS, where he was preparing *Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska* for EPA Region 10. Tim Beechie's work in applying the stream corridor classification system to the Stillaguamish River proved most valuable in developing concepts for data analysis and improvement of the resolution of field methods. Mr. Beechie, with his recognized expertise in field implementation, also assisted in the initial effort to include a quality assurance component to our data collection. Graduate student Kristy Seidel (Center for Quantitative Science) helped in the design of the initial approach to quality assurance for field methods, walked many miles of streams in pursuit of its objectives, and provided a fresh and welcome perspective.

EXECUTIVE SUMMARY

1. The extensive stream monitoring project described in this report was designed and implemented under a contract with the Washington Department of Natural Resources. It constitutes the monitoring component of the overall Timber Fish and Wildlife - Coordinated Monitoring, Evaluation and Research agenda.

2. This *interim report covers* the biennial contract period July 1, 1989 through June 30, 1991, and does not include analysis of data collected during the subsequent field season. Data analysis is an iterative process, with that described herein reflecting the work done to date. Many promising ideas have been identified to explore in future analyses.

3. The goal of this project is to design and implement a pilot level state wide monitoring project to aid in the understanding of the relationship between forest land management practices and protection of public natural resources of fish, wildlife and water quality.

4. The emphasis of this project is on in stream habitat and channel condition. The biological link between fish habitat and fish production will be done through future joint studies conducted with related TFW research projects.

5. The objectives for accomplishing the goal include:

   a. Establishing a quantitatively based monitoring program to determine baseline (where possible) and current condition and trends (in time) of in stream fish habitat, riparian areas and channel conditions found within forested watersheds where timber management occurs; and determine if meaningful changes in key indicators of riparian conditions can be detected;

   b. Testing the need for and assumptions of a basin level landscape classification scheme to determine if it is useful in understanding the sensitivity of watersheds to impacts associated with industrial scale timber management activities, and cumulative effects;

   c. Integrating this monitoring project with related concurrent research, especially that supported by TFW, as such opportunities arise.

6. The approach to designing a broad scale stream monitoring project include:

   a. Identification of 22 key stream and riparian variables that respond to changes in the amount of sediment and stream discharge carried by stream channels, and in the amount of woody debris found in streams within forested basins;

   b. Selection of methods to reliably measure these variables;

   c. Preparation of a field manual of standardized methods and data collection field forms to ensure consistency;

   d. Conducting training workshops for interested TFW cooperators in execution of the standardized field methods;

   e. Designing a quality assurance element for the field work to validate assumptions that the survey results are reliable;

   f. Developing a means to quickly and reliably transcribe data from field forms to a computer database;

   g. Designing a structure for database management to organize data compilation, analysis and transfer.

7. Three components of a hierarchical landscape classification scheme (ecoregions, valley segments and habitat units) were evaluated for their usefulness in relating stream and riparian conditions to landscape level features. It was hoped that this would allow results from surveyed stream reaches to be confidently extrapolated to areas similar in character but for which no survey data is available.

8. During the two year contract period 196 individual valley segments within four forested ecoregions were surveyed using the standardized field methods developed for this project. Nearly all of the sampled stream reaches were located in areas of intensive timber management. Eighteen segment types were evaluated state wide. Valley segments are discrete reaches of stream that are distinguished by combinations of five characteristics as described by Cupp (1989). They vary in length from a minimum of 1000 feet (305 m) to over 9 miles (14.4 km). Individual data summaries are available for each segment surveyed. Summary statistics for all segments surveyed are presented.

9. Results of data analysis described in the report segments surveyed include:

   a. Quality assurance aspects of habitat unit identification;

   b. Use of the Hankin & Reeves visual estimation technique for assessing habitat unit dimensions;

   c. Distribution of segments by ecoregion,

   d. Habitats as predictor of ecoregion,

   f. Bankfull width by segment type and channel bankfull width to depth ratio, bankfull width sorted by an index of channel gradient and confinement;

   g. Sediment particle size distribution by segment type and channel gradient and confinement index;

   h. Large woody debris (LWD) pieces by segment type, bankfull width, and gradient/confinement index;

   i. Percent habitat area comprised by pools by segment type and G/C index,

   j. Pool type frequency sorted by segment type and G/C index,

   k. Percent of pools formed by organic (LWD) obstructions by segment type and G/C index; and

   1. Cross-sectional profile survey results for one transect on the Pysht River.

10. Analysis of the two years of data indicates that the traditional aspects of pool:riffle ratio and channel width:depth ratio are highly variable for streams found within basins managed for timber production. This variability is either natural or the result of cumulative changes induced by timber harvesting activities in the basins sampled. Stratifying the data by valley segment alone does not show any discernable trends, that is valley segments are not particularly useful for describing predictable features of either riparian condition, habitat characteristics or channel geometry.

11. Interpretation of data from the first two field seasons is difficult with out sufficient information on watershed disturbance history and natural variability. Stream condition in one segment can only be judged relative to another segment of similar character. Without a reference condition or standard against which to compare the results of our analysis it is speculative to give a "status" on the condition of a particular segment. Reference sites were selected from streams entirely within old growth watersheds during the 1991 field season. These data will be incorporated into future analyses.

12. The results of the quality assurance analysis although preliminary suggest that the habitat classification system (Sullivan 1986) used proved difficult to employ. Field crews had difficulty consistently identifying distinct unit types given the diagnostic criteria in this system.

13. Recommendations are provided to enhance the reliability of the monitoring project.

INTRODUCTION

The following report examines data collected for the biennial period 1 July 1989 through 30 June 1991 on the Timber Fish & Wildlife - Stream Ambient Monitoring Project. This project has been conducted under a contract between the Washington Department of Natural Resources and the Center for Stream side Studies at the University of Washington. This summary includes field site locations, data summary, initial sorting and preliminary analysis of field survey data collected during the biennial contract period. Some additional data from the 1991 field season has been included to strengthen some portions of the data analysis, although its inclusion in the overall database is pending.

Working with the TFW Ambient Monitoring Steering Committee, the Center for Stream side Studies has developed a standardized, basin-level survey methodology and provides training and technical assistance in its use to tribal, state, and private industry resource managers. The Center provides project administration and oversight on study design, site selection, field data collection, data transcription, database design and maintenance, data sorting, analysis, and distribution.

The monitoring field project has limited its initial focus to an extensive inventory of variables describing physical fish habitat and channel features of forested streams state wide. Particular emphasis is placed on obtaining repeatable surveys that, in the short-term, are used to evaluate present resource conditions and highlight channel character and in stream habitat of streams from different forested watersheds of Washington state. In the long term, these data will be used to establish trends in the condition of forested streams state wide.

Legal & Institutional Background

Since the late 1950's, there has been growing public concern over the adverse effects of forest hind management on public resources -- particularly water quality and stream condition. Much of this concern has focused on the dramatic decline in the number of salmon and trout returning to their natal streams in Northwest fiver basins. Concern for these fish resources involves complex economic, cultural, and legal issues that will continue to dominate resource management well into the future. The outcome of the US Supreme Court decision upholding treaty-secured tribal fishing fights in US v. Washington (1974) gave substantial weight to the implied responsibility to protect essential freshwater and marine habitats that support salmon. Recent petitions under the Endangered Species Act to declare certain stocks of Northwest salmonids as threatened with extinction have added to this concern.

In the US Environmental Protection Agency's most recent National Water Quality Inventory: Report to Congress (1986), non-point sources (NPS) represented the dominant fraction of the nation's remaining surface water pollution problems. With The Water Quality Act of 1987, Congress gave states and local governments the front line responsibilities for assessing the condition of their surface waters and devising effective solutions to their NPS problems (EPA 1989). The Department of Ecology has this lead responsibility for Washington State.

Under the Clean Water Act, the term water quality is used in its broadest sense to include not only the traditional chemical and physical constituents, but designated uses such as recreation and maintenance of beneficial uses including resident and anadromous fish populations and aquatic community health. The need to protect this use necessitates concern over other water resource values such as structural components of the aquatic habitat, including, the amount of in stream large woody debris that gives complexity to the stream environment: the type, depth and area of pools, the density, of the riparian forest canopy, and the particle size of the bed material (MacDonald et ai., 1991).

The Forest Practices Rules and Regulations as modified in 1987 are administered by the Department of Natural Resources. These established "best management practices" (BMP's) for timber land management activities on state and private lands in Washington. In the area of silviculture, or commercial scale timber land management, reliance on (BMP's) is the primary focus to control non-point source pollution of streams and other water bodies. Effective BMP evaluation can only be done by directly monitoring the effect of forest land management activities on aquatic ecosystems (MacDonald **et al.,** 1991).

Forest land managers, fish and wildlife resource managers, those communities dependent upon natural resources, and policy makers need resource information to competently manage timber harvesting while protecting other public resources. Integral to a monitoring component for the TFW effort is the need for a broad assessment of the current and baseline conditions for fish, wildlife and water quality resources associated with state and private forest lands. Information is needed about:

1) the response and recovery of water resources to cumulative land-use impacts associated with past and present timber management activities and natural disturbance events (fires, floods, landslides);

2) management strategies to avoid these impacts.

Yet reliable information on the current status and trends in conditions of public natural resources subject to land-use impacts is critically lacking.

The Timber Fish & Wildlife Agreement (1986) provided for:

1) revised forest practice rules and regulations;

2) development and implementation of a coordinated research, evaluation and monitoring program to fill knowledge gaps essential for effective land management and to ensure protection of public resources.

Monitoring For Current Condition and Change

Land management activities in general, and silvicultural practices in particular, affect riparian zones, in stream habitat, and channel condition in several basic ways. First is through basin hydrology, that is, the magnitude, frequency and duration of water leaving the basin via the stream channel. Second is the amount and routing of sediment entering and leaving the channel. These two factors can subject the channel to the dual impacts of increased flows and reduced channel capacity to transport both flow and sediment. Forest harvesting practices within watersheds containing steep slopes, unstable soils, and abundant rainfall can trigger slope failures and other erosive processes that deliver large amounts of sediment to the stream channel thereby altering the condition of fish habitat. The response of certain types of channels will depend upon a variety of geomorphic factors but may include a widening of the bankfull width accompanied by increased bed scour and deposition (Lisle, 1989; Platts et al., 1989; Dunne & Leopold, 1979). The third way involves changes in the size, amount,and residency of woody debris nested within the stream which provides resiliency to the channel. This woody debris is important in providing both stability and complexity to the in stream habitat (Grette, 1985; Hicks et al., 1989). Successive harvesting of forested riparian corridors over the past century and deliberate stream clearing have eliminated much of the input of large woody debris into the channel in intensively managed watersheds (Bilby and Ward 1992, in press).

Monitoring is the most practical way to develop current condition, baseline, and long-term trend information on riparian resources within Washington's forested watersheds. The quantity and quality of physical in stream habitat supporting anadromous salmon and resident trout is particularly sensitive to disturbance events-- especially when their frequency and distribution allow little time for such habitats to recover. Providing suitable habitat conditions for these fish species, communities, and populations integrates a wide range of aquatic resource concerns and, in effect, serves as a proxy to protect both water quality and riparian resources.

Goal & Objectives For This Monitoring Project

The goal of this project is to design and implement a state wide monitoring project which aids in the understanding of the relationship between forest land management practices and protection of public natural resources of fish, wildlife, and water quality.

The specific objectives are as follows.

1) Establish a quantitatively based monitoring program to determine baseline and current conditions and trends (in time) of in stream fish habitat, riparian areas, and channel conditions found within forested watersheds where timber management occurs, and determine if meaningful changes in key indicators of riparian conditions can be detected.

2) Test the need for and assumptions of a basin level landscape classification scheme to determine if it is useful in understanding the sensitivity of watersheds to impacts associated with industrial scale timber management activities and cumulative effects.

3) Integrate this monitoring project with related concurrent research, especially that supported by TFW.

Project Tasks & Time Line

Project tasks included field methods development, refinement of a methods manual and field forms, field training workshops, data collection, development of a database, transcribing field data into a computer format, quality control and assurance of both field work and data transcription, responding to data requests, and data analysis.

Table 1. TFW monitoring project time line for 1989-91 biennium.

Project Element	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
Study Design																								
Site Selection	■	■	■						■	■	■	■	■	■				■	■	■	■	■	■	■
Planning	■						■	■	■	■	■	■	■	■	■				■	■	■	■	■	■
Field Methods																								
Methods Manual								■	■	■	■	■	■							■	■	■	■	
Methods Training	■									■	■	■	■									■	■	■
Implementation	■	■	■	■								■	■	■	■	■	■						■	■
Quality Assurance	■	■	■	■									■	■	■	■	■					■	■	■
Database Development																								
Design Field Forms								■	■	■	■	■	■							■	■	■	■	■
Data Transcription	■															■	■	■	■	■	■	■		
Data Distribution											■	■	■	■	■	■	■	■	■	■	■	■	■	■
Data Analysis																	■	■	■	■	■	■	■	■
Project Administration																								
Interagency Coord.	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
TFW & CMER Meetings	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Personnel										■	■	■	■	■	■	■								
Budgets	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■	■
Proposals						■	■	■	■	■	■	■					■	■	■	■	■	■	■	■
Month	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J
	1989						1990												1991					

Table 1 provides an overview of the various tasks and a time line for the two-year contract period, Staffing for the two year period included one full-time coordinator, one half-time graduate assistant, and 1.5 months of co-principal investigator. Field staff during the contract period were provided by the Northwest Indian Fisheries Commission.

METHODS

Since its inception, the monitoring project has been viewed as one component of a larger water shed level analysis of present and past impacts associated with timber harvesting. The Coordinated Monitoring Evaluation and Research Committee's agenda was to develop integrated applied research targeted to evaluating the effectiveness of the TFW agreement and the relationship between public resources and industrial scale forestry.

The previously stated goal of this project contains three objectives:

1) establishing the current condition of aquatic habitat within forested streams state-wide;

2) determining the trends of these conditions over space and time;

3) relating the effects of forest land management practices to these conditions and trends.

Achievement of each of these objectives is, in turn, dependent on the fulfillment of the previous one. Thus, the focus of this project during the first two years has been on establishing the current condition of Washington's streams.

How land-use affects streams

Timberland management over time affects watersheds and their component streams primarily by changing the influx of sediment, hydrologic flow regimes, and the amount and character of woody debris found within the stream channel. These in turn alter the physical character of channels and the in stream aquatic habitats they provide. Variables that respond to changes in these input factors became the focus of the monitoring project.

Approach

The most fundamental aspects of this monitoring project were designed without benefit of an existing model or approach. To our knowledge, no other such effort has been developed to monitor such an extensive list of stream variables, at such a high resolution and over such a large and diverse landmass.

The general approach to meeting the first of these objectives has been the development of a list of habitat and channel parameters that provide a meaningful indication of current stream conditions. Field methods to measure or gauge these parameters were selected and described in a field manual. Over 250 copies of the field manual have been distributed to TFW cooperators and interested state and federal agencies. Eight separate training workshops were held with a total enrollment of nearly 200 individuals. Field personnel for the two seasons were funded by the Northwest Indian Fisheries Commission. They were trained in these techniques and sent to selected field sites to conduct the stream surveys. Data from these surveys were collected and transcribed into a computerized database. A database management system was designed to automate the field-data entry, organize the data for analysis and reporting, and transfer it to interested cooperators.

It is unrealistic to survey each of the thousands of linear miles of streams and rivers in the state. A practical means to predict conditions in unsurveyed streams from a subsample of forested streams is needed. A landscape classification scheme which correlates stream characteristics at different spatial scales should fulfill this need by allowing us to collect and analyze information about selected streams and apply that information to other, similar streams.

One key to a successful understanding of the condition of streams in Washington is our ability to predict the effects of land management practices,

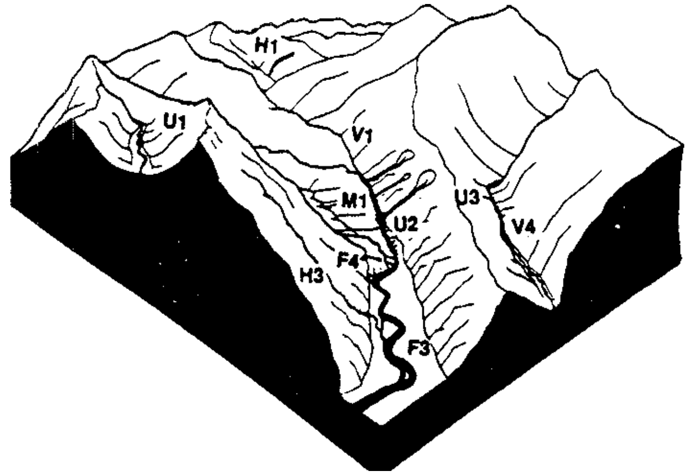

Figure 1. Oblique view of a hypothetical watershed showing component valley segment types.

even for streams from which no data have been gathered. This requires us to link information at one spatial scale with information at others. Therefore, three specific scales and associated classification schemes were selected by the Ambient Monitoring Steering Committee for testing and evaluation within this project: habitat-unit scale, the valley-segment scale, and the ecoregion scale. These are discussed in the following sections.

Forested areas of the state were first divided into ecoregions. Omernik and Gallant (1986) describe a system whereby large geographic areas, ranging from 9,000 - 60,000 mi^2 (14,400 - 96,000 km2) can be stratified by four fundamental attributes: soils, land form, land-use, and vegetative climax-communities. These criteria are applied systematically, but at a coarse scale (1: 2,500,000) because information on the attributes is available at differing levels of resolution and dependability. Ecoregion was recorded for each segment in our sample and field data were analyzed to detect trends in stream habitat as a function of ecoregion.

The second level of stratification occurs at the sub-watershed level. The drainage network making up a forested watershed was divided into its component valley segments (Figure 1) by a channel classification scheme based on six key landform and geological features (Cupp, 1989) including:

1) stream order;

2) valley sideslope gradient;

3) channel gradient;

Table 2. Valley Segment Catagories (after Cupp, 1989).

Catagory	Characteristics
	Nearly fiat cross-section; 5th order or larger
	Gentle to moderate gradient; 2nd to 4th order
	V-shaped cross-sectional profile found in lower to middle reaches of tributaries; usually incised in glacial deposits
U	U-shaped cross-sectional profile found in mid to upper reaches of tributaries. Associated with alpine glaciation
H	V- to weakly U-shaped cross- sectional profile; 1st to 2rid order; high gradient

4) ratio of valley bottom width to active channel width;

5) geology;

6) channel pattern.

Stream channel segments in Washington are placed in one of five broad categories of valley segments (Table 2) which roughly describe channel gradient and valley-floor cross-sectional profile. Based on the six diagnostic features, a total of 18 preliminary segment types have been identified for forested watersheds in Washington (Table 3). Mini.. mum segment length has been arbitrarily set at 1000 feet (305 m). Some valley segments encountered in the field exceeded 7 miles (11.2 km) in length. Details about determining segment boundaries and the specific combination of attributes that distin.- guish one type from another are given in the valley segment methods manual (Cupp, 1989) prepared for TFW and available from the Washington State Department of Natural Resources.

The third level of stratification occurs at the in stream habitat scale. During the field habitat surveys, individual habitat units were identified and measured according to the system of Sullivan (1986) and Bisson et al. (1981). Individual pools and riffies within stream segments constitute the physical habitat that provides for the critical environmental needs of aquatic organisms. An inventory of the nature and distribution of these units gives some measure of a stream's ability to support viable aquatic communities, including populations of stream fish, amphibians, and insects.

Study Sites

The selection of stream segments for the survey was made on the basis of perceived resource value and condition, since there was no *a priori* way to stratify forested streams by any of the important channel or basin attributes. Because nearly all of the streams in our sample occur within basins managed intensively for timber production, a wide range of management-related stream conditions are included. Samples have not yet been stratified by management history, which may help account for current conditions. Except for several segments provided by the Huh tribe from the Hoh River basin, stream reaches with similar geomorphology in forested watersheds unaltered by commercial timber harvesting or road construction were not included in the site selection for 1989 or 1990. However, because of their importance to this study, such sites were a priority during the 1991 field season.

The actual number of stream segments surveyed was a function of the staff resources available, seasonal runoff conditions, access, and time limitations. The location of surveyed streams is identified by its Water Resource Inventory Area (WRIA) code (Williams et al. 1975), as well as the traditional township, range and section address. Streams are divided into their component valley segments (Cupp 1989) from USGS topographic maps (1:24,000 scale). These valley segments become the initial sampling units. The WRIA code coupled with the valley segment type and sequence code becomes the unique identifier for that particular segment in the computerized database.

Data Collection

Five 2-person field crews were deployed to the pre-selected stream segments. Surveys were conducted when stream discharge had stabilized to approximate summer low flow conditions.

The field procedure involved a two-step process:

1) measuring variables that relate to the reach of stream defined by the segment criteria;

2) documenting in stream habitat features that address availability and character of aquatic habitat.

An additional protocol for measuring the influence and response of bedload material on spawning habitat was tested in selected reaches by establishing permanent cross-sectional and thalweg profiles stations and installing gravel scour and fill monitors.

Table 3. Valley bottom and sideslope geomorphic characteristics used to identify 18 valley segment types in forested landscapes of Washington. Valley bottom gradient is measured in lengths of I000 ft. or more. Sideslope gradient characterizes the hill slopes within 1000 horizontal and 300 vertical ft. distance from the active channel. Valley segment type names include alphanumeric mapping codes first, before the hyphen. (From Cupp, 1989)

Valley Segment Type	Valley Bottom Gradient	Side Slope Gradient	Valley Bottom Width	Channel Pattern	Stream Order	**Landform and Geographic Features**
F1 - Esturine Delta	<=5%	<5%	>5X	Unconstrained; highly sinous; often braided	Any	Occur at mouth of streams on estuarine flats in and just above zone of tidal influence
F2 - Alluviated Lowlands	<= 1%	>5%	>5X	Unconstrained; highly sinous	Any	Wide floodplains typically formed by present or historic large rivers within flat to gently rolling lowland land forms; sloughs, oxbows, and abandoned channels commonly associated with mainstem rivers
F3 - Wide Mainstem Valley	<=2%	>5%	>5x	Unconstrained; moderate to high sinuosity;, braids common	Any	Wide valley floors bounded by mountain slopes; generally associated with mainstem rivers and the tributary streams flowing through the valley floor;, sloughs and abandoned channels common
F4 - Alluvial/Collu Fan	1%-3%	<=10%	>3X	Variable; generally unconstrained	1-4	Generally occur where tributary streams enter low gradient valley floors; ancient or active alluvial / colluvial fen deposition overlying floodplains of larger, low gradient stream segments; stream may actively down cut through deep alluvial fan deposition
F5 - Gently Sloping Plateaus and Terraces	<=2%	<10%	IX-2X	Moderately constrained; low to moderate sinuosity	I-3	Drainage ways shallowly incised/too fiat to gently sloping landscape; narrow active floodplains; typically associated with small streams in lowlands, cryic uplands or volcanic flanks
M1 - Moderate Slope Bound	2%-5%	10%- 30%	2X	Constrained; infrequent meanders	I-4	Constrained, narrow floodplains bounded by moderate gradient sideslopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks
M2- Alluviated Moderate Slope Bound	<=2%	<5%, gradually increase to 30%	2X4X	Unconstrained; moderate to high sinuosity	1-4	Active floodplains and alluvial terraces bounded by moderate gradient hill slopes; typically found in lowlands and foothills, but may occur on broken mountain slopes and volcano flanks
V1- V-Shaped, Moderate Gradient Bottom	2{704%	30%- 70%	<2X	Constrained	>=2	Deeply incised drainage ways with steep competent side slopes; very common in uplifted mountainous topography; less commonly associated with marine or glacial outwash terraces in lowlands and foothills
V2- V-Shaped, High Gradient Bottom	6%-11%	30%ˉ 70%	<2X	Constrained	>=2	Same as V1, but valley bottom longitudinal profile steep with pronounced stair step characteristics

Table 3 cont. Valley bottom and side slope geomorphic characteristics of 18 valley segment types.

Valley Segment Type	Valley Bottom Gradient	Side Slope. Gradient	Valley Bottom Width	Channel lPattern	Stream Order	Landform and Geographic Features
V3 - Bedrock Canyon	3%-11%	>=70%	<2X	Highly constrained	>=2	Canyon-like stream corridors with frequent bed rock out crops; frequently stair stepped profile; generally associated with filded, faulted, or volcanic land forms
V4 - Alluciated Mountain Valley	1%-4%	Channel adjacent slopes <10%; increases to >30%	2X-4X	Unconstrained; high sinuosity with braids and side channels common	2-5	Deeply incised drainage ways with relatively wide floodplains; distinguished as "alluvial flats" hi otherwise steeply dissected mountainous terrain
U1 - U-shaped Trough	<3%	<5%; gradually increases to >30%	>4X	Unconstrained; moderate to high sinuosity; side channels and braids common	1-4	Drainage ways in mid to upper watersheds with history of glaciation, resulting in U-shaped profile; valley bottom typically composed of glacial drift deposits overlain with more recent alluvial material adjacent to channel.
U2 - Incised U-Shaped Valley, Moderate Gradient Bottom	2%-5%	Steep channel adjacent slopes, decreases to <30% then increases to >30%	<2X	Moderately constrained by unconsolidated material; infrequent short flats with braids and meanders	2-5	Channel down cuts through deep valley bottom glacial till, colluvium or course glacio-fluvial deposits; cross sectional profile variable, but generally weakly U-shaped with active channel vertically incised into valley fill deposits; immediate side slopes composed of unconsoli-dated and often unsorted coarse grained deposits
U3 - Incised U-Shape Valley, High Gradient Bottom	6%-1 t%	Same as U2	<2X	Same as U2	2-5	Same as U2
U4 - Active Glacial Outwash Valley	1%-7%	Initially <5%, increases to >600/0	<4X	Unconstrained; highly sinous and braided	1-3	Stream corridors directly below active alpine glaciers; channel braiding and shifting common; active channel nearly as wide as valley bottom
H1 - Moderate Gradient Valley Wall / Headwater	3%-6%	>30%	<23[	Constrained	1-2	Small drainage ways with channels slightly to moderately entrenched into mountain we. slopes or headwater basins
I-I2 - High Gradient Valley Wall / Headwater	6%-11%	>30%	<2X	Constrained; stair stepped	1-2	Small drainage ways with channels moderately entrenched into high gradient mountain slopes or headwater basins; bedrock exposures and outcrops common; localized alluvial/colluvial tea'- race deposition
H3 - Very High Gradient Valley Wall / Headwater	>1 1%	>60%0	<2X	Constrained; stair stepped	1-2	Small drainage ways with channels moderately entrenched into very steep mountain slopes or headwater basins; bedrock exposures and outcrops frequent

A methods manual (Ralph, 1990) developed and refined during the contract period gives further details on the field methods described below. Copies are available upon request from the Washington State Department of Natural Resources at (206) 753-5315.

Response Variables Selection

Measurable response variables were chosen to allow us to quantify the net effect of changes in flow and sediment at both the stream channel segment and habitat unit scales. Both channel geometric variables and habitat variables were included (Table 4).

Summary statistics of measurements taken at the habitat-unit scale serve as response variables within and between the valley segments. These variables provide a critical link between the two scales. They include frequency and area of habitat units, residual depth of pools, nature of the hydraulic obstruction forming pools by type, and location and distribution of woody debris. A sample valley segment level summary is included in Appendix A.

Standardized Field-methods

A standard methodology for sampling streams was developed to evaluate present conditions. Field methods were selected after a review of the literature based on the perceived needs for both accuracy and precision in the survey results. MacDonald et al. (1991) completed an extensive literature review of physical channel and habitat sampling methods, and discussed the considerations in selecting these for specific monitoring project objectives.

The standard methodology developed incorporates two distinct surveys, both of which are performed on each valley segment in the sample. These surveys are called the horizontal control survey and the habitat **unit survey.**

Horizontal control survey: The horizontal control survey was designed to collect information at the valley segment scale. Part of this survey is the establishment of permanent turning point reference stations along the shoreline as well as at the beginning and end points of the valley segments in the field. These reference points are fixed along the stream corridor using numbered aluminum shiner tags and survey flagging. Distances and compass bearings between these turning points are recorded so that these stations can be relocated during future surveys. Photographs are taken between turning points, when conditions allow, to give a visual record of the general character of the stream corridor.

For each valley segment, the following variables are measured:

Channel gradient, using a hand held clinometer, is determined at either end of selected riffle units. Although the accuracy of using clinometers is approximately +0.5%, it provides a measure of gradient to compare to channel gradients taken from USGS quad maps.

Sediment particle size distribution within selected riffle units is sampled by the pebble count method of Wolman (1954) three times per mile (1.6 kin). The procedure involves randomly removing 100 individual bed particles from within riffle units and measuring their median axis diameter. The actual number of pebbles measured in this procedure was reduced to 50 to reduce staff exposure to frigid water temperatures. A modified Wentworth scale described in the field manual was used to scale particle sizes and to create 10 size categories. Information on surface particle size distribution can be used to corroborate estimates of two year flood flow magnitude and channel geometry. In addition, a visual estimation technique of apparent gravel **embeddedness** was made during the pebble count to

Table 4. Response variables.

Channel Segment Level

- -Channel bankfull width
- -Channel mean bankfull depth
- -Riffle unit gradient
- -Bank cutting length
- -Slope failure area
- -Sediment particle size
- -Gravel embeddedness.

Habitat **Level**

- -Discharge (Q)
- -Habitat unit classification
- -Habitat unit length
- -Mean habitat unit width
- -Residual pool depth
- -Character of pool-forming obstructions
- -Woody debris (frequency, size, & position)
- -Canopy closure
- -Adjacent land-use
- -Seral stage of adjacent vegetation
- -Vegetation type of riparian zone

give a qualitative index of the percent of surface fine grained bed material.

Sediment input sources were considered by recording length of bank cutting, areas of slope failure, and their position between turning point reference markers. This provides some indication of the condition of the banks and the extent of bank and hillslope erosion which influences in stream habitat quality and quantity.

Channel bankfull width and depth measurements were taken during the horizontal control survey. A 100 ft. (32.6 m) tape was stretched across the channel and fixed at the apparent bankfull flow channel mark. Definition of this mark followed that of Dunne and Leopold (1978). Average channel bankfull depth measurements were determined by taking the average of a series of measurements from within the channel along the transect defined by the fixed tape. These depth measurements started at the thalweg depth and progressed to both sides of the channel. Channel width measurements are a good indicator of stream size when coupled with basin characteristics such as area and precipitation (Orsbom, 1990), and substrate size distribution (Dunne and Leopold, 1978).

Habitat unit survey: The habitat unit survey involves a series of measurements at the individual pool and riffle scale, and includes information about the amount and location of woody debris, the seral stage, vegetation type, and land-use of adjacent riparian areas.

Discharge measurements using a Swoffer #2100 current velocity meter and a top setting wading rod were taken at channel cross sections located at the beginning of the segment. This measurement was made when each habitat survey was begun and subsequently every five days or whenever a signifi~ cant precipitation event occurred during the survey. Since habitat type and area are a function of stage (water surface elevation), knowing the discharge at the time of the survey is essential when correlating future habitat inventories of the same stream reach.

Individual habitat units were identified according to the criteria of Sullivan (1986). Their location was recorded relative to fixed turning points established in the horizontal control survey thus allowing monitoring at the same stream location over time.

Six riffle type units and five pool type units were distinguished as well as areas of subsurface stream flow (Figure 2). The position of the unit within the channel, either dominant, subdominant, or occurring within a secondary channel, was also recorded.

Physical areas for each type of habitat unit can be calculated from estimates or measurements of their respective length and width. Residual pool depths

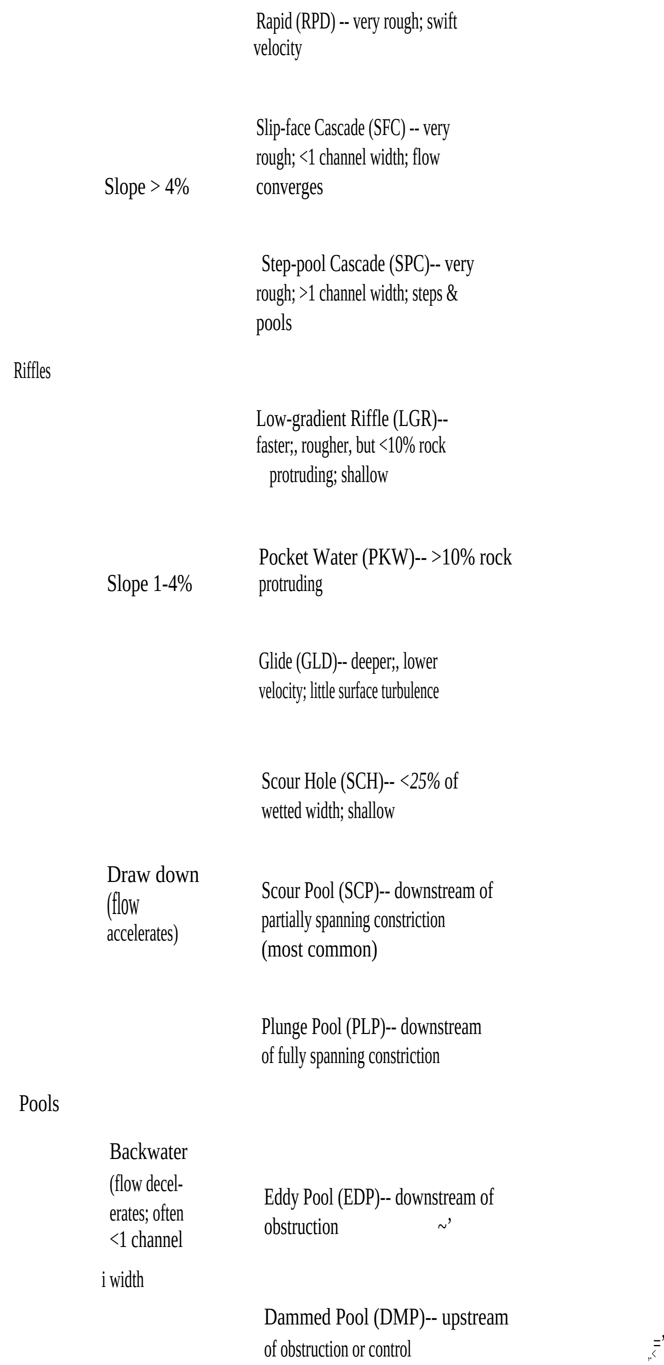

Figure 2. Key to habitat units (after Sullivan, 1986).

were measured according to the method of Lisle (1987). Measurements are made using hip chains, electronic distance meters, expandable ten foot stadia rods, and 100 meter tapes, depending upon field conditions encountered. In this way the relative frequency and contribution to area of any particular habitat type can be calculated, allowing comparisons over time and between similar stream reaches.

Visual estimates of the length and width of individual habitat units were made using the technique of Hankin & Reeves (1988). By using this method we hoped to expedite the process of taking habitat dimensions while maintaining confidence in the data.

The number of pieces and location of woody debris within the channel were noted during the habitat survey. Two size classes of woody debris were distinguished: small logs are 4 to 20inches (10 cm - 50 cm) in diameter and a minimum of 10 feet (3m) in length and large logs are > 20 inches (50 cm) in diameter. Root wads, counted separately, were at least 2 feet (.6 m) in diameter to be included. The location within the stream channel of each piece of woody debris was also noted.

Canopy closure (adapted from Platts et al., 1978) was measured by use of a spherical densiometer from points mid-stream three times every mile (1.6 km), or at distinct changes in riparian vegetation condition. Closure for a given segment is expressed as the percent of canopy closure averaged for all measurements taken.

Riparian vegetation seral stage within 50 feet (15.3 m) horizontal of either side of the stream was recorded adjacent to each habitat unit. Seral stage category for each side of the channel was chosen from seven such categories ranging from recently clear-cut to old growth forest. Vegetation type, either deciduous, coniferous, or mixed, was noted. An apparent land-use category was also assigned to each unit.

Cross-sectional profiles and scour chains: In an effort to refine the area of concern for spawning gravels, a technique to monitor bed elevation changes and depth of scour and fill events was field tested. The methods included in the horizontal control survey for describing particle size distribution and embeddedness were limited. To supplement these measures, field tests of establishing permanent channel cross-section profile stations and installing scour chains to determine depth of scour and fill were made. Nine permanent stations, each with three cross-sectional transects, were established on the mainstream and South Fork of the Pysht River in Clallam County. Methods followed Nawa and Frissell (1991, in prep.) who were consulted on field implementation. Cross-sectional profile data describes bed elevation changes (scour and fill) in response to flood flows that may result in important changes in habitat. Orsborn (Washington State University, personal communication) suggested that such measurements be included as part of the extensive field monitoring protocol to give greater detail on channel changes associated with sediment and discharge.

Using an engineers auto level, tripod and stadia rod, repeat surveys of channel transects were performed each year. Permanent transect sites were located in alluviated, lower gradient (<2%) reaches. At least one scour chain and bead monitor were installed along the downstream cross-section transect at each of nine sites. These units were relocated and reset during subsequent field surveys.

Installation was as follows: a two-meter pipe containing a monitor at least 1 meter in length was driven into the gravel at a surveyed point along the transect. Once positioned the drive pipe was removed from around the monitor, which remains suspended vertically unless and until the gravel supporting it is scoured by high flows. It then assumes a horizontal position coincident with the depth of scour. As gravels are redeposited over top it becomes buried. Every year at low flow stage, measurements were made of both the depth of scour and subsequent fill superimposed on top and the monitors were reset.

Data Management

Data transcription

During the initial effort at data collection in 1989, the design of the field forms complicated the process of transcribing data to a computer database. All field data had to be hand entered which proved to be quite expensive. Errors were introduced during the transcription because some handwriting proved difficult to decipher. These forms allowed the surveyor too much choice in making the desired entry and thus compounded the issue of quality control and interpretation of what was recorded.

After this initial experience, we abandoned the more traditional field forms in favor of optically scanned field forms that would expedite transcription to the database and error checking. Copies of the field forms developed for this purpose are included in Appendix B. The result has been to substantially increase the speed with which field data can be transcribed and to eliminate the problem of compounding errors in transcription. A Scantron 8000 optical reader was purchased by the Northwest Indian Fisheries Commission and made available for the exclusive use of the field project. This procedure has the added benefit of allowing an error checking program to be applied to the raw data file before it is loaded into the central database. Typical errors can be automatically identified and then corrected on the field forms before field crews involved in its collection have been dismissed. The result is that a file free of the most obvious errors is created and loaded into the database.

Database Development

Because TFW had no predetermined specifications for the database management scheme, a system was developed to meet the anticipated needs of this project -- including the need to distribute the data easily. A great deal of effort was put into the design of the database to accommodate the need for future database expansion, data sorting and data analyses.

Prior to actually designing and implementing a database, two basic questions were considered.

1) Which hardware platform should be used?

2) Which database software should be used?

Hardware options included mainframes, micro.. computers, and PC-based systems. We chose to implement a PC-based system since it provided the greatest flexibility/ Advantages to a PC-based system included:

1) many of the people/groups interested in the data had PC's available to them;

2) there were many database software packages to choose from;

3) data would be easily transferred, via floppy disks, to interested parties.

While not a problem after three field seasons, potential long-term disadvantages of a PC-based system would include:

1) space/storage problems as the database got larger;

2) considerable increases in application program executions as the database got larger.

However, we believe both of these problems will be eliminated in the near future, given the rapid advancement in the technology of data storage and data processing on personal computers.

We looked at several database software options for PC-based systems. These *included Dbase, Rbase, Foxpro*, and *Clipper*. All four packages have similar structures for relational database tables; tables created using one package should be portable into any of the other packages. *Dbase, Rbase,* and *Foxpro* include menu-based systems for database development. *Clipper* comes with a menu-driven database utility program that allows limited manipulation of database tables; however, this is not the main strength of the software. Unlike the other packages, *Clipper* serves as a programming language with a full complement of database development commands and functions. We chose to use *Clipper* for database development and implementation since it offered the most flexibility for a long-term application. Several advantages over the other packages included:

1) easy creation of customized application programs for reading, writing, and manipulating data;

2) easy creation of customized front-end menus for future application development;

3) creation of executable load modules for applications, which could then be loaded onto other PC's without the need to own *Clipper*,

The data management process developed for this project is outlined below. The process is applied to the data from individual valley segments and repeated until all segments are loaded into the database.

1) Field forms are processed through the optical read scanner and an ASCII file is created.

2) An error checking program is run on the ASCII file. The error check program, written in *Clipper*, identifies specific errors or missing information on the data sheets. Errors and warnings are listed in an error report.

3) Any errors listed in the error report are corrected by the field crews, on the original survey forms.

4) Steps 1 through 3 are repeated for the corrected survey forms until there are no remaining errors. When there are only a few errors, the ASCII file may be directly edited, as opposed to reprocessing the corrected forms through the scanner. Editing must be done very carefully so as not to

corrupt the file. Direct editing of the file is not recommended.

5) The error-free file is loaded into the Ambient Monitoring database using a program written in Clipper. The user must be prepared to enter the units used for field forms 2 and 3, the ecoregion, and whether or not bedrock was coded for each pebble count.

After all valley segments have been loaded, a valley segment summary report program written in *Clipper* may be run on the data. The program generates a one page summary for each valley segment.

Quality Assurance & Control

Data collected as part of the monitoring program protocol will be used to assess the current conditions, as well as trends over time, of in stream habitat, riparian areas, and channel condition. Inherent in the ability to assess stream conditions, is the assumption that the monitoring protocol uses methods that can generate reliable replicate surveys. The ability to apply consistent methodologies is especially important when making comparisons between different streams or comparisons of individual streams overtime. We must ensure that any detected changes in channel or habitat condition (as evidence in the key variables) are true changes and not merely artifacts of observer bias from year to year.

Two aspects of our field work were evaluated:

1) the effectiveness of the Hankin and Reeves (1988) visual estimation technique in a large-scale monitoring effort, given the limitation of a large number of temporary field staff;

2) the replicability of the identification and measurement of habitat units.

Visual Estimation of Habitat Unit Dimensions

By using the Hankin and Reeves (1988) visual estimation technique, we hoped to reduce the amount of time needed to perform the stream surveys without sacrificing data quality. However, this required that we test the accuracy of these estimates. The following analysis was devised.

Visual estimates of habitat length and width were paired with measurements of length and width for the same unit. For each unit type, within a given segment, an observer's ability to work within the Hankin and Reeves model was tested by a regression of measured vs. estimated areas. Assuming the observer met the criteria for the model, the observer's consistency was evaluated by looking at how the points determined by paired measurements fell with respect to the plot of y=x (perfect estimation). To be considered a consistent estimator, the majority of the points must all lie above or below this line thereby allowing a correction factor to be applied to the data. A more detailed description of this analysis is included in Appendix C.

Survey Replicability

The replicability of the identification and measurement of habitat units was investigated by performing single replicate surveys for specified portions of selected valley segments using the standardized field methods. The quality control surveys focused on the habitat level data because the identification of habitat types is subjective and most likely to contain *inconsistencies.* Data relating to horizontal controls, mass wasting, bank cutting, and substrate pebble counts were not collected during the replicate surveys.

As much as possible, the replicate surveys were performed during times of similar flow. The objective was to see if two different crews could similarly identify the types and dimensions of the habitat units, and, if not, were there particular types often confused. There were 19 replicate surveys done in 1991. One experienced crew was designated to perform all replicate surveys. They did not perform any of the original surveys in the 19 segments.

Of these 19 segments, only 11 were available for this analysis. The replicates were performed on portions of 1 F3,3F4,2M1,2M2, 1 U4, 3V1, 1 V2, 2 V3, and 4 V4 segments that were being surveyed as part of the regular field season.

The data from the replicate survey was compared to the corresponding data from the original survey by generating maps of the units along an axis of cumulative length. Maps of major habitat units (units that spanned more than 50% of the wetted channel) were plotted as a function of cumulative length. Minor units (which spanned less than 50% wetted channel) were also plotted at the cumulative length prior to their occurrence in a sequence. A page from a typical map is shown in Figure 3. The left side of the map is the original survey; the right is the replicate. Major units for either survey are shown in the first column with minor units stacked next to their associated major units. From the 11 maps that were generated, nine were actually compared. We were unable to compare two sets of maps

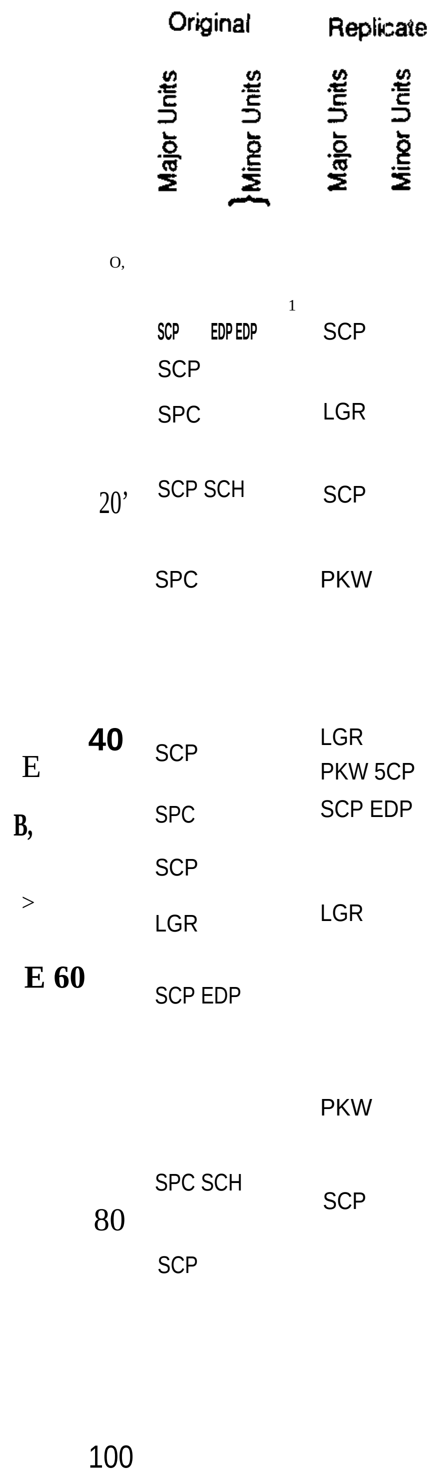

Figure 3. Map comparing location and classification of habitat units for original and replicate surveys.

due to extreme differences in the mapped habitat types.

Comparisons were made by counting the number of times the habitat units matched between the two surveys. To do this, a matrix was created with 12 rows and 12 columns (Table 5). Each row represented a habitat unit type in the original survey and each column represented the same type in the replicate survey. Each time a habitat unit in the original survey was mapped onto a unit in the replicate survey, a "mark" was placed in the cell corresponding to the original unit type. and the replicate unit type. For instance, if a unit were classified as a plunge pool in the original survey and a scour pool in the replicate survey, a "mark" would be placed where the "plunge pool" row intersected the "scour pool" column. For a perfectly reproducible survey, the mappings of units would be 1:1 and cell counts ("marks") would only occur in the cells where the row and column labels are the same. These cells form a diagonal line across the center of the matrix.

Data **Analysis**

Two desk top computer software packages were used in analysis of the field data, PC-SAS and S-Plus. The packages were mainly used to generate summary statistics for the graphical displays of various data relationships used in this report. Various other statistical analyses, such as using parametric and nonparametric versions of t-tests and ANOVAs to assign significance values to specific comparisons were not yet used. It is inappropriate to perform such specific statistical tests, resulting in p-values, without first having a good understanding of the data. Many of the our plots show highly variable data, as demonstrated by the large interquartile ranges show in figures later in this document. At this point in time, we can only list probable components of the variation, but we are unable to adequately partition out specific sources. As such, it would be difficult, if not impossible, to assess differences between groups and to interpret the meaning of a significant or nonsignificant p-value. Appropriate tests will be performed in the future after elements contributing to the high variation (such as observer bias, disturbance regime, stream discharge, measurement errors, etc.) are identified and better understood.

Summary Statistics

Field data from stream segments were stratified by valley segment classification in an attempt to make qualitative comparisons of and draw conclu-

Table 5. Sample matrix for comparing original and replicate surveys.

Original Survey		Quality Control Survey: Cascades			Riffles			Pools					
		RPD	SFC	SPC	LGR	PKW	GLD	SCH	SCP	PLP	EDP	DMP	BVP
Cascades	RPD												
	SFC												
	SPC												
Riffles	LGR												
	PKW												
	GLD												
Pools	SCH												
	SCP												
	PLP												
	EDP												
	DMP												
	BVP												

Legend

RPD	Rapid	LGR	Low-gradient Riffle	SCH	Scour Hole	EDP	Eddy Pool
SFC	Slip-face Cascade	PKW	Pocket Water	SCP	Scour Pool	DMP	Dammed Pool
SCP	Step-pool Cascade	GLD	Glide	PLP	Plunge Pool	BVP	Beaver Pond

sions about different valley segment types. A second measure of stream segment classification, the Gradient/Confinement Index, was developed to allow a more logical stratification of data from surveyed sites. Data from field sites were reorganized into an index based upon their gradient range and relative channel confinement. Descriptions of valley bottom gradient and channel pattern (from Table 3) for each valley segment type were assigned ratings between 1 and 4 according to the rules shown in Table 6. The rounded mean of these two ratings for each segment type is the Gradient/Confinement (G/C) index. The final G/C index for each segment type is shown in Table 7.

Discriminant Analysis

A discriminant analysis of valley segment types was performed to determine if the percent of total stream area comprised by each habitat unit type within a segment could predict valley segment type.

Table 6. Rules for rating valley bottom gradient and channel pattern from valley segment type descriptions in Table 3.

Description	Rating
Valley Bottom Gradient	
No minimum gradient, usually < 2%	1
Never <1%, usually 2-4%	2
Never <2%, usually 4-6%	3
Never <3%, usually >6%	4
Channel Pattern (Confinement)	
Unconstrained	1
Moderately constrained	2
Constrained	3
Highly Constrained	4

Table T Valley bottom gradient and stream confinement ratings assigned to each valley segment type. Gradient/ confinement index is the rounded mean of these two ratings.

Segment Type	Gradient Rating	Confinement Rating	G/C Index
F1	1	1	1
F2	1	1	1
F3	1	1	1
t:4	**2**	1	**2**
F5	1	2	2
M1	3	3	3
M2	1	1	1
V1	3	3	3
V2	4	3	4
V3	4	4	4
V4	2	1	2
U1	1	1	1
U2	3	2	3
U3	4	2	3
1J4	2	l	2
1tl	**4**	**3**	**4**
H2	4	3	4
H3	4	3	4

Discriminant analysis may be thought of as a multivariate extension of one-way analysis of variance. A (univariate) one-way analysis of variance tests for differences between the means of three or more populations stratified by a *single* response variable. In discriminant analysis, there are two *or more* response variables, which are assumed to be approximately normally distributed. Population means are compared based on this set of response variables to determine the sub-set of response variables which best discriminates among the different groups. This sub-set of response variables is then used to predict the valley segment type for each segment and the predicted segment types are compared to the actual segment types to assess the accuracy of the prediction.

The discriminant analysis was performed as follows.

1) Valley segment types in which we had sampled less than 4 segments were excluded from the analysis because they lacked the necessary degrees of freedom.

2) Percent of total habitat area comprised by each of the 11 habitat types listed in Figure 2 along with two others -- Beaver Ponds and Secondary Channels -- was calculated for each valley segment type. These were our response variables. As an illustration, the percent habitat area for all samples of four segment types occurring within the Coast Range Ecoregion is displayed in Figure 4. (The order of the habitat units along the x-axis conforms to the order in Figure 2, followed by Beaver Pond and Secondary Channel).

3) The subset of response variables (percent habitat areas) which best predicted valley segment type was determined. Two response variables, EDP and SCH were excluded from the final analysis as they consistently loaded last in the discriminate function (meaning they were poor predictors of valley segment type relative to the others).

4) The remaining 11 variables were used to predict valley segment classification for each valley segment and the resulting prediction was compared to the segments actual segment type.

5) The analysis was done first on the entire 1989 data set. It was then repeated on the 1990 data set. These were termed unstratified analyses. A third data get was then formed by combining the 1989 and 1990 data. Each of the three data sets was then divided by ecoregion and steps 1-4 were repeated for data get and each ecoregion. These were termed stratified analyses. The geomorphology shared among streams within an ecoregion constrains physical characteristics of those streams. This is the justification for stratifying the data by ecoregion.

RESULTS AND DISCUSSION

Information on over 20 habitat and channel related variables was collected during the course of the standardized segment survey procedure. The data sorting and analysis reported in this section are based on data from the 1989 & 1990 field seasons, with the notable exception of the quality assurance and control analyses consisting of:

I) habitat estimation, based on 1989 data;

2) survey replicability, based on 1991 data.

The results of this study include not only the outcome of analysis of the data collected, but also successful development of field methods and data management needed to undertake a study of this magnitude.

Data Management

The database management scheme developed during the course of the biennium worked well. It meets the needs for a flexible system that allows import and export of data, design of custom applications, formatting of data files and format records and storage of large amounts of data. Using *Clipper, a* custom application has been developed that allows easy export of data files for distribution. Also, a program is distributed with the data files that allows the recipient to generate summary reports for the segments in the database. For further analysis of the data, the file can be loaded into the users own database system (be it *Clipper* or another database).

Data transcription

The use of optically scannable field data forms greatly increased the speed and accuracy of data processing. When dealing with large amounts of field data collected by a number of staff throughout file state, this approach has proven a reasonable means to ensure standardization for recording field data. Although initial investment in both the scanning equipment, design of field forms, and software programing were high, the process should continue to expedite the input of monitoring information well into the future. Errors in the original field data can be identified and corrected soon after the data collection, and before the errors are compounded by manual data entry. Software applications for error checking and generation of data summaries need only minor modification if and when field forms are revised.

Database development

The Ambient Monitoring database was designed to provide convenient storage and retrieval capabilities for the large volume of field data collected each year. A relatively simple design, maintaining as much consistency as possible with the current field forms, was implemented. Data was divided into "tables" (individual data sub-set on the computer) that logically suited the anticipated analyses.

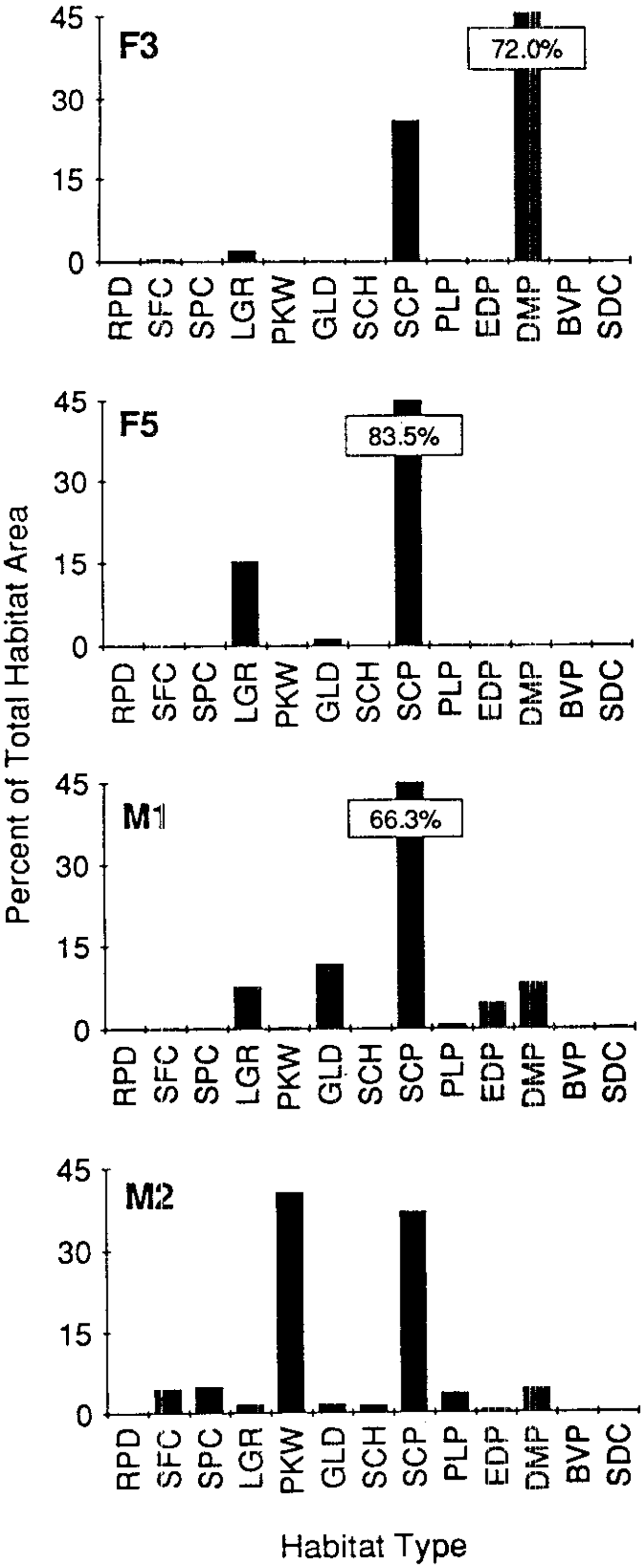

Figure 4. Percent of stream habitat area comprised of each relational database that contains 16 tables. There are habitat type for four different valley segment types in three control tables that contain static descriptive ecoregion 1, "Coast Range."

information on habitat names, valley segment tie-scriptions, and definitions of coded variables, and 12 valley segment data tables which are updated from field data. Three of these 12 tables are specific to 1989 data only and as such will never be updated again. The remaining table stores habitat and substrate "pointers" (which tell the computer where to find habitat and substrate data in other tables) that are updated as new data is added to the database.

The basic "key" (index unique to each valley segment used to organize the database) for the valley segment data tables is Year+WRIA+Valley Segment. Habitat unit and substrate data is accessed using the pointers described above to access other tables.

Data from 1989 was loaded to the database using a series of four *Clipper programs.* Currently, due to the use of scanned field forms, data for a given valley segment is easily loaded to the database using a single program. Data may be loaded as it becomes available; there is no need to wait until the end of the field season to process data.

At any time, valley segment summary reports may be executed by running a single *Clipper* program against the current version of the database. The existing report program generates a summary for each segment stored in the database. The program could be easily modified to allow the user to specify reports only for segments of interest. This would allow the user to generate individual reports for each new segment loaded to the database.

Information stored in the database is easily accessed through programs written in *Clipper*. Raw data and/or computed data may be written to ASCII files or to other user defined database files. Various delimiters may be specified for the ASCII files to accommodate the various statistical packages to which the data may be imported.

Quality Assurance & Control

Visual Estimation of Habitat Unit Dimensions

The Hankin and Reeves (1988) method to determine habitat unit (pools and riffles) area using visual estimation was evaluated for application to this monitoring project using data collected during the 1989 survey. Data from 1990 and subsequent seasons will be analyzed similarly during the next biennium.

Physical dimensions for all channel units in a segment of a stream were estimated and a subsample of these were measured. The subsample, with pairs of estimated and measured values, allows the calculation of a ratio estimator representing the magnitude of observer bias. This ratio estimator becomes the "correction factor" that allows one to have confidence that estimation equals measurement. This method has greatest utility when observations are consistently biased either above or below the measured values. This method is currently being applied throughout the 19 national forests of Washington and Oregon, and elsewhere throughout the western states. Details of our analysis are included in Appendix C of this report and are briefly summarized below.

Many of the data sets from which correction factors were generated resulted in poor correlation. The two main reasons were the inability of callers to be consistent, and the small number of paired points in a subsample used to calculate a correction factor. Eighty-four percent of the paired measurements had less than 10 points, the recommended minimum needed to calculate individual correction factors. Cases of poor model fit were generally observer dependent and habitat type independent. Many observers had difficulty in consistently under or over estimating habitat unit length and width. The types of problems listed above occur, in part, as a consequence of the inherent difficulty with training and field control on a large scale project.

As a result, this technique was dropped from the field methods in 1991 in favor of measurement of all habitat unit dimensions. The presumed increased accuracy justified the increase in time spent in the field.

Survey Replicability

Table 8 shows the totalled cell counts across the nine maps that compared the original and replicate surveys. The diagonal elements representing correct mappings are highlighted. Three larger boxes showing units which correctly mapped cascades to cascades, riffles to riffles, and pools to pools are also highlighted. Table 8 contains an additional row and column labelled "UNP" (unpaired). The unpaired categories represent "extra" units that could not be mapped to units in the other survey. Values in the *row* labeled "UNP" represent replicate survey units that were left-over for a given mapping. Values in *the column* labeled "UNP" represent left-over original survey units.

While the highest counts for most unit types corresponded with themselves, there were some

Table 8. Comparison of original and quality control surveys. Numbers in the table represent the number of habitat units classified as row label during original survey which were subsequently reclassified as column label during the replicate survey. Unpaired units are stream habitats recoreded in one survey that could not be mapped to units in the other survey.

Quality Control Survey

Original Survey		Cascades			Riffles			Pools						
		RPD	SFC	SPC	LGR	PKW	GLD	SCH	SCP	PLP	EDP	DMP	BVP	UNP
Cascades	RPD	2			1		1							1
	SFC		7	3	5		2		4		1			3
	SPC		3	32	16	17	1		13	12	13	4		3
Riffles	LGR			1	57	3	1		7	1		1		9
	PKW				4	5		2				1		3
	GLD						1		1					2
Pools	SCH					1		4	3					3
	SCP	1		1	8	6	2	4	136	8	10	8		24
	PLP			2	1		1	1	8	34	1			5
	EDP			1	1	6		1	6		34	2		21
	DMP	1		4		1			4	1	3	10		5
	BVP													
	UNP			5	15	7	3	6	22		22	17		

Legend

RPD	Rapid	LGR	Low-gradient Riffle	SCH	Scour Hole	EDP	Eddy Pool
SFC	Slip-face Cascade	PKW	Pocket Water	SCP	Scour Pool	DMP	Dammed Pool
SCP	Step-pool Cascade	GLD	Glide	PLP	Plunge Pool	BVP	Beaver Pond

UNP unpaired

apparent difficulties in the identification of habitat unit types. Values tabulated in Table 8 indicate that step-pool cascades, slip-face cascades, pocket water, dammed pools, eddy pools, and scour pools may be difficult unit types to identify. There may also be some difficulty in the identification of low-gradient riffles and plunge pools under certain conditions, There were not enough rapids, glides, or scour holes surveyed to evaluate their identification,

Step-pool cascades were most often confused with pocket water or plunge pools. On other occasions one crew would call a long step-pool cascade while the other crew would indicate the presence of a step-pool cascade, in addition to, low-gradient riffles, dammed pools, and eddy pools. Slip-face cascades were most often confused with step-pool cascade/low-gradient riffle combinations. Pocket water units were most often confused with low-gradientriffles. Dammed pools were often called by one crew with dammed pool/eddy pool/scour pool combinations called by the other crew. Eddy pools were sometimes confused with pocket water. The main problem with eddy pools, however, was that one crew would call a number of them as secondary units and the other crew would choose not to call them at all. Scour pools were called the same 65% of the time, although they were confused with a wide variety of other types of units when called differently.

The results of the habitat sequence quality control analysis are difficult to specifically interpret. They do raise a basic concern about the ability of different groups of people being able to consistently distinguish among habitats. Some of the observed differences are likely due to misalignment of the quality control surveys with the stream segment surveys. Other differences, however, may be due to variations in stream discharge and/or the result of individual observer bias. Of the nine paired surveys that were mapped, six had identical or very close discharges. The other three had discharges with differences from between one and tour cubic feet per second which corresponds to a range of from 20% to 118%.

This analysis elucidates some of the problem areas and leads us to think about the following.

1) Is the current classification of habitat units into 12 categories appropriate? Are some of the habitat types genuinely difficult to distinguish (especially for inexperienced field crews)? The results show some of the variations in how habitat units may be called. Perhaps a broader habitat classification scheme would be more appropriate. As shown in Table 8, except for step-pool cascades, most of the variations in the identification of habitat units fell within the same broad categories of cascades, fifties, and pools.

2) In general, is it reasonable to expect consistency for the recorded data given the large number of field crews involved in the collection of the data?

3) How much effect does stream discharge have on the various habitat categories? Can these effects be separated out across 12 habitat types? Understanding changes due to variations in discharge will be very important when trying to make comparisons between different streams as well as comparisons between the same streams over time.

This analysis is the first look at the ability to perform reproducible surveys in terms of the identification of habitat units. The replicate survey data will ultimately be analyzed to determine the following.

1) Were the area measurements attributed to habitat units similar for the paired surveys?

2) Can any differences in area dimensions be consistently attributed to variations in the width or length dimensions?

3) Can any of the observed inconsistencies be attributed to specific field crews, or do they seem to he independent of the field crews?

4) Can any of the observed inconsistencies be attributed to specific valley segment types?

5) Do any observed inconsistencies seem to be "averaged out" over multiple segments of data? The term "averaged out" may take on different meanings depending on the sort of analyses under consideration.

Data Analysis

The data sorting and analyses discussed in this section are confined to 1989 and 1990, the first two field seasons of data. Field data from the 1991 season are (at the time of this writing) in the process of being scanned, loaded into the database and checked for errors; they will be included in future analyses. Results are first presented in the context of the classification scheme (ecoregion, segment and habitat unit) and as a comparison by the G/C index referred to in the methods section.

Individual Segment Data Summaries

Summaries for each of the 196 valley segments surveyed during 1989 and 1990 are available. An sample is contained in Appendix A. Segment lengths were determined from horizontal distances from turning point survey data and generally exaggerate the actual length of segment. When stream discharge is listed as 0 the flow on that day was too low to measure; when blank, no flow data was recorded during the habitat survey. Pool to riffle and pool to riffle to cascade ratios were determined from the area of habitat units in those three broad categories. Habitat units are shown in the histograms on the form by percent occurrence and by total area. **All** other parameters on the summary sheet are self explanatory.

A comprehensive listing of key attributes derived from all segments surveyed are given in Appendix D. This summary provides a quick way of comparing attributes of"similar" segments if one discounts the influence of basin area, precipitation, geology and disturbance history. Many of the analyses discussed below were derived from extracting information from this appendix.

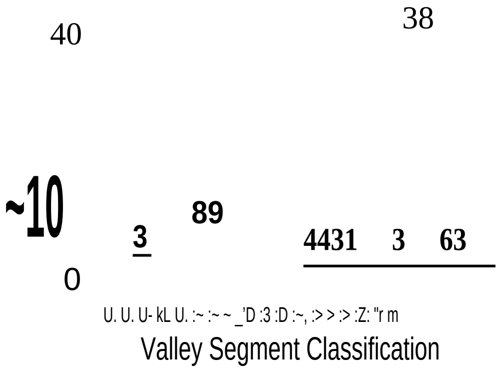

Figure 5. Number of valley segments surveyed for each habitat type during 1989 and 1990.

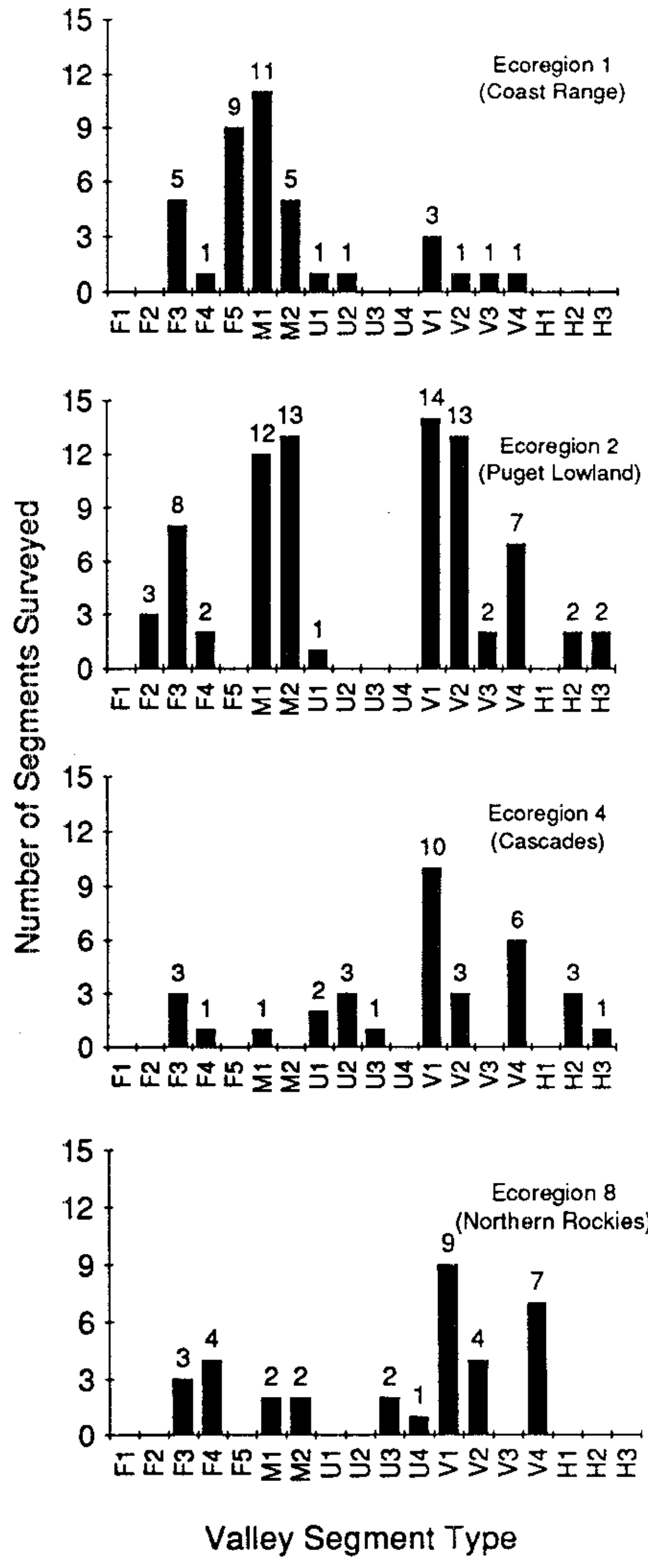

Figure 6. Number and type of valley segments surveyed by ecoregion.

Valley Segment Distribution

For the 1989-90 field seasons 196 valley segments were surveyed (Figure 5). A comprehensive listing of all segments surveyed in these years in given in Appendix D. Survey efforts were not distributed equally among all segment types because local geology and relief determine regional differences in the relative proportion and distribution of segment types. In our survey, V-shaped segments were two times as numerous (n = 86) as the next most numerous type, M-types (n = 49). Least numerous of the segments surveyed were U- and H-types. It is unlikely that these proportions mimic the normal distribution of valley segments across the landscape because their selection in 1989 included discontinuous segments on any given stream.

The distribution of valley segments by type included in the broad survey are stratified by the ecoregion within which they occurred (Figure 6). No clear pattern can be seen in the distribution of segments by ecoregion no doubt due to the arbitrary way in which sites were selected for survey and the coarse scale at which ecoregion boundaries are delineated.

Discriminant Analysis

The 1989 data set included 94 segments distributed across 12 valley segment types. When discriminant analysis was done for the unstratified 1989 data set, 48% of the cases were classified correctly. That is, the 11 response variables correctly predicted valley segment type 48% of the time. Stratifying the data by ecoregion increased the percentage of segment types classified correctly (Table 9).

The 1990 data had 92 cases distributed across 15 valley segment types. The discriminant analysis for the unstratified data set classified 45% of the cases correctly. Again, stratifying the data improved the prediction (Table 9).

When the two years were combined, the percent correctly classified by ecoregion was about 60% for each of the ecoregions (Table 9). As the number of segments increased, the number correctly classified decreases probably due to increasing variability in segment characteristics. For highly variable (and probably non-normally distributed) data such as this, these percentages are actually quite promising. These results indicated that, at least on a preliminary basis pending further refinement of the classification scheme, the variables chosen were meaningful for classifying valley segments.

Channel Width and Depth

Mean bankfull width and mean bankfull depth values were calculated for each segment in the survey. Figure 7 shows valley segments versus channel width. The range of channel widths for a given segment type is rather substantial for all segments except F2, F5, U1, U2, and V3. The range in widths measured for segment types suggests that this large range is due to inherent natural variability or that a number of segments surveyed have had major channel changes due to disturbance events. To examine this element further, all segments were sorted as a function of channel width and placed in one of five arbitrary channel size classes (Figure 8). For all segment s in a particular width class, the trend is for increasing width to depth ratio as bankfull channel width increases. That is, streams become relatively more shallow as their bankfull width increases. This is in agreement with conventional expectations of how river channels behave.

Figure 9 shows the plot of bankfull width by G/C index. As might be expected due to the inherent relationship between G/C index and confinement, channel bankfull width tends to decrease as gradient and confinement increase.

Table 9. Percentages of valley segment types classified correctly by discriminate analysis technique.

	Ecoregion			
1989	I	**2**	**3**	**8**
% Correct	86	64	61	100
Number of Cases	22	36	23	13
% Correct Unstratified = 48%, n--94				
1990				
% Correct	94	58	100	9O
Number of Cases	17	43	11	21
% Correct Unstratified = 45%, n--92				
1989 & 1990 Combined				
% Correct	56	50	62	68
Number of Cases	39	79	34	34

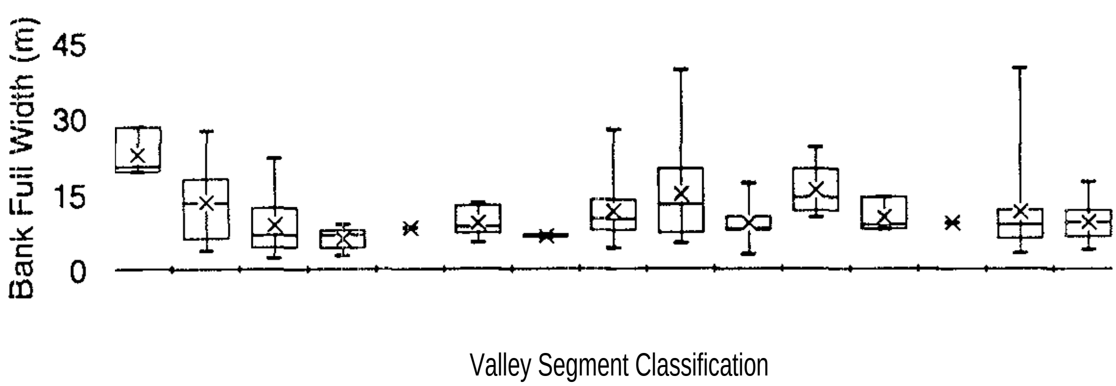

Figure 7. Bankfull width by valley segment type. Boxes show median and quartiles. Ticks are at maximum and minimum, "X" denotes the mean,

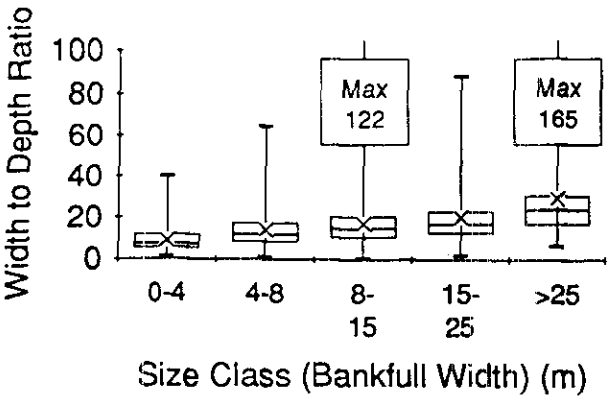

Figure 8. Width to depth ratios by stream size. Boxes show median and quartiles. Ticks are at maximum and minimum. "X" denotes the mean.

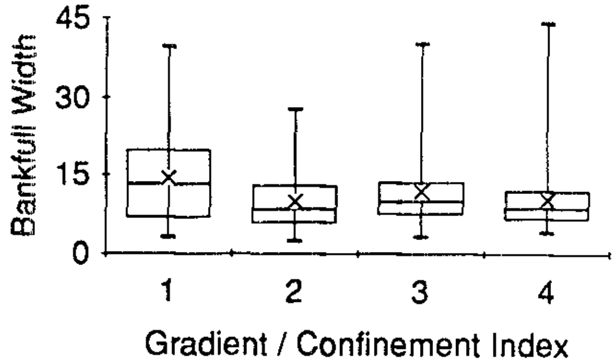

Figure 9. Bankfull width by gradient/confinement index. Boxes show median and quartiles. Ticks are at maximum and minimum. "X" denotes the mean.

The response of some stream channels *to in*creased peak flows and increased sediment loads can sometimes be deduced from such indicators as bankfull width and the ratio of width to mean depth. Interpretation of simple measurements of these channel characteristics involves a comparison with known expected values or, lacking that, upon prediction of these geometric relationships in undisturbed conditions. No such predictive indices currently exist for forested streams in Washington. We suggest that a regional index of channel geometry such as one proposed by Orsborn (1990) is essential to determining the net effect of land-use impacts on stream channels. Sorting segment data by basin area might also help eliminate scatter in channel width values seen in the data and help sort out whether the large range in width values is due to natural variation or the result of basin disturbances. This exercise would take some time but is fairly straight forward since *segment* boundaries will be clearly delineated on base maps and an electronic digitizer used to calculate basin areas.

Channel Substrate

.particle Size: Pebble counts using the Wolman (1954) method were included in only the 1990 segment survey. These counts were averaged and a mean particle size was calculated for all samples of a particular segment type (Figure 10). Substrate size distribution as a function of segment type alone does not seem to present any clear trend or pattern. In this instance a valley segment type designation does not allow prediction of mean substrate size. Using the G/C index the distribution of mean particle size and ranges seems to increase and narrow, respectively as a function of increasing segment gradient and channel confinement (Figure 11). Not surprisingly this suggests that channel gradient and confinement are

o~8
v

t/)

" "   B 3 ;   > > >

Valley Segment Classification

Figure 10, Substrate *size by* valley segment *classification.* Boxes *show* median and quartiles, 'Ticks are at maximum and minimum. "X" denotes the mean.

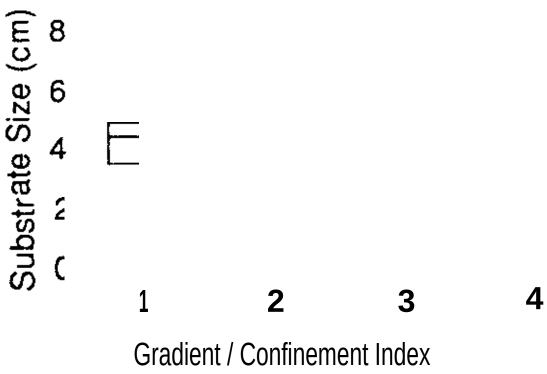

Figure 11. Substrate size by gradient confinement index. Boxes show median and quartiles. Ticks are at maximum and minimum. "X" denotes the mean.

determinant factors in D5D size particles within the channel substrate.

The rationale for including particle size sampling in this monitoring survey was to provide information useful to the anticipated work of the Sediment Hydrology and Mass Wasting Steering Committee of TFW. Recent developments in the area of stream geomorphology have included techniques to calculate the two year flow event and channel geometry based in part on the diameter of the particle size.,; of channel substrate. Most of the streams in forested areas do not have flow gauges located on them. Information about increased flood flows is therefore generally not existent. This variable was included to serve the interest Of learning whether flood flows have been changed by basin harvesting and if subse--quent channel changes have resulted from increased flow and sediment.

Embeddedness: A visual estimate of percent substrate embeddedness (four categories) is made during the pebble counts discussed above. This feature is included in the segment summary reports available for every segment surveyed. No further analysis of trends for this parameter have yet been made. This information, although subjective, is primarily useful for giving a relative sense of the extent of the problem when seen in areas of known spawning activity by salmon and trout. It is not truly quantitative and should only he used to "red flag" an area where more detailed evaluation of the incidence of fines is warranted because of concern for incubating eggs or alevins. Burton and Harvey (1990) have developed an excellent method to sample and aria-lyze cobble embeddedness, adopting elements of both Burns (1984) and Skille and King (1989). This method takes considerable time and as such was not included in the standard field survey.

Sediment Sources: Sources of sediment input were considered important features to note during the horizontal survey. Both length of bank cutting and areas of slope failure were estimated during the survey. This information is summarized on the individual reports for each segment and in the high level segment summary (Appendix D). This information gives a relative sense of the extent and nature of erosion throughout a stream segment. Survey crews expressed some uncertainty about distinguishing between slope failures caused by hillslope processes and those triggered by erosion at the toe of a slope adjacent to the stream.

Cross-sectional Profile Survey: Cross-sectional profile survey data at 27 transects located within the Pysht River were plotted for 1989 and 1990 data. A sample is shown in Figure 12.

Preliminary results show that considerable annual bed-elevation fluctuations occurred at transects in the low-gradient mainstream. For example, two scourchains and two bead monitors were installed at depths > 0.5 meters along Transect 3A (Figure 12) at the lower most surveyed station in the mainstream. None of these four monitors could he recovered in the 1990 or 1991 survey after excavating at their known installation positions along the transect. This suggests that mainstream spawning in this reach would be unsuccessful because the depth of scour due to winter storms exceeded the typical depth to which salmon redds are built. Bed elevation in 1990 had a net increase at surveyed points along Transect 3A as much as 0.33 m from 1989 levels. At the time of installation (1989) a steelhead redd was noted approximately 7 meters upstream of this transect.

Such information on scour and fill events is essential to evaluating impacts on spawning areas in forested streams. Permanent transects and the use of these techniques could easily be included as a part of any other future monitoring efforts.

Large Woody Debris

LWD Count: An index of woody debris, combined logs and root wads per 1000 feet (305 m) of stream channel, is given for all segment types in Figure 13. The woody debris loading index was highly variable but was relatively low for pooled F-

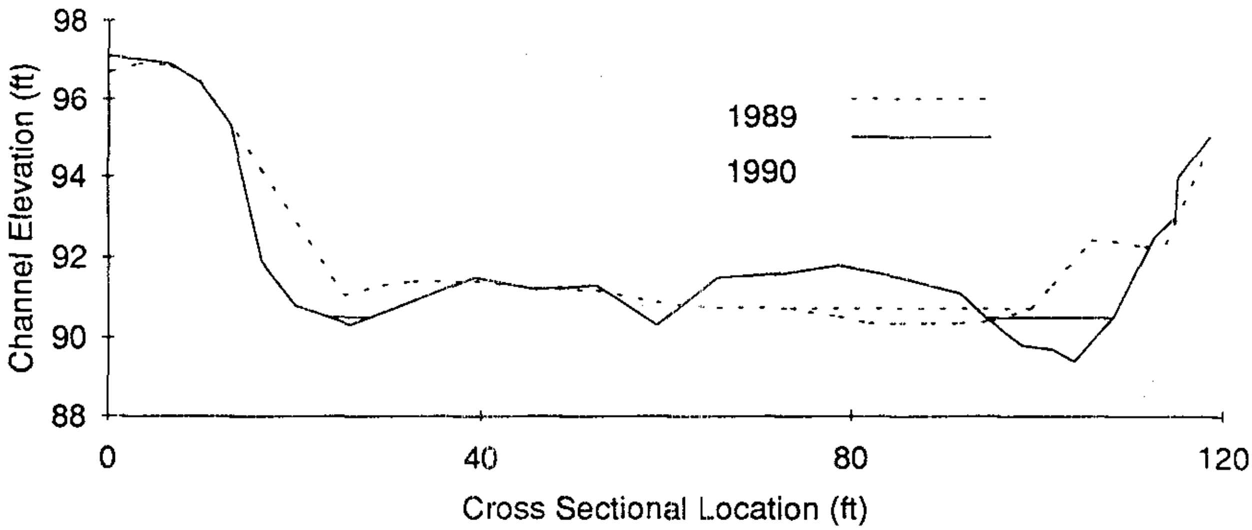

Figure 12. Cross sectional channel profiles from 1989 and 1990 at Pysht River Site 3A.

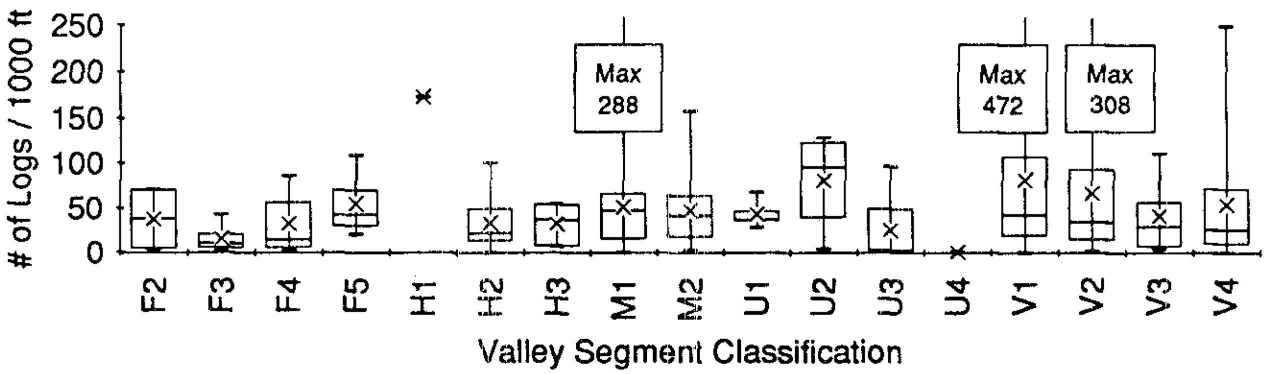

Figure 13. Number of logs per 1000 ft. of stream by valley segment type. Boxes show median and quartiles. Ticks are at maximum and minimum. "X" denotes the mean.

type segments with only 13 of 40 segments (32%) having > 40 pieces per 1000 feet. V-type segments, as a class, had generally higher woody debris loading, with the exception of V3 types that are highly constrained bedrock canyon reaches. Most notable were V1 segments with 21 of 37 segments (57%) having > 40 pieces per 1000 feet (median = 78 per 1000 ft), and some V 1 segments having loading rates in excess of 450 pieces per 1000 ft. When LWD count per 1000 ft was plotted against G/C index, steeper, more confined segments have a higher count, although the quartile ranges are essentially constant from indices 2-4 (Figure 14). Interpretation of these data is difficult until more information on actual basin history can be assembled. Riparian stand information is available from this project and

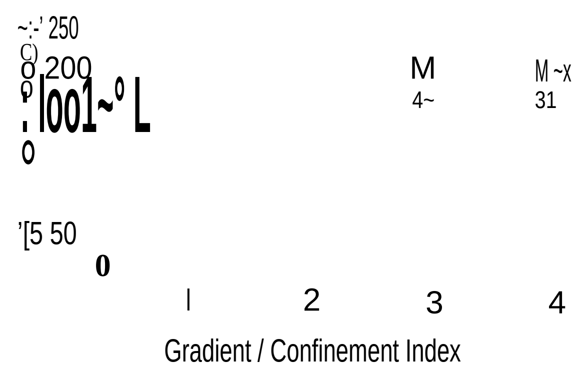

Figure 14. Number of logs per 1000 ft. of stream by valley gradient/confinement index. Boxes show median and quartiles. Ticks are at maximum and minimum. "X" denotes the mean.

can be included in future analysis of LWD loading and distribution,

LWD Count vs. Bankfull Width & Segment Type: The number of pieces of woody debris as a function of valley segment type was examined. All sites in the 1989-90 data, with the exception of two segments in old growth condition from the Hoh River, are in areas of commercial timber harvest, Woody debris loading for selected segment types is plotted by channel bankfull width (Figure 15).

Moderate gradient (2-6%) V-shaped valley segments (V1 type) retain relatively large amounts of woody debris when channel width is below 40 meters. V-shaped high gradient segments (6-11%) known as V2 types are generally narrower in channel width. Such segments retained relatively less woody debris overall than V1 types, especially as channel width exceeded 30 meters. Alluviated mountain valley segments lying Within V-shaped valley, known as V4 types, seem to show a similar trend, as bankfull width increases the woody debris loading index declines. Patterns in woody debris

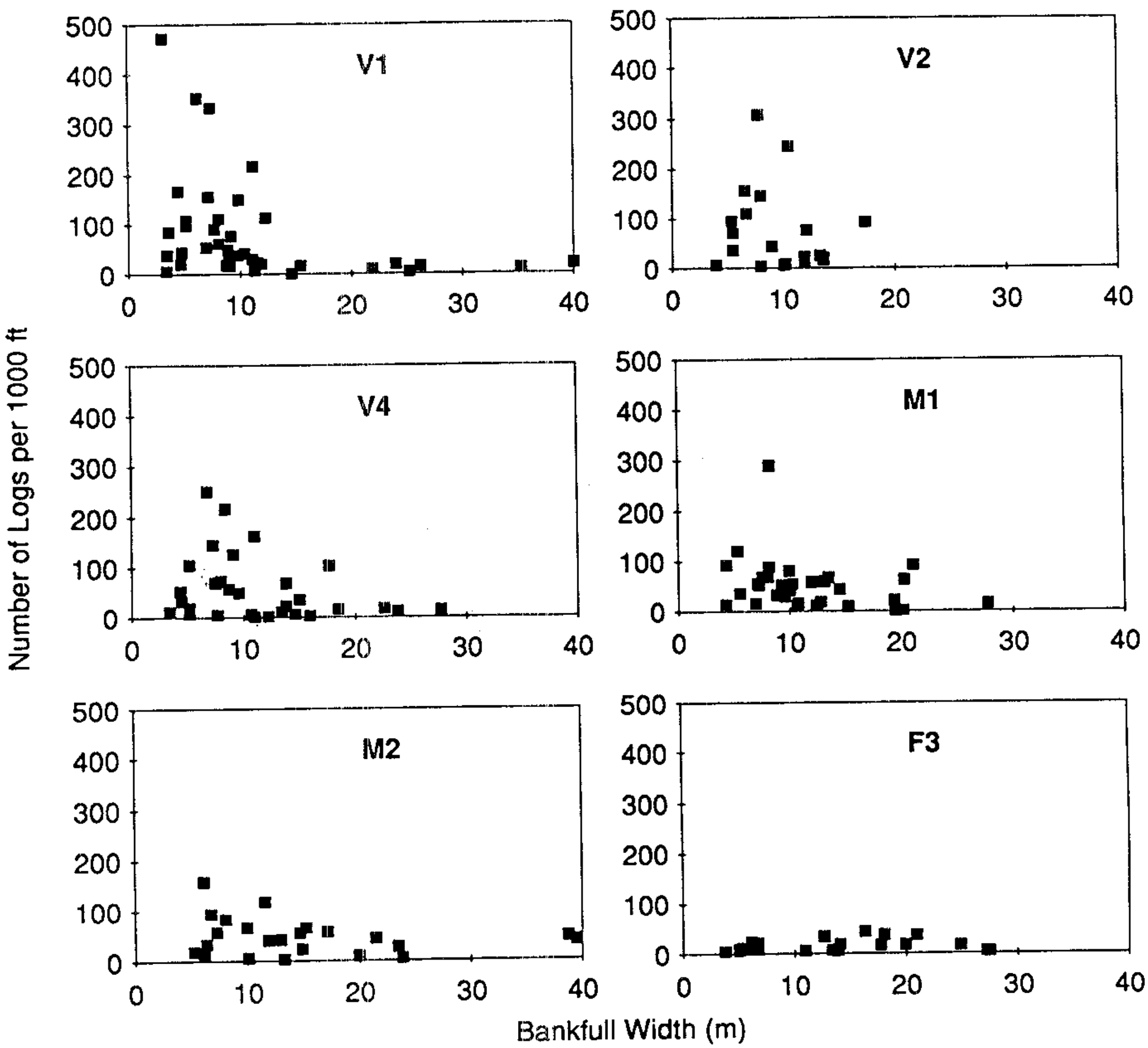

Figure 15. Number of logs per 1000 ft of stream by bankfull width in six valley segment types.

loading index for moderate slope bound segments (M1), alluviated moderate slope bound segments (M2), and wide mainstream valley segment types (F3) showed little trend in woody debris loading and channel width, a somewhat surprising fact perhaps explained by the tendency to have woody debris clumped in logjams rather than distributed throughout a channel.

Future analysis of the relationship between woody debris and riparian stand condition might be revealing, especially when coupled with information on past disturbance within the basin. Data provided through a consultant contract for Charley Creek, Taneum Creek, Mashel River, Snow Creek, and the Pysht River will be used to expand on this idea. An examination of differences in woody debris loading in sites located on the east side of the state versus the west side will be included. Data from segments located within old growth forests collected during the 1991 season will also be added to the analysis.

Percent Habitat Area

The pool: riffle and pool: riffle: cascade ratios for each valley segment surveyed are given in Appendix D. These relationships are difficult to interpret because no standards for the ideal or expected ratios have been established for valley segment or channel types, especially a standard that relates to differing disturbance histories. However, as information is gained on these ratios for various disturbance histories (including old growth areas) we may expect to gradually construct a set of standards for expected ratios to judge the magnitude and significance of stream conditions recorded at individual stream sites.

Pool Area: Figure 16 displays the percent of total in stream habitat area attributable to pools by segment type. Pools provided the least amount of habitat area for H3, U3 and U4 segments. Pools are generally not common in high gradient streams such as H3 types that are usually dominated by cascade type units. The paucity of pools in the U3 and U4 types is more curious. The individual data sets comprising these areas need to be examined to understand the cause of this low pool area. The influence of gradient and confinement on percent of total habitat areas comprised by pools can be seen in Figure 17. As gradient and confinement increase the percent of pools decreases. In all cases however, the range in percent values is quite broad.

_1’991Tvoe Frequency: The percent of each of the four major categories of pools by segment type is shown in Figure 18. Again sorting the data by segment type alone does little to reveal patterns from which one can make meaningful conclusions. For instance dammed pools and plunge pools are usually associated with large woody debris that nearly always spans the full width of the wetted stream, except in high gradient reaches. For high gradient H3 segments nearly 90% of all pools are plunge pools resulting from either woody debris or boulders. Damned pools were most commonly found in U2 type segments. When this variable is sorted by gradient/confinement as in Figure 19 it becomes clear that scour pools comprise the highest percent-

Figure 16. Percent of stream comprised by pools vs. valley segment type. Boxes show median and quartiles. Ticks are at maximum and minimum. "X" denotes the mean.

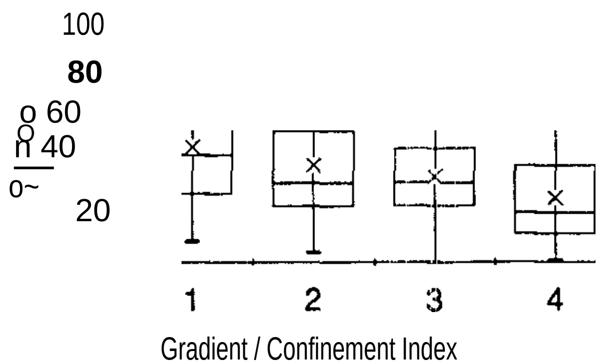

Figure 17. Percent of stream comprised by pools vs. gradient/ confinement index. Boxes show median and quartiles. Ticks are at maximum and minimum. "X" denotes the mean.

age of all pools in all segments. A clear but gradual trend of decreasing scour pool frequency can be seen as gradient and confinement increase.

In stream Obstructions Forming Pools; The percent of pools formed by organic obstructions (woody debris) by segment type in shown in Figure 20. No clear trend can be seen in the data sorted by segment type alone. Woody debris accounts for at least 50% of pool formation in eight of the 15 segment types evaluated. Although sample sizes for each valley segment are not equal, woody debris accounted for >70% of all pools formed in segment type U1 (n = 4), an unconstrained lower gradient (<3%) stream running through a glacially carved U-shaped valley. Organic obstructions accounted for <20% pool formation in V3 segments (n = 3) which are highly

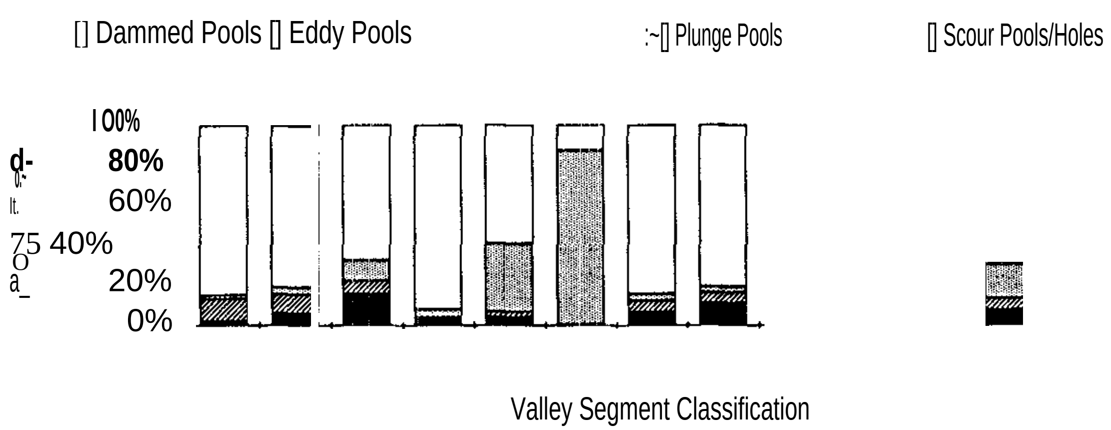

Figure 18. .Relative p0ol type frequency by valley segment type.

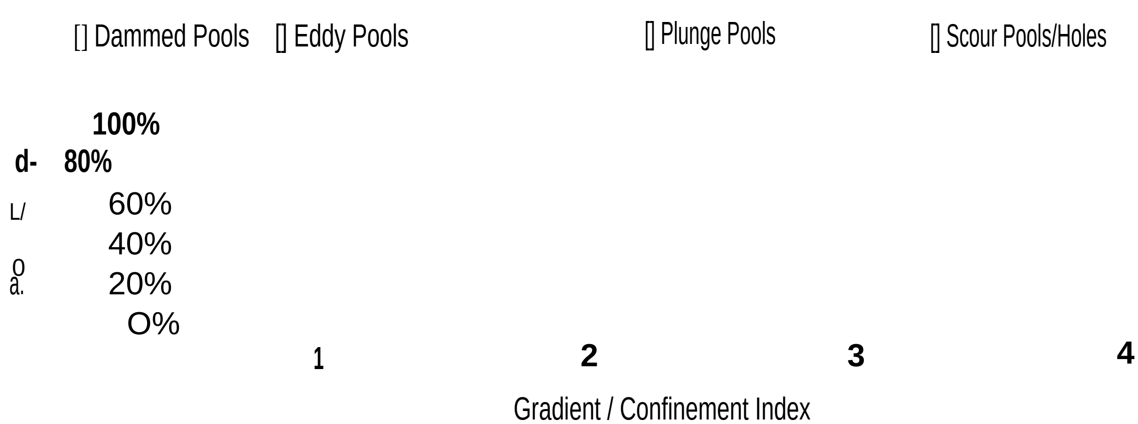

Figure 19, Relative pool type frequency by gradient/confinement index.

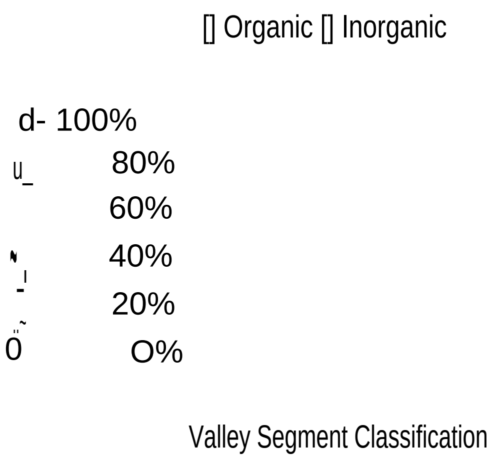

Figure 20. Percent of pool obstructions formed by organic debris vs. valley segment type.

constrained, steep gradient bedrock controlled canyon reaches. In contrast V4 segments (n = 24) which are unconstrained alluviated mountain valleys with wide floodplains, showed nearly 65 % of pools formed by organic obstructions.

The pool forming obstruction data was sorted by G/C index (Figure 21). Non-organic obstructions (boulders, bedform) accounted for more pools in segments having higher gradients and confinement, while organic debris accounted for more pools in lower gradient segments, when it was abundant. The highest pool frequency (63%) formed by organic

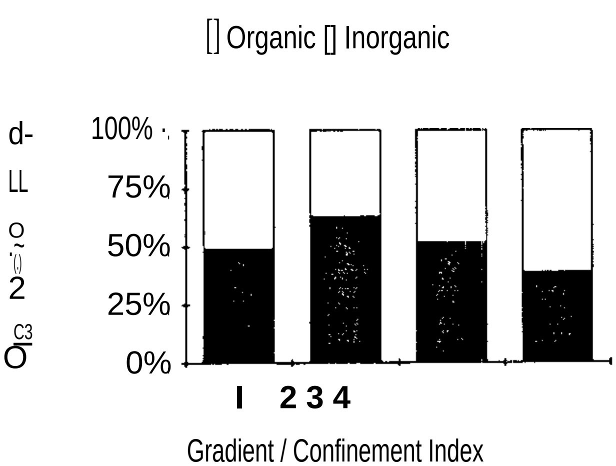

Figure 21. Percent of pool obstructions formed by organic debris vs. gradient confinement index.

obstructions is for segments that are moderately constrained and with moderate gradient (<5%). Steeper more highly confined channels had the least amount (40%) of organic obstructions.

SUMMARY

Variables for Habitat Inventory & Channel Condition

Ideal indicators for monitoring the impacts of land management activities should be highly sensitive (responsive) to management actions, have low spatial and temporal variability, be accurate, precise and easy to measure, and be directly related to the resources of concern. They should provide useful feedback to land managers, directly link management activities to the status of the resource of concern, allow statistical inferences to be made to larger land areas not sampled and allow quantitative estimates of risk and uncertainty. Unfortunately, *ideal parameters do not exist*, and monitoring projects are rarely able to fulfill all of these objectives (MacDonald et al., 1991).

Selection of Field Methods

If monitoring is to detect change in an important variable, the method should provide a reliable measure (i.e., accurate) at the appropriate resolution (i.e., precision). Many of the methods were selected because they would give a reasonable assessment of the variable of concern, and could thus serve as a "red flag" to focus future attention in areas that merited further investigation of a more rigorous nature. Methods that would reduce subjectivity were chosen where ever practical. The extensive monitoring survey was designed to be applied throughout a broad geographic area using temporary field staff-- its methods had to be easily taught, and consistently applied in the field.

Interpreting Cause and Effect

Attempting to implement a stream monitoring project across a large land mass is complicated by inherent variability imposed by diverse combinations of climate, geology, vegetation, and land form. Regional reference sites (Hughes, 1986) that would allow a basis of comparison to "steady state" conditions are in short supply due to historical and current harvesting patterns state wide. Only a few old growth forested stream segment sites are included in the current monitoring database, although over two dozen segments from such sites were surveyed during the 1991 field season.

Because there is much unquantified variability across the landscape, it is difficult to distinguish between natural inherent variability, that associated with past natural or man-caused disturbance events (e.g., fires, hydrologic storm events, timber harvesting, grazing), or the consequences of current forest practices intended to protect public resources. This variability can be clearly seen in the data from this monitoring project.

At the geographic scale of watersheds and at distribution and rates of timber harvest, there is no control over "treatments" applied to watersheds or streams (Hilborn and Waiters, 1981). Since an upstream-downstream or before-and-after-impact approach is unlikely, finding unimpacted streams with similar watershed features to those sites sub-. jected to forest harvesting should be a high priority in future site selection.

Interpretation of apparent trends will be consid.. erably enhanced as accumulating information:

1) allows comparison to a "before" condition or some reference site that is similar in character and history (e.g., 1991 field data);

2) includes an understanding of the natural charac.- ter and disturbance and management history;

3) ensures that survey procedures are repeated at the same sites at three to five year intervals to detect changes over time and trends in the condition of the stream.

Classification as a Tool in Monitoring

Recent development of stream classification schemes has emphasized geomorphology and a stream's relationship to its watershed across a wide range of scales. (Lotspeich and Platts, 1989; Rosgen, 1985; Frissell, et al., 1986; Naiman, et al., 1992). Use of an appropriate classification scheme should allow between-basin comparisons of in stream habitat across a number of diverse ecoregions (Omernik and Gallant 1986), valley forms, geomorphic characters and channel conditions. However, design of an effective and practical landscape classification must be integrated with essential information on both natural features and man-induced alterations (road density, stand age, erosional sources).

At present it appears that no *single* classification system at any of the spatial scales of interest currently available can meet the needs expressed by TFW. If such a system is desired, it will need to be developed through a concerted integrated effort to encompass the range of spatial scales from habitat units to the subregion or province level.

Ecoregion Level

The attempts at relating segment type to in stream habitat stratified by ecoregion were promising but inconclusive. As the first attempt at stratifying the state, ecoregion alone does not appear to provide much useful predictive power in explaining the nature of streams as defined by valley segments, or the stream habitat condition therein. Further refinement of physiographic province and basin level attributes currently underway should provide more useful correlates (J. Omernik, EPA Corvallis, Oregon, personal communication).

Valley Segment Level

Specific comparisons between valley segment types have revealed some differences on certain habitat responses. Interpretation of this information is restricted by an inability to account for the inherent variability and the role of past impacts on streams. Furthermore, inherent limitations for data analysis exist within this system. Segment types are merely descriptive. Stream characteristics often vary arbitrarily between groups rather than in a systematic manner such as trends in important characteristics. These trends are easier to plot, analyze, and summarize than purely categorical data. Re suits from comparisons of multiple valley-segment types are, therefore, often not intuitive and are difficult to summarize.

The stream channel classification scheme currently used is ill suited for the purposes of stratifying stream segments when the objective is to account for inherent differences in segment character in a systematic way. Although Cupp (1989) and Beechie and Sibley (1990) indicate that there are some differences between valley segments types reflected at the habitat unit level, the "type" designation for valley segment is meant to denote a unique combination of basin and channel geomorphic characteristics. Beechie and Sibley (manuscript in review) indicated that there is a substantial overlap among the combinations of the six diagnostic criteria used to differentiate among segment types, and further suggest that *the a priori* nature of the criteria ignore the influence basin level processes for hydrology and sediment delivery may have on in stream habitat character.

The valley segment approach, while useful in identifying the broad character of a stream reach, is not truly systematic because attributes do not occur along a continuum. The relative influence of each diagnostic attribute is different for any given segment type. Thus, types are purely categorical rather than systematic. Diagnostic features such as channel gradient do not have discrete values that distinguish one type from another (see discussion on rationale for' G/C index to illustrate this point further). Additionally, there are no "rules" described for two of the most important variables, i.e. geology and confinement. Channel gradient and confinement for segment types fall within overlapping range of values. These factors greatly confound the task of sorting field data for analysis. Discrete values for these should be considered as the primary features in revising this *classification* scheme.

Habitat Unit Level

The habitat unit classification system currently being used (Sullivan 1986) is hierarchical in that it subdivides pools and riffle units into six and five units respectively, primarily based upon their gradient. As the results of the quality assurance tests show, this habitat classification scheme is difficult to apply consistently *across* the *variations* of stream size and character encountered in this state wide survey, especially by temporary field crews. It does not account for all of the habitat features encountered, nor can field crew members he taught to unerringly identify its components. Even when the gradient criteria are applied, consistency is a problem. Also, the criteria suggested seem to be difficult to apply across the range of sizes of streams, i.e., there is no easy way m "size" the criteria to the stream being surveyed. The gradient criteria which is the basis for distinguishing one refit type from another does not account for all conditions encountered. One approach worth evaluating is that of applying "fuzzy set theory" to habitat unit identification (Roberts 1989) which could accommodate the inherent limitation of picking only one habitat unit label to describe the occurrence of a unit.

Hawkins et al. (199I) suggest that more than one system of habitat classification may be necessary to account for the inherent variability experienced with streams of different sizes. A more discrete set of rules needs to be formulated to ensure consistency in identification and reduce subjectivity, or unit types should be compressed to three or four easily recognizable types. In the latter case, however, the taxonomy of habitat units would be simplified to the point of losing valuable information about the subtle but important determinants of fish habitat quality and quantity. The ability to distinguish between important qualitative differences of stream reaches would be lost. Types of habitat that contribute critical refuge for juvenile fishes during winter periods would go unaccounted for in the inventory. Conversely, the value of certain pool types such as scour pools may be grossly overstated.

Basin level changes in the amount and timing of watershed discharge and sediment routing through the stream channel and the recruitment and retention of in stream woody debris are the predominant management related factors that determine the present condition of the response variables included in the survey. The focus of the analysis to date has been on pools formed by woody debris loading and its role in forming pools. There are several interesting variations on this theme that should be considered in future analyses of the data. These include the role of riparian stand condition on woody debris, and differences in pool types as a function of gradient and channel confinement where discrete values for segments can be determined from maps. There may be other correlates but they appear to be masked by different disturbance histories. More information on disturbance history will ultimately be needed to properly reconstruct cause and effect.

Habitat Complexity; Empirical evidence suggested by the data and from field site visits suggests that where woody debris loading is low, scour pools occur more frequently in reaches bordered by clearcut and second growth systems than other pool types such as plunge pools and dammed pools. The latter pool types axe typically associated with fully spanning logs. This corroborates what was found by Bilby and Ward (1991) where plunge pools formed by LWD were significantly more common at old-growth sites than all stream-size classes at second-growth sites and overall pool frequency was significantly greater at old-growth sites than the other two stand age classes.

Some pool types may be more highly "valued" by salmonids during critical life stages than their occurfence in the stream would suggest. For instance, deep pools may provide hydraulic refuge habitat for juvenile fish during winter storm flows that would ,otherwise force these fish from the stream. This critical winter habitat may be more limiting to smolt production than *summer low flow habitat.* Measuring these subtle features and the characteristics they provide is the subject of ongoing research through the Big Fish Project (P. Peterson, CSS, Univ. of Washington, personal communication).

Topics for future analysis include:

1) investigating the frequency of occurrence of the habitat sequence of low gradient fifties - slip-faced cascades - scour pools, which are typically associated with streams with little or no large woody debris;

2) an analysis of mean pool depth and maximum pool depth as indicators of pool quality and persistence (C. Frissell, Oregon State University, personal communication).

Woody Debris: Bilby and Ward (1991) found that frequency of LWD in clear-cut and second growth sites for streams 15 m wide was 50% and 59% respectively of that found in old growth streams of the same width. In channels 5 m wide, this relationship was found to be increase to *56%* and 77% respectively. Wood volume was greatest in streams with old growth riparian zones when channel widths exceeded 10 m. Such comparisons using our survey data are difficult because of the need to choose streams with similar channel character to those used by Bilby and Ward. Murphy and Koski (1989) found that differences in channel type (and thus stream power) played a large role in determin-. ing the amount of woody debris occurring in a given reach of stream. But these comparisons should be quite revealing, especially when using data from the 27 old growth segments surveyed in 1991.

Channel Bankfull Width. profile and Width_to Channel dimensions are highly correlated with size of the basin (drainage area) and magnitude of flood events with a relatively consistent recurrence interval of 1.5 years (Dunne & Leopold, 1978). Changes in either basin hydrology or sediment load will leave their imprint on channel dimensions. In an assessment of stream channel condition, Madej (1978) designed and calibrated a regional index of channel width, depth and cross-sectional area and compared predicted dimensions with actual dimensions from Big Beef Creek (Kitsap County, WA). Orsbom (1990) has suggested incorporating a regional model of basin and channel characteristics into a long-term monitoring project. A regional approach to calibrating channel conditions would allow some "standard" of comparison between predicted and actual channel profiles, thereby offering some quantitative assessment of cumulative watershed effects on forested stream channels and fish habitat. Such standards are essential to interpretation of data from this monitoring effort.

GENERAL CONCLUSIONS & RECOMMENDATIONS

1) Since monitoring is by its very nature an iterative process, repeat surveys of stream reaches should be conducted every three to five years to detect changes in important variables.

2) The Cupp (1989) valley segment classification system, while promising, does not work well in a state wide application involving a multi-team approach. Being more categorical than systematic, it seem to be as much art as science; this causes difficulty in training field personnel to use the classification system.

3) A new approach should be taken for continued analysis of data from the segments already surveyed. One suggestion is to stratify them by actual gradient values taken from 1:24,000 USGS maps for the segment of interest, by a measure or index of confinement or ratio of active channel width to valley width, watershed area and precipitation.

4) An understanding of the specific character and disturbance history of a basin is essential to insightful interpretation of the current condition of aquatic resources in any given basin.

5) A sense of what streams should look like in their natural state (i.e. not subjected to land-use related impacts) is essential to determining whether a particular stream is in "good" or "bad" condition. A general"profile" of stream condition cannot be formulated unless and until a standard reference or expected condition can be determined.

6) The habitat unit typing system used in this project needs further refinement to minimize the variability from observer to observer. Measurable attributes should be generated to allow more reliable discrimination between habitat unit types.

LITERATURE CITED

American Fisheries Society. 1985. Glossary of stream habitat terms. W.T. Helm (ed.) In: Aquatic Habitat Inventory - Glossary and standard methods. Habitat Inventory Committee, Western Division, American Fisheries Society, 34 pp.

Beechie, T. and T. Sibley. 1990. Evaluation of the TFW Stream Classification System: Stratification of Physical Habitat Area and Distribution.

Report prepared for Washington Department of Natural Resources.

Beechie, T. and T. Sibley. In Review. Effectiveness of a Classification System for Establishing Habitat Characteristics of Streams in the North Cascades, Washington. Transactions of the American Fisheries Society.

Bilby, R. E. and J.W. Ward. 1992. Large woody debris characteristics and function in streams draining old-growth, clear-cut and second-growth forests in Southwestern Washington. (In press) Canadian Journal of Fisheries and Aquatic Sciences.

Bisson, P.A., J.L. Nielson, R.A. Palmason, and L.E. Gore. 1981. A system of mapping habitat types in small streams, with examples of habitat utilization by salmonids during low stream flow. pp. 62-73. In N.B. Armantrout (ed.) Acquisition and utilization of aquatic habitat information. Proceedings of a conference held in Portland, Oregon, 1981. Western Division, American Fisheries Society.

Bums, D.C. 1984. An inventory of embeddedness of salmonid habitat in the South Fork Salmon River drainage, Idaho. For USDA Forest Service, Payette and Boise National Forests.

Burton T.A. and G.W. Harvey. 1990. Estimating intergravel salmonid living space using the cobble embeddedness sampling procedure. Idaho Department of Health and Welfare, Division of Environmental Quality, Boise, Idaho. Water Quality Monitoring Protocols, Report No. 2. 16 PP.

Conquest, L.L., S.C. Ralph, and R.J. Naiman. 1992. Implementation of large-scale stream monitoring efforts: Sampling Design Considerations and Data Analysis Issues. In: Biological Monitoring of Freshwater Ecosystems (S. Loeb, Editor), Academic Press, New York.

Cupp, C.E. 1989. Stream corridor classification for forested lands of Washington. Report to Washington Forest Protection Association, 711 Capital Way, Evergreen Plaza Bldg., Olympia, WA 98501.46 pp.

Environmental Protection Agency. 1989. Nonpoint Sources: Agenda for the Future. Office of Water (WH-556), Washington D.C., 31 pp.

Dunne, T. and L.B. Leopold. 1978. Water in Environmental Planning. W.A. Freeman and Company.

Frissell, C.A., W.J. Liss, C.E. Warren, M.D. Hurley. 1986. A hierarchical framework for stream habitat classification: viewing streams in a watershed context. Environmental Management: 10, 199-214.

Grette, G.B. 1985. The role of large organic debris in juvenile salmonid rearing habitat in small streams. Master’s Thesis. University of Washington, Seattle, WA.

Hankin, D.G. and G.H. Reeves. 1988. Estimating total fish abundance and total habitat area in small streams based on visual estimation methods. Can. J. Fish. Aquat. Sci. 45: 834-844.

Hawkins, C.P., J.L. Kershner, P. Bisson, M. Bryant, L. Decker, S.V. Gregory, D. McCullough, K. Overton, G. Reeves, R. Steedman, and M. Young. 1991. Recommendations for a system of stream habitat classification. Draft of a paper, Department of Fisheries and Wildlife and U.S. Forest Service Fish Habitat Relationships Unit, Utah State University, Logan, Utah.

Hickes, B.J., J.D. Hall, P.A. Bisson, and J.R. Sedell. 1989. Responses of salmonid populations to habitat changes caused by timber harvest. Preprint of Chapter 14, "The influence of Forest and Rangeland Management on Salmonids and their Habitat’’ , American Fisheries Society. Technical Paper 8451, Oregon Agricultural Experiment Station, Corvallis, OR 97331

Hilborn, R. and S.C. Stearns. 1982. On inference in ecology and evolutionary biology: the problem of multiple causes. Acta Biotheoretica 31, 145-164pp.

Hilborn, R. and C.J. Waiters. 1981. Pitfalls of environmental baseline and process studies. Environmental Impact Assessment Review, Vol. 2, No. 3, pp. 265-277.

Hughes, R.M., D.P. Larsen, J.M. Omernik. 1986. Regional reference sites: a method for assessing stream potentials. Environmental Management: 10, pp. 629-635.

Kappesser, G. 1991. The use of Wolman pebble counts and channel geometry to define channel stability. Idaho Panhandle National Forests, Coeur d’Alene, Idaho. In review.

Lisle, T.E. 1982. Effects of aggradation and degradation on riffle-pool morphology in natural gravel channels, Northwestern California. Water Resources Research, VoL 18, No. 6, pp. 1643-1651.

Lisle, T.E. 1987, Using "residual depths" to moni.. torpool depths independently of discharge. USDA Forest Service, Pacific Southwest Forest and Range Experiment Station. Berkeley, California, Research Note PSW-394.

Lisle, TE. 1989. Sediment transport and resulting deposition in spawning gravels, north coastal California. Water Resources Research, Vol. 25, No. 6, pp. 1303-1319.

Lotspeich, F. and W. Platts. 1982. An integrated land-aquatic classification system. American Journal of Fisheries Management 2: pp. 138-149.

MacDonald, L.H., A.W. Smart and R.C. Wissmar. 1991. Monitoring guidelines to evaluate effects of forestry activities on streams in the Pacific Northwest and Alaska. Report prepared for Environmental Protection Agency, Region 10, Seattle, WA. EPA/910/9-91-001, 166 pp.

Madej, M. A. 1978. Response of a stream channel to an increase in sediment load. M.S. Thesis, Department of Geological Science, University of Washington. 111 pp.

Murphy, M.L. and K.V. Koski. 1989. Input and depletion of woody debris in Alaska streams and implications for stream side management. Paper submitted to North American Journal of Fisheries Management.

Naiman, R.J., D.G. Lonzarich, T.J. Beechie, S.C. Ralph. 1992. General principals of classification and the assessment of conservation potential in rivers. In: (P. Boon, G. Petts and P. Callow, Editors), River Conservation and Management. Wiley & Sons, Chichester, UK.

Nawa, R.K. and C.A. Frissell. 1992. Measuring scour and fill of gravel stream beds with scour chains and sliding bean monitors. Pre-submission review draft of 5/91 - Prepared for submission to Canadian Journal of Fisheries and Aquatic Sciences.

Omernik, J.M. and A.L. Gallant. 1986. Ecoregions of the Pacific Northwest. U.S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, OR. EPA/600/3-86/033.

Platts, W.S., C. Armour, G.D. Booth, M. Bryant, J.L. Bufford, P. Cuplin, S. Jensen, G.W. Lienkaemper, G.W. Minshall, S.B. Monsen, R.L. Nelson, J.R. Sedell, J.S. Tuhy. 1987. Methods for evaluating riparian habitats with applications to management. General Technical Report INT-211, Ogden, UT. US Department of Agriculture, Forest Service, Intermountain Research Station, 177 pp.

Platts, W.S., R.J. Torquemada, M.L. McHenry, D.K. Graham. 1989. Changes in salmon spawning and rearing habitat from increased delivery of fine sediment to the South Fork Salmon River, Idaho. Transactions of the American Fisheries Society: 118: pp. 274-283.

Roberts, D.W. 1989. Fuzzy systems vegetation theory. Vegetatio 83: 71-80.

Rosgen, D.L. 1985. A stream classification system. In R.R. Johnson, et al., Editors. Riparian ecosystems and their management: reconciling conflicting uses. First North American Riparian Conference, Tucson, Arizona, pp. 91-95.

Skille, J. and J. King. 1989. Proposed cobble embeddedness sampling procedure. USDA Forest Service, Intermountain Research Station, in draft.

Sullivan, K. 1986. Hydraulics and fish habitat in relation to channel morphology. Ph.D. dissertation. Johns Hopkins University, Baltimore, Md.

Williams, R.W., R.M. Laramie and J.J. Ames. 1975. A catalog of Washington streams and salmon utilization. Vol. 1 Puget Sound Region; Vol. 2 Coastal. Washington Department of Fisheries, Olympia, WA.

Wolman, G. 1954. A method of sampling coarse river bed material. Trans. American Geophysical Union, Vol. 35, Number 6.

APPENDIX A. INDIVIDUAL VALLEY SEGMENT SUMMARIES

[)am from the 1990 Ambient Monitoring field season have been consolidated into Individual Valley Segment Summaries (see sample on page A-2). Each summary consists of one page of descriptive information, Some of the information is simply reported as entered on the field forms, while other information is the result of calculations based on the data. These calculations are described below to assist in the interpretation of the summaries.

Segment Length - The cumulative segment length based on the horizontal control survey.

Mean Gradient - The average segment gradient based on measured values from the horizondal control survey.

Bankfull Width/Depth - The average segment bankfull width/depth based on measured values form the horizontal control survey.

Width/Depth Ratio - The total of all bankfull width measurements divided by the total of all bankfull depth measurements.

Pool/Riffle/Cascade Ratio - The total corrected area of all pools to the total corrected area of all fifties to the total corrected area of all cascades. (See Total Area below for a description of corrected area.)

Habitat Units

Code, Description - The three letter alpha designator for habitat units, followed by a de., scription of the unit type.

Freq. - The frequency of occurence of each habitat unit type.

% Total - The percent contribution of each habitat unit type given the total number of habitat units in the segment.

Mean RPD - The average residual pool depth derived by subtracting pool depth 1 from pool depth 2.

CF - The correction factor generated from the pairs of measured and estimated units dimentions of the given unit type. The correction factor, based on the methods of Hankin and Reeves (1988), is the sum of the measured areas divided by the sum of the estimated areas for all paired measurements. A blank correction factor implies that the areas for the given unit type were either all measured or all estimated. (See Appendix C for more information on correction factors.)

Total Area - The total corrected area, in square meters, for each habitat unit type. The corrected area for a given unit type is the total estimated area of all units of the given type, multiplied by the correction factor described above.

95% C.I. - The 95% confidence interval for the total corrected areas. Lower bound = total area minus 95% C.I. (lower bound is 0 of calculated value is less than 0); upper bound =total area minus 95% C.I. A confidence interval of 0.0 means that all units of the given type were measured. A missing confidence interval indicated that all units of the given type were estimated.

% Tot - The relative contribution of each habitat unit type to the total area of all habitat units in the segment.

Subsurface Flow - The number of occurences, and the total length of subsurface flow in the main and side channels.

Land Use - The percent contribution of each category of land use over the entire segment. Land use data were collected for each habitat unit. The reported values reflect a weighting based on the lengths of the individual habitat units.

Substrate - The percent contribution of each catagory of substrate based on pebble counts.

Seral Stage - The percent contribution of each catagory of substrate based on data collected for each habitat unit.

- The percent contribution of each catagory of vegetative type based on data collected for each habitat unit.

Canopy Closure - The mean % canopy closure based on measured values taken periodically during the collection of habitat unit data. The minimum and maximum % closure readings are also reported.

NOTE: Blank entries in any fields of the segment reference and physical description sections imply that the information was not available.

VALLEY SEGMENT SUMMARY REPORT
TFW Ambient Monitoring Program - 1990

WRIA #: 51.0046 NAME: NORTH STAR SURVEY DATE: 7/16/90
SEGMENT: V1-2 - V-Shaped, Moderate Channel Gradient Bottom CALLER: CM

LOWER ELEVATION: 835 meters UPPER ELEVATION: 859 meters

LOWER SEGMENT: - UPPER SEGMENT: V4-3 ECOREGION: 8B

PHYSICAL DESCRIPTION

SEGMENT LENGTH - 557.0 meters STREAM ORDER - 2 DISCHARGE - 6.520 cfs

Mean GRADIENT - 5.0% BANKFULL WIDTH - 3.5 meters BANKFULL DEPTH - 0.5 meters

WIDTH/DEPTH RATIO - 3.5 / 0.5 = 7.0

POOL/RIFFLE/CASCADE RATIO - 404.9 / 118.7 / 783.7 = 0.5 / 0.2 / 1

HABITAT UNITS

	Code	Description	Freq	% TOT	MEAN RPD (m)	CF	TOTAL AREA (m^2)	95% C.I. (+/-)	% TOT
(cascades)	RPD	Rapid	0						
	SPC	Step-pool	20	31.25		0.93	768.8	87.8	58.81
	SFC	Slip-face	1	1.56			14.9	0.0	1.14
(riffles)	PKW	Pocketwater	1	1.56			20.4	0.0	1.56
	GLD	Glide	0						
	RUN	Run	0						
	LGR	Low Gradient	7	10.94		0.71	98.3	53.9	7.52
(pools)	DMP	Dammed Pool	5	7.81	0.40	0.89	73.7	14.1	5.64
	EDP	Eddy Pool	2	3.13	0.20		9.6	0.0	0.73
	PLP	Plunge Pool	9	14.06	0.27	0.56	44.7	62.1	3.42
	SCP	Scour Pool	18	28.13	0.23	0.96	269.5	57.8	20.62
	SCH	Scour Hole	1	1.56	0.19		7.3	0.0	0.56
	BVP	Beaver Pond	0						
	SDC	Secondary Ch.	0						
	TOTAL		64				1307.3		

SUBSURFACE FLOW	Freq	Total Length (meters)
Main Channel	0	
Side Channel	0	

MASS WASTING: Total Sites - 0

BANK CUTTING: Total Sites - 0

WOODY DEBRIS: Total Logs - 69, Total Wads - 10

LAND USE	%
AGRICULTURE	
LIVESTOCK GRAZING	
TIMBER	100.00
RESIDENTIAL	
RIGHT OF WAY	
MINING	
RMZ	
WETLAND	
OTHER	

SUBSTRATE	Size	%
FINE SAND	0.125-0.25 cm	1.34
MED. SAND	0.25-0.5 cm	4.01
COARSE SAND	0.5-1.0 cm	2.01
PEA GRAVEL	1-2 cm	3.34
SM. GRAVEL	0.8-1.6 in	10.70
MED. GRAVEL	1.6-3 in	26.76
COARSE GRAVEL	3-6 in	32.44
SM. COBBLE	6-12 in	14.72
MED. COBBLE	12-25 in	4.68
LG. COBBLE	25-50 in	
BOULDER	> 50 in	
BEDROCK		

Most Common EMBEDDEDNESS: 25 - 50%

SERAL STAGE	%
CLEAR CUT	
GRASS/FORB	
SHRUB	
POLE	
YOUNG	1.79
MATURE	98.21
OLD GROWTH	

VEG TYPE	%
DECIDUOUS	
CONIFEROUS	
MIXED	100.00

CANOPY CLOSURE: Mean - 65.9%, min - 40%, max - 86%

APPENDIX B. FIELD-DATA COLLECTION FORMS

Attached are sample field-data collection forms. These forms are optically scannable and printed on waterproof paper. A detailed description of these forms and their use is contained in Ralph, t990.

TFW Ambient Monitoring

VALLEY SEGMENT SUMMARY

1. Use this form once for each valley segment.
2. Note Access points in block provided.
3. Date indicates initial survey start date.
4. Refer to code reference sheet and field manual for codes and procedures.

FORM 1

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks. Page ___ of ___.

STREAM NAME

○ CREEK ○ RIVER

DATE

DAY: 1–31

MONTH: ○ MAY ○ JUNE ○ JULY ○ AUG ○ SEPT ○ OCT ○ NOV

YEAR: ○ 90 ○ 91 ○ 92 ○ 93

VALLEY SEGMENT

OFFICE USE ONLY

W.R.I.A NUMBER

○ UNLISTED

STREAM ORDER

1 2 3 4 5 6 7

SURVEYORS/AFFILIATIONS

CALLER

S1	A1	S2	A2	S3	A3

DESCRIPTION OF ACCESS AND REFERENCE TO TURNING POINTS:

A5200 Mark Reflex® by NCS MP83525:321 Printed in U.S.A.

rev. 4/90

Please complete back of form.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

LOWER BOUNDARY LOCATION

TOWN | RNG | SEC | ¼ OF ¼

ELEVATION

○ FEET
○ METERS

PHOTOGRAPHS

YR | AFF | C | ROLL

TURNING POINT

LOWER (NEXT) VALLEY SEG.

W V H U F

OFFICE USE ONLY

NOTES:

UPPER BOUNDARY LOCATION

TOWN | RNG | SEC | ¼ OF ¼

ELEVATION

○ FEET
○ METERS

PHOTOGRAPHS

YR | AFF | C | ROLL

TURNING POINT

UPPER (NEXT) VALLEY SEG.

W V H U F

OFFICE USE ONLY

TFW Ambient Monitoring

HORIZONTAL CONTROL SURVEY

FORM 2

1. Complete horizontal control survey (this form) and provide Mass Wasting and Substrate data (FORM 3) before starting habitat unit survey (FORM 4's).
2. *Complete written header.*
3. Refer to code reference sheet and field manual for codes and procedures.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page ___ of ___

STREAM NAME (CIRCLE ONE ↓) CREEK / RIVER

DATE MO. | DAY | YR.

VALLEY SEGMENT

W.R.I.A. NUMBER ○ UNLISTED

UNITS (CIRCLE ONE) FEET / METERS

DISCHARGE (CIRCLE ONE ↓) MEAS / EST

TURNING POINTS "n" ○ LEFT BANK ○ RIGHT BANK | "n + 1" ○ LEFT BANK ○ RIGHT BANK

AZIMUTH (0-359) ○ MAGNETIC ○ TRUE

GRADIENT (%) ○ <.5

PHOTOGRAPHS ROLL | FRAME

DISTANCE TP n | TP n + 1

BANKFULL WIDTH | DEPTH

TURNING POINTS "n + 2" ○ LEFT BANK ○ RIGHT BANK | "n + 3" ○ LEFT BANK ○ RIGHT BANK

AZIMUTH (0-359) ○ MAGNETIC ○ TRUE

GRADIENT (%) ○ <.5

PHOTOGRAPHS ROLL | FRAME

DISTANCE TP n + 2 | TP n + 3

BANKFULL WIDTH | DEPTH

A5200

Mark Reflex by NCS MP83527 32

Printed in U.S.A.

rev. 4/90

Continue on back of form.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

TURNING POINTS
"n + 4" — LEFT BANK / RIGHT BANK
"n + 5" — LEFT BANK / RIGHT BANK

AZIMUTH (0-359)
MAGNETIC
TRUE

GRADIENT (%)
.5

PHOTOGRAPHS
ROLL | FRAME

DISTANCE
TP n + 4 | TP n + 5

BANKFULL
WIDTH | DEPTH

TURNING POINTS
"n + 6" — LEFT BANK / RIGHT BANK
"n + 7" — LEFT BANK / RIGHT BANK

AZIMUTH (0-359)
MAGNETIC
TRUE

GRADIENT (%)
.5

PHOTOGRAPHS
ROLL | FRAME

DISTANCE
TP n + 6 | TP n + 7

BANKFULL
WIDTH | DEPTH

TURNING POINTS
"n + 8" — LEFT BANK / RIGHT
"n + 9" — LEFT BANK / RIGHT

AZIMUTH (0-359)
MAGNETIC
TRUE

GRADIENT (%)
.5

PHOTOGRAPHS
ROLL | FRAME

DISTANCE
TP n + 8 | TP n + 9

BANKFULL
WIDTH | DEPTH

TFW Ambient Monitoring

MASS WASTING AND SUBSTRATE

1. Indicate Turning Points adjacent to each Mass Wasting site or Bank Cutting site.
2. Refer to code reference sheet and field manual for codes and procedures.
3. Continue on additional FORM 3's as needed.

FORM 3

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page ___ of ___.

STREAM NAME (CIRCLE ONE ↓)	DATE	VALLEY SEGMENT	W.R.I.A. NUMBER	UNITS (CIRCLE ONE)	DISCHARGE (CIRCLE ONE ↓)
CREEK / RIVER	MO. / DAY / YR.		◯ UNLISTED	FEET / METERS	MEAS / EST

MASS WASTING

TURNING POINTS		LENGTH	WIDTH	TURNING POINTS		LENGTH	WIDTH	TURNING POINTS		LENGTH	WIDTH
DOWNST.	UPST.			DOWNST.	UPST.			DOWNST.	UPST.		

STREAM BANK CUTTING

TURNING POINTS		LENGTH	TURNING POINTS		LENGTH	TURNING POINTS		LENGTH	TURNING POINTS		LENGTH
DOWNST.	UPST.		DOWNST.	UPST.		DOWNST.	UPST.		DOWNST.	UPST.	

rev. 4/90

Continue on back of form.

1. Conduct Pebble Count only in riffle-class units and at intervals described in field manual.
2. Particle class codes are described on code-reference sheet.
3. Use mid-point, or B-axis, for particle class assignment.
4. Refer to code reference sheet and field manual for codes and procedures.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

TURNING POINTS

DOWNST.				UPST.			
0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9

SUBSTRATE CHARACTERIZATION (PEBBLE COUNT — 100 PARTICLES)

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

RIFFLE EMBED.

- ○ <5%
- ○ 5-25%
- ○ 25-50%
- ○ 50-75%
- ○ >75%

51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98	99	100
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2	2
3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4	4
5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5	5
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10

NOTES (Mass wasting, etc.):

TFW Ambient Monitoring

HABITAT UNIT DATA

FORM 4A

1. Use this form when beginning a survey of a new valley segment OR as the first form used each day to complete the survey of the valley segment.
2. Assign new date each day.
3. Continue recording habitat unit data on FORM 4B.
4. Measure depths to nearest 0.1 feet or 0.01 meters.
5. For paired units, the second record is used for actual measurements.
6. Refer to code reference sheet and field manual for codes and procedures.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page ...... of

STREAM NAME

DATE — DAY: 1–31; MONTH (SEE NOTE ABOVE): MAY, JUNE, JULY, AUG, SEPT, OCT, NOV; YEAR: 90, 91, 92, 93

VALLEY SEGMENT: W, V, H, U, F; 0–9; OFFICE USE ONLY 0–9

W.R.I.A. NUMBER: UNLISTED; 0–9

UNITS: FEET, METERS

DISCHARGE: MEASURED, ESTIMATED; 0–9

TURNING POINTS: DOWNST, UPST; 0–9

UNIT NUMBER: 0–9

UNIT TYPE: B C C, D D D, E F F, G G H, L K P, P Q R, R M W, S S, Y

UNIT CAT.: 1, 2, 3; MEAS.; EST.

LENGTH | WIDTH | DEPTH (1) | DEPTH (2) | OBS. | LOGS (SM., LG.) | ROOT WADS | WOOD LOCATION (A, B, C, D) | SERAL ST. (LB, RB) | LAND USE (LB, RB) | % CANOPY CLOSURE: 0–9

VEG TYPE: DEC, CON, MIX

rev. 4/90

Continue on back of form.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

UNIT NUMBER	4 digits	0 1 2 3 4 5 6 7 8 9
UNIT TYPE	3 columns	B C C / D D D / E F F / G G H / L K P / P L R / R M W / S S / Y
UNIT CAT.		1 2 3; MEAS.; EST.
LENGTH	5 digits	0 1 2 3 4 5 6 7 8 9
WIDTH	4 digits	0 1 2 3 4 5 6 7 8 9
DEPTH (1)	3 digits	0 1 2 3 4 5 6 7 8 9
DEPTH (2)	4 digits	0 1 2 3 (first digit); 0 1 2 3 4 5 6 7 8 9
OBS.	1 digit	0 1 2 3 4 5 6 7 8 9
LOGS	SM. (2 digits), LG. (2 digits)	0 1 2 3 4 5 6 7 8 9
ROOT WADS	2 digits	0 1 2 3 4 5 6 7 8 9
WOOD LOCATION	A, B, C, D (2 digits each)	0 1 2 3 4 5 6 7 8 9
SERAL ST.	LB, RB	0 1 2 3 4 5 6 7 8 9
LAND USE	LB, RB	0 1 2 3 4 5 6 7 8 9
% CANOPY CLOSURE	2 digits	0 1 2 3 4 5 6 7 8 9
VEG TYPE		DEC, CON, MIX

UNIT NUMBER | UNIT TYPE | UNIT CAT. | LENGTH | WIDTH | DEPTH (1) | DEPTH (2) | OBS. | LOGS SM. LG. | ROOT WADS | WOOD LOCATION A B C D | SERAL ST. LB RB | LAND USE LB RB | % CANOPY CLOSURE | VEG TYPE

UNIT NUMBER | UNIT TYPE | UNIT CAT. | LENGTH | WIDTH | DEPTH (1) | DEPTH (2) | OBS. | LOGS SM. LG. | ROOT WADS | WOOD LOCATION A B C D | SERAL ST. LB RB | LAND USE LB RB | % CANOPY CLOSURE | VEG TYPE

TFW Ambient Monitoring

HABITAT UNIT DATA (CONT'D)

FORM 4B

1. Date is carried from FORM 4A.
2. Measure depths to nearest 0.1 feet or 0.01 meters.
3. For paired units, the second record is used for actual measurements.
4. Refer to code reference sheet and field manual for codes and procedures.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

Page __ of ___

STREAM NAME (CIRCLE ONE ↓) CREEK / RIVER	DATE: MO. / DAY / YR.	VALLEY SEGMENT	W.R.I.A. NUMBER (○ UNLISTED)	UNITS (CIRCLE ONE) FEET / METERS	DISCHARGE (CIRCLE ONE ↓) MEAS / EST	TURNING POINTS: DOWNST. / UPST.

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	B	C	D	SERAL ST. LB	RB	LAND USE LB	RB	% CANOPY CLOSURE	VEG. TYPE
0–9	B C C / D D D / E F F / G G H / L K P / P L R / R M W / S S / Y	1 2 3 / ○ MEAS. / ○ EST.	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	○ DEC / ○ CON / ○ MIX

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	B	C	D	SERAL ST. LB	RB	LAND USE LB	RB	% CANOPY CLOSURE	VEG. TYPE
0–9	B C C / D D D / E F F / G G H / L K P / P L R / R M W / S S / Y	1 2 3 / ○ MEAS. / ○ EST.	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	○ DEC / ○ CON / ○ MIX

rev. 4/90

Continue on back of form.

Use a No. 2 pencil. Fill bubbles darkly and completely. Do not make stray marks.

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	B	C	D	SERAL ST. LB	SERAL ST. RB	LAND USE LB	LAND USE RB	% CANOPY CLOSURE	VEG. TYPE
0–9	B C C / D D D / E F F / G G H / L K P / P L R / R M W / S S / Y	1 2 3 / MEAS. / EST.	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	DEC / CON / MIX

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	B	C	D	SERAL ST. LB	SERAL ST. RB	LAND USE LB	LAND USE RB	% CANOPY CLOSURE	VEG. TYPE
0–9	B C C / D D D / E F F / G G H / L K P / P L R / R M W / S S / Y	1 2 3 / MEAS. / EST.	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	DEC / CON / MIX

UNIT NUMBER	UNIT TYPE	UNIT CAT.	LENGTH	WIDTH	DEPTH (1)	DEPTH (2)	OBS.	LOGS SM.	LOGS LG.	ROOT WADS	WOOD LOCATION A	B	C	D	SERAL ST. LB	SERAL ST. RB	LAND USE LB	LAND USE RB	% CANOPY CLOSURE	VEG. TYPE
0–9	B C C / D D D / E F F / G G H / L K P / P L R / R M W / S S / Y	1 2 3 / MEAS. / EST.	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	0–9	DEC / CON / MIX

APPENDIX C. USING VISUAL ESTIMATION IN A WATERSHED MONITORING STUDY

Loveday L. Conquest, Tamre P. *Cardoso, Kristy* D. Seidel, Stephen C. Ralph

Center for Quantitative Science

Center for Stream Side Studies, University of Washington

INTRODUCTION

Hankin and Reeves (1984) introduced a method to determine habitat area using visual estimation. The method involves estimating physical dimensions for all channel units in a segment of a stream and actually measuring only a subsample of these. The subsample with pairs of estimated and measured values allows the calculation of a ratio estimator representing the magnitude of observer bias. This method has greatest utility when observations are consistently biased either above or below the measured values.

The underlying assumptions for valid use of a ratio estimator as a correction factor are:

1) The data, consisting of paired estimated and measured units, follow a linear relationship passing through the origin.

2) The variance of the estimate increases proportionally with the size of the unit.

Currently there is much interest in monitoring/the condition of small stream fish habitat throughout the state. When undertaking such a large scale project, it is important to use sampling methods which maximize efficiency of data collection without sacrificing reliability. The Hankin and Reeves visual estimation technique is intended to accomplish this. The technique was developed and tested with a small group of highly trained and closely supervised observers.

In the Timber, Fish and Wildlife Ambient Monitoring Project (TFW/AMP), where the Hankin and Reeves technique was used in the collection of habitat area data, such stringent control could not be exercised. In order to assess how well the method performs in this setting, we examined data collected in 95 stream segments inventoried during the 1989 field season.

METHODS

Our analysis of the 95 stream segments was focused on how well the data fit within the assumptions required for a valid ratio estimator. The following three techniques were *used* to assess model fit.

1) Graphical display of each of the data sets from which a correction factor was generated.

2) Calculation of indicators of the strength of the linear relationship between paired data (r-squared; influence of outlying points)

3) Consideration of the effect of sample size on confidence in model fit and the precision of results.

RESULTS

Many of the data sets from which correction factors were generated resulted in poor model fit. The two main reasons for poor fit were the inability of callers to be consistent, and the small number of paired points in a subsample used to calculate a correction factor. The distribution of the number of paired observations is shown in Figure 1. Eighty-four percent of the paired measurements had less than 10 points. A minimum of 10 paired measurements is recommended for use in calculating correction factors.

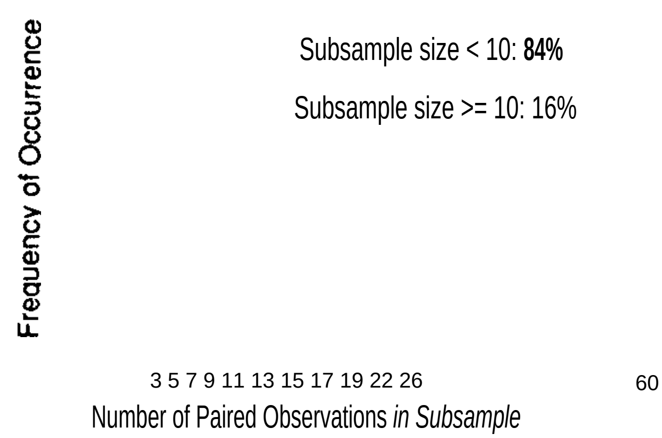

Figure l. Distribution of Sample Sizes

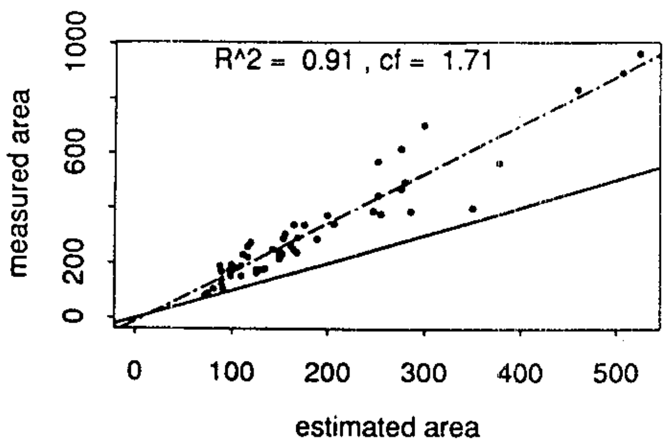

Figure 2. Estimates which conform well to the model

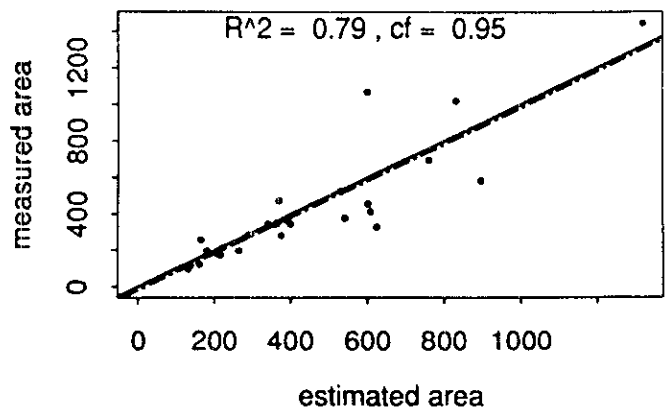

Figure 4. Over and under estimation.

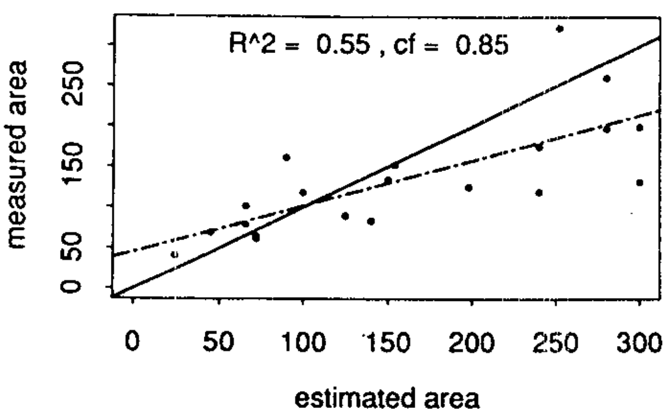

Figure 3. Highly variable estimates.

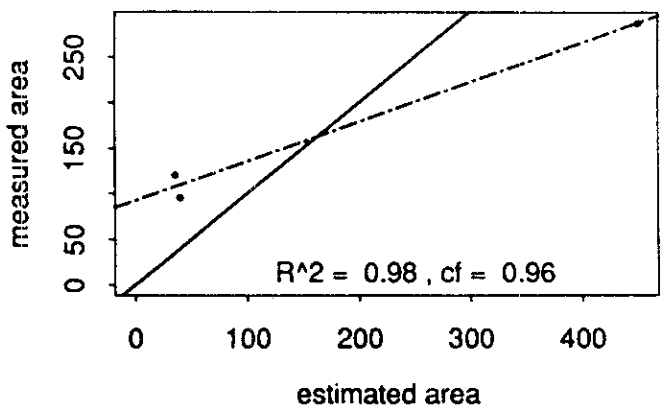

Figure 5. Correction factor generated from only three data points.

Figures 2 through 5 show representative examples of the various model fits for the analysis of the 95 stream segments. On each plot, the dashed line is the regression line through the points of paired measurements. The solid line is the theoretical estimated equals measured line. Points falling above the solid line indicate underestimation while points falling below the solid line indicate overestimation. "R^2" is the R^2 value which provides an indication of the strength of the linear relationship. The correction factor is denoted by "cf". A correction factor greater than 1 indicates that measurements were generally underestimated, while a correction factor less than 1 indicates that measurements were generally overestimated,

Figure 2 shows an example that conformed well to the Hankin and Reeves model. There were 52 paired measurements used to calculate the correction factor. The caller consistently underestimated habitat measurements. The paired measurements formed a good linear fit through the origin.

Figure 3 shows an example of highly variable estimates that resulted in poor model fit. Although there were 20 paired measurements used to calculate the correction factor, the caller was extremely inconsistent. The resulting data did not meet the basic linearity assumptions for a ratio estimator model

Figure 4 shows another example from an inconsistent caller. The caller both under and over estimated habitat areas and as a result, ended up with a correction factor (0.95) that had little effect. The under and over estimation basically cancelled ,out each other. The net effect of the correction factor was to cause an overall slight correction for overestimation.

Figure 5 shows an example of a correction factor generated from only three data points. Although the R-squared value (0.98) suggested a good linear fit, the linear relationship did not extend through (or close to) the origin. Further, the extremely overes-. timated point strongly influenced the linear fit. There is not enough data to determine whether or not the overestimated point was an outlier or a typical point.

CONCLUSIONS

The confidence in the accuracy of many habitat area estimates is low due to the small sample sizes used to compute correction factors. Many correction factors were based on four or less paired measurements. Cases of poor model fit were generally observer dependent and habitat type independent. Many observers had difficulty in consistently under or over estimating unit parameters.

The types of problems listed above occur, in part, as a consequence of the inherent difficulty with training and control on a large scale project.

RECOMMENDATIONS

The following recommendations are made based on the results of this analysis:

1) Provide more extensive and individualized training for field personnel.
2) Conduct follow-up sessions with crews to ensure that methods are being properly implemented.
3) Screen field crew applicants for their ability to consistently estimate physical dimensions, and for their availability to work the entire field season.
4) If the above measures cannot be implemented or prove insufficient to ensure reliability of the data, measure all habitat units.
5) Incorporate a quality assurance program as a part of regular data collection.

APPENDIX D. HIGH LEVEL VALLEY SEGMENT SUMMARIES

Segment level characteristics which allow comparison of all of the valley segment surveyed in 1989 and 1990 are included in this appendix. The following description will be helpful in interpreting the data.

- The year of the survey.

Ecoregion - Denotes the location of the segment in one of the following ecoregions: (1) Coastal including Olympic Peninsula, (2) Puget Lowlands, (4) Cascade Range (both East & West sides), and (8) Northern Rockies. The "A" and "B" designation refer to most typical and least typical of that region's character, respectively.

- This refers to bankfull width,

W/D - The width:depth ratio.

P/R - Refers to pool:riffle, although Pool / Riffle / Cascade ratio is also given.

Segment length - Total length of the segment based on horizontal control turning point distances. (NOTE: Some of these are in error because the surveyor coded in the measurement units incorrectly. These errors did not come to our attention until data were more carefully reviewed. Making these corrections will be done by going back to the original data sheet:, verifying the error and then editing the database.)

Bank Cutting - The length of bank cutting indicates the lineal length of both right and left banks showing significant erosion. Measured in meters.

Mean Canopy - Mean canopy closure expressed as a percentage.

Year	Segment Type	WRIA	Ecoregion	Order	Discharge (cfs)	Stream Name	BFW (m)	W/D	Logs per 1000 ft	Wads per 1000 ft	Mean Grad (%)	P/R	Pool /	Riffle /	Cascade	Seg Len (m)	Mass Wasting (m^2)	Bank Cutting	Mean Canopy
90	F2-1	13.0028	2 A	4	25.510	DESCHUTES	19.4	46.8	38	9	1.3	0.5	17818.2 /	33013.9 /	2259.7	4042	1840.0	2522	20.0
90	F2-1	21.0449	2 A	4	16.750	PRAIRIE	20.4	47.1	71	1	1.5	0.5	6561.2 /	12169.1 /	60.2	2452	1281.0	219	41.8
90	F2-1	17.0219	2 A	4	2.360	SNOW	28.3	14.9	5	0	1.4	0.5	6241.0 /	11049.5 /	1314.8	39337	315.0	337	79.9
89	F3-0	14.0012	2 A	3	0.000	KENNEDY Creek	12.7	31.6	34	7	0.9	2.0	3266.8 /	1534.5 /	59.5	938	0.0	63	55.3
89	F3-0	39.1378	4	2	0.000	W F TEANAWAY	13.4	19.4	7	5	2.6	0.3	18506.1 /	48985.5 /	5775.6	12272	654.0	992	18.3
89	F3-0	39.1351	4 B	2	0.000	M F TEANAWAY	13.9	15.1	6	4	2.1	0.3	10378.2 /	34234.3 /	2468.9	6869	2280.5	1371	21.3
89	F3-0	01.0264	2 A	0	0.000	HUTCHINSON Creek	14.1	14.6	18	0	1.3	2.0	5359.1 /	2327.6 /	308.8	1071	0.0	0	73.8
89	F3-0	20.0447	1 A	3	0.000	ELK Creek	16.4	8.4	43	3		4.1	5932.9 /	1394.8 /	36.9	1599	0.0	0	90.9
89	F3-0	21.0032	1 A	2	0.000	HURŠY	17.8	2.1	16	1	1.5	1.0	9470.0 /	7803.4 /	1278.8	6128	917.8	532	87.5
89	F3-0	19.9902		4	0.000	PYSHT River	20.0	15.7	17	0	1.2	0.8	13411.2 /	16730.3 /	173.1	2832	315.8	343	78.9
89	F3-0	01.0465	4 A	0	0.000	W CORNELL Creek	24.9	24.5	16	1	1.4	0.3	784.8 /	2823.5 /	44.4	592	0.0	7	30.4
89	F3-1	51.0046	8 B	2	0.000	NORTH STAR Creek	3.8	7.6	5	1	1.2	0.7	3287.0 /	4977.2 /	47.8	3391	1474.3	751	65.3
90	F3-1	20.0470 A	1 A	3	0.410	CANYON SPRINGS	5.1	15.3	9	0	0.8	40.0	2544.7 /	51.6 /	12.0	721	0.0	42	47.3
90	F3-1	52.0031 A	8 B	2	3.111	SNANAMPKIN	5.1	16.1	6	6	2.8	0.3	2089.7 /	1064.1 /	5107.4	2464	33.0	73	48.1
90	F3-1	14.0009	2 A	3	1.170	SCHNEIDER	5.4	14.7	11	1	2.0	7.9	5297.4 /	667.8 /	0.0	4079	1845.0	4578	60.1
90	F3-1	58.0170	8 A	2	2.880	HUNTERS	6.0	10.3	8	9	1.5	0.1	1839.3 /	19040.6 /	581.9	8280	0.0	0	45.0
90	F3-1	14.0020	2 B	4	3.150	SKOOKUM	6.2	19.8	24	14	3.3	5.2	50066.1 /	9531.7 /	188.0	10343	6759.0	9003	48.2
90	F3-1	13.0138	2 A	3	16.000	MCLANE	6.8	24.9	21	13	1.5	0.7	5514.5 /	7839.4 /	0.0	2448	325.0	2180	54.5
90	F3-1	20.0465	1 A	3	1.200	SPRUCE CREEK	6.8	24.9	8	1	1.2	4.1	1934.3 /	244.8 /	224.7	839	0.0	145	65.7
90	F3-1	39.1081	4 B	4	6.275	TANEUM MAIN	11.0	12.8	6	1	1.2	0.3	4255.7 /	12402.3 /	616.5	2277	313.0	362	51.7
91	F3-1	08.0351	1 A	3	2.368	MF TAYLOR	18.1	18.7	37	5	4.7	0.4	2155.2 /	1241.0 /	4057.9	1098	0.0	542	63.0
90	F3-1	13.0028	2 A	4	54.630	DESCHUTES	21.0	46.7	36	8	0.9	0.6	17010.2 /	26336.7 /	2068.3	3023	4576.0	1686	21.6
90	F3-1	17.0219	2 A	4	2.106	SNOW	27.3	20.0	5	0	1.0	0.4	3776.7 /	7646.8 /	1716.9	23020	0.0	93	78.8
90	F3-1	11.0067	2 A	3	10.250	TANWAX	27.5	12.0	4	1	2.5	11.9	100959.5 /	7967.9 /	483.9	6103	51.0	60	65.8
89	F4-0	58.0016	8 A	2	0.000	SIXMILE Creek	4.4	8.3	6	2	3.9	0.2	149.4 /	654.3 /	149.9	471	12.1	457	59.7
89	F4-0	04.0384	2 A	3	0.000	SAVAGE Creek	6.9	5.9	12	0	4.0	0.7	1016.9 /	1478.3 /	27.1	2093	180.0	81	91.2
89	F4-0	01.0465	4 A	0	0.000	W CORNELL Creek	12.5	12.0	15	1	4.1	0.2	1215.0 /	1282.2 /	4358.5	1517	0.0	200	58.0
89	F4-0	20.0447	1 A	3	0.000	ELK Creek	22.0	11.5	86	10	1.0	0.8	2270.4 /	834.3 /	1978.5	948	172.8	178	77.9
90	F4-1	52.0021 A	8 B	2	3.109	LOUIE	2.3	6.8	10	9	3.6	0.2	403.9 /	2029.5 /	329.1	2431	0.0	80	48.5
90	F4-1	58.0170	8 B	2	4.590	HUNTERS	4.3	7.3	3	1	2.7	0.7	15479.2 /	19387.3 /	2714.0	7041	1255.0	896	41.4
91	F4-1	08.0368	1 A	2	0.400	SF TAYLOR	6.4	9.1	57	15	2.7	2.5	2465.3 /	275.9 /	710.1	1069	162.0	1144	54.0
90	F4-1	13.0057	2 A	3	0.890	FALL	7.0	20.0	45	2	1.8	0.6	427.7 /	199.5 /	487.8	581	0.0	432	57.1
90	F4-1	52.0042 A	8 B	3	7.961	GOLD	8.4	11.9	4	4	2.0	0.1	1986.4 /	13497.5 /	7658.6	5158	0.0	0	35.2
91	F4-1	20.0530 A	1 A	3	18.000	UN NAMED	8.9	10.8	51	2	1.3	1.8	7082.9 /	3980.5 /	12.8	1893	0.0	356	59.0
91	F4-1	08.0351	1 A	3	3.180	MF TAYLOR	16.4	14.0	78	3	3.5	0.5	2841.6 /	1922.5 /	4052.8	1440	0.0	2233	47.0
89	F5-0	20.0505	1 A	2	0.000	E TWIN Creek	4.3	14.3	70	1	2.0	1.9	1061.6 /	549.5 /	2.6	764	421.7	319	81.1
89	F5-0	20.0448	1 A	3	0.000	ALDER Creek	8.8	20.9	109	3	1.5	1.3	2438.7 /	1935.8 /	11.5	791	139.3	399	72.0
90	F5-1	20.0509 A	1 B	2	0.200	SPRINGS	2.8	11.8	30	0	0.6	18.0	445.1 /	24.7 /	0.0	315	0.0	202	88.0
90	F5-1	20.0524	1 B	2	4.850	COUGAR	3.9	12.4	43	0	0.9	5.0	2812.8 /	557.9 /	0.0	912	0.0	806	64.0
90	F5-1	20.0471	1 B	3	2.300	IRON MAIDEN	5.4	23.0	21	0	0.7	0.3	140.1 /	458.6 /	2.9	232	0.0	32	89.7
90	F5-1	22.0400	1 B	4	9.000		7.0	30.1	27	2	1.5	0.3	564.6 /	1550.1 /	231.4	698	0.0	162	52.5
90	F5-1	20.0481	1 B	3	3.100	SHELTER CREEK	7.1	17.1	34	1	0.8	29.5	1682.4 /	57.1 /	0.0	588	0.0	285	65.0

Year	Segment Type	WRIA	Ecoregion	Order	Discharge (cfs)	Stream Name	BFW (m)	W/D	Logs per 1000 ft	Wads per 1000 ft	Mean Grad (%)	P/R	Pool /	Riffle /	Cascade	Seg Len (m)	Mass Wasting (m^2)	Bank Cutting	Mean Canopy
90	F5-1	20.0476	1 B	3	0.750	SPLIT CREEK	8.0	29.0	94	4	1.0	2.8	53.5 /	0.0 /	19.0	243	0.0	32	71.0
90	F5-1	22.0076 A	1 B	3	3.530	BRITTAIN	9.1	15.2	67	6	0.8	4.1	8169.9 /	1994.6 /	0.0	1317	691.0	296	74.3
91	H1-1	09.0181	1 A	3	2.009	CHARLIE	8.4	9.3	173	25	9.3	0.5	1156.4 /	217.4 /	2328.9	919	0.0	14	28.7
89	H2-0	39.1157		3	0.000	S F TANEUM	7.7	7.0	101	4	10.1	0.9	1831.3 /	577.2 /	1528.3	819	3405.7	122	63.9
89	H2-0	09.0222	4 B	3	0.000	CANTON Creek	9.5	6.8	14	1	13.3	0.0	79.9 /	56.3 /	9453.8	2641	320.5	5	14.5
90	H2-1	13.0138	2 A	3	16.000	MCLANE	5.5	18.3	18	2	3.5	0.1	340.5 /	308.1 /	4116.2	1531	964.0	243	48.5
89	H2-1	09.0206	4 B	1	0.000	CHARLEY Creek	7.3	6.1	29	1	12.4	0.0	171.9 /	28.4 /	4676.8	1624	1465.4	0	51.2
89	H2-1	13.0073	2 A	1	0.000	MITCHELL Creek	12.8	5.1	50	2	10.8	0.7	249.1 /	18.5 /	362.1	335	659.5	9	97.8
89	H2-1	09.0207	4 B	1	0.000	CHARLEY Creek	13.4	9.6	22	2	15.2	0.2	499.8 /	34.6 /	2973.4	782	0.0	0	16.3
89	H2-1	13.0069	2 A	2	0.000	MITCHELL Creek			0	0			0.0 /	0.0 /	0.0	2009	0.0	0	
89	H3-0	04.0384	2 A	2	0.000	SAVAGE Creek	7.1	18.4	8	0	29.5	0.1	60.9 /	0.0 /	764.1	971	0.0	0	87.2
89	H3-1	09.0205	4 A	2	0.000	CHARLEY Creek	6.4	4.3	37	2	24.7	0.1	87.7 /	11.6 /	1326.7	614	9846.7	106	46.4
89	H3-1	13.0073	2 A	1	0.000	MITCHELL Creek			55	2	14.3	0.2	33.8 /	0.0 /	179.9	138	260.1	21	96.8
89	M1-0	20.0506	1 A	2	0.000	W TWIN Creek	8.9	22.2	33	0	2.3	0.6	1919.6 /	2240.8 /	785.4	1588	520.2	386	67.3
89	M1-0	15.0400	2 A	2	0.000	SEABECK Creek	9.6	9.6	29	1	1.8	1.8	2780.7 /	1476.2 /	33.8	2361	223.0	1532	94.7
89	M1-0	20.0448	1 A	3	0.000	ALDER Creek	12.0	19.9	58	1	1.7	1.0	3757.5 /	3537.2 /	411.8	1809	0.0	0	74.1
89	M1-0	20.0451	1 A	4	0.000	WILLOUGHBY Creek	12.8		18	2	3.0	0.2	482.7 /	1735.4 /	747.4	762	278.7	176	39.3
89	M1-0	14.0012	2 A	0	0.000	KENNEDY Creek	13.5	25.9	67	4	1.4	1.0	4624.1 /	4642.4 /	16.0	1701	418.5	486	62.1
89	M1-0	19.0115	1 A	2	0.000	S FORK PYSHT	15.3	12.9	9	1	1.5	1.8	7558.2 /	3994.2 /	123.2	2330	3505.0	330	84.3
89	M1-0	20.0442	1 A	4	0.000	WINFIELD Creek	19.4	38.9	21	2	1.4	0.9	20901.1 /	22544.7 /	66.8	6043	13941.8	789	58.1
89	M1-0	09.0201	4 B	3	0.000	CHARLEY Creek	20.2	14.1	2	0	2.3	0.0	226.3 /	2818.4 /	1868.5	761	0.0	15	24.3
89	M1-0	21.0065	1 A	0	0.000	CHRISTMAS Creek	20.3	15.3	62	2	1.4	1.5	20745.2 /	12242.1 /	1881.0	4391	2773.3	2005	59.9
89	M1-0	20.0447	1 A	3	0.000	ELK Creek	21.1	12.5	91	1	2.8	0.9	3571.8 /	2275.9 /	1789.0	1446	490.0	598	86.6
89	M1-1	51.0046	8 A	2	0.000	NORTH STAR Creek	4.3	5.3	14	1	1.9	0.2	780.4 /	2980.1 /	219.8	1131	0.0	0	81.8
90	M1-1	13.0086	2 A	3	0.780	HUCKLEBERRY	5.4	27.0	120	13	2.3	0.5	1276.2 /	2153.1 /	347.8	1099	651.0	265	51.0
90	M1-1	13.0138	2 A	3	16.000	MCLANE	5.6	17.3	36	6	3.2	1.6	2166.1 /	1187.6 /	193.8	1599	566.0	1433	53.1
90	M1-1	15.0400	2 A	2	0.683	SEABECK	7.0	14.6	16	3	<.5	0.4	1352.5 /	3241.1 /	241.3	1340.9	120.0	298	86.7
90	M1-1	13.0089	2 A	4	0.460	JOHNSON	7.2	22.0	55	10	2.1	0.4	1042.2 /	2504.2 /	131.0	1192	137.0	734	71.2
90	M1-1	14.0020	2 B	0	2.760	SKOOKUM	7.3	24.3	52	2	3.0	0.6	1437.8 /	1136.7 /	1319.7	872	979.0	920	59.0
90	M1-1	13.0095	2 A	3	4.680	THURSTON	7.6	25.5	68	11	1.8	0.4	951.3 /	2386.4 /	286.1	783	108.0	556	62.4
91	M1-1	04.0786	1 A	2	2.800	ALL	8.1	11.5	69	1	3.2	0.4	392.7 /	389.4 /	547.8	893	0.0	498	
91	M1-1	03.0352	1 A	3	1.442	MUDDY	8.2	10.3	88	3	2.3	0.4	1853.1 /	2268.9 /	2199.5	1707	2992.0	2355	
91	M1-1	04.1157	1 A	3	10.500	PUMICE	8.3	16.5	288	1		1.7	1455.2 /	406.0 /	446.7	409	0.0	5	
90	M1-1	20.0470	1 B	2	1.187	CANYON	10.0	15.3	80	12	7.4	0.1	576.5 /	595.3 /	4375.0	1660	2100.0	37	77.2
90	M1-1	20.0459	1 B	2	0.569	TOWER	10.1	11.2	42	4	9.4	0.1	288.7 /	216.0 /	3764.3	1437	2490.0	385	81.4
91	M1-1	21.0462	1 A	2	8.000	WILLABY	10.3	10.7	55	8	1.9	1.3	2052.5 /	1128.2 /	512.6	649	0.0	159	64.3
90	M1-1	20.0476	1 B	3	0.560	SPLIT CREEK	10.7	35.7	11	0	9.3	0.0	0.0 /	0.0 /	405.3	219	79.0	21	27.0
90	M1-1	20.0506	1 B	4	4.200	TWINS	10.8	27.7	16	1	3.0	1.8	1086.8 /	566.7 /	28.8	1588	720.0	544	71.0
91	M1-1	14.0035	1 A	3	34.700	GOLDSBOROUGH	12.4	16.7	11	2	0.8	0.3	16103.4 /	41718.9 /	10667.5	6736	1593.0	0	53.0
91	M1-1	03.0359	1 A	3	9.291	ALDER	13.1	26.1	59	2	3.2	0.6	6442.2 /	4504.4 /	7055.5	2738	1816.0	3148	
90	M1-1	22.0076 A	1 B	3	3.530	BRITTAIN	14.5	24.1	43	4	0.8	2.9	4938.0 /	1654.7 /	42.5	764	1674.0	32	72.5
90	M1-1	52.0031 A	8 B	2	3.111	SNANAMPKIN	19.5	11.8	0	0	1.1	0.1	83.3 /	744.8 /	126.3	2878	0.0	21	47.0

Year	Segment Type	WRIA	Ecoregion	Order	Discharge (cfs)	Stream Name	BFW (m)	W/D	Logs per 1000 ft	Wads per 1000 ft	Mean Grad (%)	P/R	Pool /	Riffle /	Cascade	Seg Len (m)	Mass Wasting (m^2)	Bank Cutting	Mean Canopy
90	M1-1	15.0446	2 A	4	11.258	TAHUYA	27.8	11.4	15	4	0.7	0.9	9639.8 /	10137.9 /	304.4	3435	1046.0	554	62.2
90	M1-1	.	2 B	3	0.000	SKOOKUM TRIB			59	2		0.3	163.2 /	0.0 /	552.1	248	189.0	93	60.0
90	M1-1	14.0001	2 A	3	1.560	PERRY			21	1		0.4	744.0 /	388.3 /	1482.4	552	0.0	205	57.4
90	M1-2	13.0086	2 A	3	0.840	HUCKLEBERRY	4.4	26.2	92	12	2.4	0.4	1043.3 /	1070.1 /	1455.7	1031	136.0	641	35.2
90	M1-2	22.0076 A	1 B	3	2.910	BRITTAIN	9.3	27.4	53	5	0.7	3.9	20821.9 /	5238.8 /	63.3	4241	1244.0	328	85.1
89	M2-0	62.0547	8 B	3	0.000	TACOMA Creek	6.8	2.5	93	7	0.7	1.6	1352.4 /	812.2 /	26.8	137	0.0	0	57.0
89	M2-0	14.0012	2 A	0	0.000	KENNEDY Creek	11.6	22.8	118	10	1.2	2.1	10927.2 /	5010.9 /	120.8	2123	152.4	552	38.9
89	M2-0	19.9901		3	0.000	GREEN Creek	11.9	6.7	40	1	1.7	1.2	7608.0 /	6343.1 /	177.4	3075	833.3	443	46.9
89	M2-0	01.0264	2 A	0	0.000	HUTCHINSON Creek	13.3	9.9	3	1	0.9	0.5	737.9 /	1056.2 /	356.5	263	464.5	20	77.1
89	M2-0	19.0115	1 A	3	0.000	S FORK PYSHT	20.0	15.9	9	1	1.2	2.5	17881.2 /	7190.9 /	0.0	3164	1501.0	227	80.6
89	M2-0	21.0065	1 A	0	0.000	CHRISTMAS Creek	21.5	15.5	43	2	2.9	1.3	7091.4 /	4683.0 /	619.1	1409	46.4	310	45.5
89	M2-1	51.0046	8 B	2	0.000	NORTH STAR Creek	5.3	10.5	18	1	0.9	3.4	6333.1 /	1836.0 /	0.0	1503	0.0	3	49.3
90	M2-1	14.0001	2 A	3	1.560	PERRY	6.2	15.5	12	1	2.0	0.7	1647.5 /	1868.3 /	346.5	715	617.0	905	27.9
91	M2-1	04.1157	1 A	3	8.100	PUMICE	6.2	10.4	158	2	3.5	1.0	3115.7 /	1573.8 /	1594.8	1110	144.0	45	
90	M2-1	14.0020	2 B	4	2.760	SKOOKUM	6.4	32.0	33	3	2.0	1.7	5039.0 /	2595.2 /	448.8	2367	396.0	553	54.9
90	M2-1	13.0138	2 A	3	16.000	MCLANE	7.3	22.5	57	10	1.5	1.3	3964.6 /	3077.0 /	56.9	2171	431.0	1474	55.0
90	M2-1	22.0400	1 B	4	7.500		8.1	27.0	82	2	1.0	0.4	1937.1 /	4271.4 /	520.8	1532	6231.0	229	62.0
91	M2-1	15.0389	1 A	2		BIG BEEF CR	10.0	14.8	66	23	1.1	1.3	11598.1 /	8016.5 /	629.1	2868	0.0	218	70.7
90	M2-1	39.1081	4 B	4	10.860	TANEUM MAIN	10.1	13.4	6	1	1.3	0.3	13740.7 /	53904.6 /	1026.1	8194	5254.0	1302	38.4
90	M2-1	15.0356	2 A	1	1.040	GAMBLE	14.7	6.0	55	1	<.5	0.1	238.8 /	1747.0 /	0.0	879	216.0	0	93.0
89	M2-1	15.0420	2 A	3	0.000	DEWATTO River	15.3	14.7	65	7	1.3	2.5	20541.9 /	8110.6 /	38.5	3428	950.7	1075	62.1
90	M2-1	21.0449	2 A	4	13.950	PRAIRIE	17.2	30.4	57	2	1.2	0.4	7354.8 /	16050.1 /	344.2	3304	15612.0	40	44.5
90	M2-1	11.0067	2 A	3	10.250	TANWAX	23.5	17.4	27	2	2.0	0.5	2444.6 /	4534.3 /	622.1	1605	0.0	0	59.0
90	M2-1	15.0446	2 A	4	0.025	TAHUYA	23.9	15.1	5	1	1.3	1.6	8741.1 /	5377.3 /	132.8	14376	0.0	151	60.6
90	M2-1	13.0123	2 A	3	3.530	LINCOLN	38.8	25.0	46	5	4.5	0.4	3892.9 /	3866.7 /	6844.1	3143	3030.0	1098	51.0
90	M2-1	20.0248	1 A	3	2.850	DOWANS	39.6	28.3	38	4	2.0	0.9	8961.4 /	8367.9 /	1799.6	3387	2801.0	536	64.0
89	M2-2	15.0420	2 A	3	0.000	DEWATTO River	14.9	15.4	22	9	1.9	2.2	6422.8 /	2745.7 /	132.5	1389	180.0	564	69.4
89	M2-3	15.0420	2 A	3	0.000	DEWATTO River	13.0	13.6	42	2	2.5	3.9	4987.7 /	949.2 /	333.4	783	0.0	366	86.8
91	U1-1	46.0126	1 A	2	2.186	MAD	3.0	10.4	29	1	4.0	0.2	2788.3 /	7367.5 /	7842.3	1152	0.0	214	
90	U1-1	39.1128	4 B	2	7.070	NF TANEUM	7.9	11.8	37	2	3.1	0.3	1899.0 /	5463.1 /	86.3	1361	1473.0	302	48.3
90	U1-1	15.0446	2 A	4	0.438	TAHUYA	8.3	25.5	47	6	0.8	0.7	2198.5 /	3029.7 /	130.0	1268	0.0	0	79.9
90	U1-1	20.0509	1 B	3	1.450	509	10.7	40.1	36	2	1.2	3.0	1119.9 /	368.5 /	6.3	997	75.0	836	71.7
90	U1-2	39.1128	4 B	2	0.600	NF TANEUM	17.2	14.3	68	3	3.0	0.9	1240.4 /	1310.9 /	79.5	1657	0.0	94	45.6
89	U2-0	19.0115	1 A	2	0.000	S FORK PYSHT	13.1	10.8	5	1	1.3	5.8	12159.5 /	2097.4 /	0.0	2871	1723.0	107	94.0
90	U2-1	39.1128	4 B	2	12.010	NF TANEUM	24.2	17.3	74	5	1.0	0.8	2230.8 /	2305.4 /	567.7	932	0.0	0	12.6
90	U2-2	39.1128	4 B	2	5.580	NF TANEUM	10.4	15.6	129	4	1.4	0.7	3928.8 /	3946.9 /	1450.8	2209	0.0	0	43.9
90	U2-3	39.1128	4 B	2	2.400	NF TANEUM	15.7	11.6	118	1	2.0	0.6	1738.6 /	1260.8 /	1628.1	1415	0.0	0	33.8
89	U3-0	01.0465	4 A	0	0.000	W CORNELL Creek	14.5	9.3	3	0	4.9	0.1	484.2 /	24.3 /	3944.3	2107	1525.7	94	
90	U3-1	52.0042 A	8 B	3	11.666	WFORK	8.1	14.7	3	3	1.0	0.2	10544.4 /	37081.0 /	7069.7	7537	0.0	143	24.4
90	U3-1	52.0021 A	8 B	2	3.153	LOUIE	9.0	6.6	2	6	3.7	0.2	215.8 /	921.8 /	31.7	2108	0.0	37	66.4
91	U3-1	04.0786	1 A	2	1.455	ALL			97	11	7.5	0.4	443.5 /	245.2 /	890.1	427	0.0	125	
90	U4-1	52.0000	8 B	3	19.421	WEST FORK	9.4	21.0	1	1	1.5	0.2	1235.0 /	6246.0 /	729.1	1070	0.0	45	

Year	Segment Type	WRIA	Ecoregion	Order	Discharge (cfs)	Stream Name	BFW (m)	W/D	Logs per 1000 ft	Wads per 1000 ft	Mean Grad (%)	P/R	Pool	Riffle	Cascade	Seg Len (m)	Mass Wasting (m^2)	Bank Cutting	Mean Canopy
89	V1-0	20.0452	1 A	2	0.000	W F WILLOUGHBY	4.8	11.2	43	1	2.6	0.2	388.3	715.2	1138.9	1077	0.0	0	89.6
89	V1-0	13.0130	2 A	0	0.000	MINE Creek	6.2	12.5	353	4	4.9	1.4	743.8	162.8	374.5	423.3	0.0	38	50.0
89	V1-0	62.0547	8 A	3	0.000	TACOMA Creek	7.2	8.9	157	1	4.8	2.6	4020.8	794.4	780.9	320	0.0	285	70.6
89	V1-0	13.0126	2 A	3	0.000	W F DESCHUTES	7.4	14.6	334	6	3.1	1.3	7696.7	1969.2	4038.3	3629	2410.6	572	49.1
89	V1-0	09.0205	4 B	2	0.000	CHARLEY Creek	8.8	7.1	18	4	3.8	1.1	449.7	368.1	23.7	339	0.0	611	20.9
89	V1-0	19.9901		3	0.000	GREEN Creek	8.9	7.2	49	1	3.4	0.9	3115.8	3001.9	584.9	2400	1082.2	166	90.3
89	V1-0	13.0028	2 A	4	0.000	DESCHUTES River	9.2	17.7	76	6	4.3	0.5	9990.3	8887.1	11233.6	5037	2275.9	273	29.2
89	V1-0	01.0264	2 A	0	0.000	HUTCHINSON Creek	11.3	12.0	7	0	2.7	0.4	1493.8	1565.7	2381.7	807	0.0	0	82.4
89	V1-0	20.0451	1 A	3	0.000	E F WILLOUGHBY	11.5		24	1	2.6	0.1	526.2	1438.5	4028.0	1689	1616.4	289	76.3
89	V1-0	04.0384	2 A	3	0.000	SAVAGE Creek	11.9	11.1	20	1	6.9	0.2	687.6	2266.8	2215.8	1780	385.4	54	95.1
89	V1-0	14.0012	2 A	0	0.000	KENNEDY Creek	12.3	19.3	114	4	3.8	1.7	1480.8	416.6	432.0	609	0.0	14	51.1
89	V1-0	09.0201	4 B	3	0.000	CHARLEY Creek	25.2	16.8	4	0	3.5	0.0	160.9	5270.1	4117.8	1086	0.0	116	26.5
90	V1-1	58.0170	8 A	2	4.590	HUNTERS	3.4	1.6	6	0	3.0	1.0	197.5	70.7	136.9	241	210.0	0	45.6
90	V1-1	22.0079 A	2 B	2	0.150	ELWOOD	3.6	8.9	85	6	0.7	2.6	1886.6	713.5	0.0	2637	360.0	51	30.7
89	V1-1	51.0046	8 B	2	0.000	NORTH STAR Creek	4.7	8.1	20	0	4.0	0.3	709.8	1042.6	1398.7	1012	22.3	0	80.6
90	V1-1	13.0086	2 A	3	0.780	HUCKLEBERRY	5.2	17.3	98	5	2.3	0.3	368.9	476.8	664.1	516	447.0	264	28.4
90	V1-1	13.0124	2 A	2	2.690	LEWIS	5.2	11.1	108	9	2.5	0.4	773.2	937.2	1026.0	860	20.0	337	67.2
90	V1-1	11.0110	4 A	3	3.000	MASHEL RB TRIB	7.0	8.8	54	12	2.0	0.9	253.8	280.2	0.0	205	0.0	0	72.0
89	V1-1	39.1157	4 B	3	0.000	S F TANEUM	8.1	9.6	61	6	4.2	0.6	2062.8	1143.9	2219.7	1389	1635.0	226	57.6
90	V1-1	51.0046 A	8 B	2	1.810	UN NAMED TRIB	9.0	6.0	33	1	4.5	0.4	367.2	452.3	552.8	616	0.0	0	56.9
90	V1-1	39.1128	4 B	2	11.294	NF TANEUM	10.4	10.8	42	3	2.0	0.6	1896.4	2744.9	382.8	1073	0.0	32	56.4
91	V1-1	09.0181	1 A	3	3.430	CHARLEY	11.1	9.5	30	1	2.5	0.3	3805.1	91.3	12339.6	2391	1660.0	91	54.7
90	V1-1	52.0031 A	8 B	2	3.100	SNANAMPKIN	14.6	9.0	0	0	3.2	0.5	132.2	40.3	207.5	9550	0.0	0	40.6
89	V1-1	09.0201	4 B	3	0.000	CHARLEY Creek	15.4	12.3	16	1	3.8	0.3	662.2	1395.0	852.3	609	0.0	47	58.3
90	V1-1	17.0219	2 A	4	1.312	SNOW	26.2	21.1	15	0	0.8	0.3	2677.1	5403.2	2868.1	22617	4404.0	0	70.3
91	V1-1	39.1378	1 A	2	5.388	WF TEANAWAY	35.3	19.6	10	0	4.0	0.6	1675.0	1519.1	1179.8	902	20.0	0	48.0
90	V1-1	11.0101	4 A	3	9.260	MASHEL	40.1	30.8	19	2	1.8	0.5	10900.3	13893.9	7185.1	4456	446.0	209	40.6
89	V1-1	13.0069	2 A	4	0.000	MITCHELL Creek			28	3	5.8	0.6	1471.0	828.3	1742.6	893	5288.0	129	82.2
91	V1-1	04.1148	1 A	3	13.600	CAMP			174	7	6.0	0.4	2447.4	924.1	5787.9	1209	20507.0	675	20.0
90	V1-2	51.0046	8 B	2	6.520	NORTH STAR	3.5	7.0	38	5	5.0	0.4	404.9	118.7	783.7	557	0.0	0	65.9
90	V1-2	13.0086	2 A	3	0.900	HUCKLEBERRY	4.5	16.9	168	10	4.0	0.1	318.4	422.3	1781.1	870	10.0	872	54.0
90	V1-2	39.1128	4 B	2	12.010	NF TANEUM	7.7	15.4	90	4	1.2	1.3	5831.3	3345.9	1055.6	1769	0.0	0	60.5
89	V1-2	39.1157	4 B	3	0.000	S F TANEUM	8.1	20.3	111	2	6.2	0.9	1875.2	880.3	1227.3	1705	139.4	1501	70.4
89	V1-2	13.0069	2 A	3	0.000	MITCHELL Creek	9.1	6.1	16	3	7.7	0.4	567.9	309.8	1129.4	717	47.7	117	85.4
91	V1-2	09.0181	1 A	3	1.648	CHARLEY	9.9	15.2	150	5	3.5	0.5	2502.9	291.4	4633.1	1580	2808.0	235	69.5
91	V1-2	04.1148	1 A	2	5.300	CAMP	11.2	18.7	216	3	2.2	2.6	5284.8	1119.4	934.5	1231	21634.0	1230	55.0
89	V1-2	09.0201	4 B	3	0.000	CHARLEY Creek	21.9	12.5	10	0	2.9	0.1	1608.4	13248.3	2466.3	2003	487.7	0	47.3
90	V1-3	13.0086	2 A	3	0.900	HUCKLEBERRY	3.2	12.1	472	5	4.3	0.8	232.8	222.9	75.6	314	0.0	31	79.7
89	V1-3	09.0201	4 B	3	0.000	CHARLEY Creek	24.0	26.6	19	0	5.3	0.4	852.3	1125.4	1095.2	581	148.6	69	45.7
90	V1-3	51.0046	8 B	2	4.500	NORTH STAR			58	1		0.3	181.0	75.8	534.6	253	0.0	0	56.4
90	V1-4	51.0046	8 B	2	3.300	NORTH STAR	9.8	6.1	38	6	4.5	0.5	396.4	209.2	532.6	381	0.0	0	63.6
90	V1-5	51.0046	8 B	2	3.650	NORTH STAR			48	2		0.4	244.7	289.3	361.9	385	0.0	0	59.4

Year	Segment Type	WRIA	Ecoregion	Order	Discharge (cfs)	Stream Name	BFW (m)	W/D	Logs per 1000 ft	Wads per 1000 ft	Mean Grad (%)	P/R	Pool /	Riffle /	Cascade	Seg Len (m)	Mass Wasting (m^2)	Bank Cutting	Mean Canopy
89	V2-0	58.0016	8 B	2	0.000	SIXMILE Creek	4.0	8.0	6	0	3.8	0.1	272.1 /	623.6 /	1463.9	1271	363.1	137	78.5
89	V2-0	13.0130	2 A	3	0.000	MINE Creek	5.4	10.9	95	1	3.5	1.0	198.4 /	12.5 /	184.5	644	0.0	0	79.3
89	V2-0	39.1157	4 B	3	0.000	S F TANEUM	5.5	7.4	70	2	5.3	1.5	5326.2 /	1497.8 /	2010.5	3182	353.1	1435	70.4
89	V2-0	19.9901		3	0.000	GREEN Creek	6.7	6.4	110	0	8.4	0.8	370.7 /	58.7 /	420.9	256	175.6	35	93.3
89	V2-0	13.0129	2 A	2	0.000	HARD Creek	7.8	9.4	308	8	10.0	1.2	1311.7 /	151.0 /	913.6	869	4486.6	211	61.3
89	V2-0	01.0264	2 A	0	0.000	HUTCHINSON Creek	8.0	1.1	4	0	10.0	0.2	164.6 /	0.0 /	873.0	305	0.0	0	87.2
89	V2-0	01.0465		3	0.000	W CORNELL Creek	10.1	7.6	6	0	12.3	0.2	258.9 /	53.2 /	1261.7	1114.9	58850.0	0	9.0
89	V2-0	04.0384	2 A	3	0.000	SAVAGE Creek	10.2	10.5	8	0	15.3	0.0	50.9 /	0.0 /	1285.5	1007	397.0	0	83.3
89	V2-0	09.0222	4 A	3	0.000	CANTON Creek	11.9	9.6	14	0	9.3	0.0	241.6 /	166.1 /	9732.8	1777	508.1	51	47.3
89	V2-0	10.0122	2 A	4	0.000	GREENWATER River			2	3		0.2	5898.1 /	23193.2 /	1781.5	10937	0.0	0	
89	V2-1	51.0046	8 B	2	0.000	NORTH STAR Creek	5.5	9.2	36	0	4.7	0.2	337.0 /	282.9 /	1165.1	532	0.0	0	79.2
90	V2-1	13.0125	2 A	2	0.480	BUCK	6.6	13.2	157	20	4.5	0.1	274.0 /	77.2 /	2400.6	715	165.0	212	27.1
90	V2-1	13.0128	2 A	3	0.190	WARE	8.0	13.3	146	14	3.0	0.4	709.8 /	360.8 /	1433.1	712	36.0	145	27.0
89	V2-1	13.0069	2 A	3	0.000	MITCHELL Creek	11.9	23.8	22	1	9.5	0.3	278.8 /	459.0 /	612.5	303	3325.6	12	89.1
91	V2-1	09.0181	1 A	3	2.550	CHARLEY	12.1	15.1	76	3	4.2	0.6	1679.0 /	414.3 /	2347.4	892	0.0	11	61.7
89	V2-1	09.0206	4 B	2	0.000	CHARLEY Creek	13.6	9.2	16	0	7.3	0.1	269.4 /	230.3 /	2677.8	920	139.3	33	59.0
89	V2-1	13.0073	2 A	2	0.000	MITCHELL Creek	13.6	11.3	20	3	11.3	0.5	958.7 /	423.2 /	1590.6	1135	1912.6	71	97.7
91	V2-1	21.0469	1 A	2	5.100	ZIEGLER	17.4	12.1	92	11		0.3	639.1 /	0.0 /	2480.3	493	0.0	0	56.7
89	V2-1	13.0072	2 A	0	0.000	MITCHELL Creek			22	0	14.6	4.0	42.6 /	0.0 /	10.6	126	0.0	0	98.5
90	V2-1	13.0095	2 A	3	4.380	THURSTON			54	4	3.0	0.5	1275.6 /	1853.4 /	491.5	1195	351.0	827	36.3
91	V2-2	09.0181	1 A	3	2.550	CHARLEY	10.5	19.7	244	8	4.7	0.7	1116.8 /	98.8 /	1511.1	828	306.0	61	66.7
89	V2-2	13.0072	2 A	2	0.000	MITCHELL Creek	13.3	17.7	25	0	11.4	0.2	171.6 /	243.2 /	619.0	312	20.9	9	94.3
90	V2-2	51.0046	8 B	2	3.300	NORTH STAR			34	0		0.4	168.3 /	17.1 /	430.5	214	0.0	0	62.7
90	V2-3	51.0046	8 B	2	1.230	NORTH STAR	9.0	9.3	43	1	7.3	0.3	288.4 /	202.7 /	750.3	706	0.0	0	63.7
90	V3-1	13.0086	2 A	3	0.840	HUCKLEBERRY	5.2	26.0	111	9	2.5	0.7	653.8 /	237.9 /	757.5	497	1935.0	139	39.2
90	V3-1	22.0076 A	1 B	3	3.030	BRITTAIN	10.7	22.7	29	1	2.4	1.3	3830.5 /	2261.9 /	642.6	1300	74.0	15	79.9
91	V3-1	39.1378	1 A	2	7.257	WF TEANAWAY	44.0	10.5	5	1	4.3	0.7	1098.3 /	378.1 /	1151.4	588	0.0	0	52.0
90	V3-1	14.0001	2 A	3	1.560	PERRY			57	2		0.2	242.0 /	474.1 /	596.8	276	0.0	37	55.5
91	V3-2	39.1378	1 A	2	4.260	WF TEANAWAY			7	0	3.5	1.0	533.4 /	153.8 /	401.7	255	0.0	0	16.0
89	V4-0	58.0016	8 B	2	0.000	SIXMILE Creek	5.2	4.2	7	2	2.7	0.5	977.9 /	1942.1 /	207.8	2597	1172.8	325	56.4
89	V4-0	62.0547	8 B	3	0.000	TACOMA Creek	6.8	8.4	250	2	2.8	2.7	12466.5 /	4543.0 /	43.4	865	0.0	1861	43.2
89	V4-0	39.1351	4 B	2	0.000	M F TEANAWAY	14.6	18.5	6	6	2.2	0.2	1257.8 /	6524.3 /	738.8	925.1	0.0	253	20.9
89	V4-0	01.0264	2 A	0	0.000	HUTCHINSON Creek	15.9	13.8	3	0	2.6	0.1	1754.0 /	19705.9 /	1069.2	1667	0.0	0	78.6
89	V4-0	19.0113	1 A	0	0.000	PYSHT River	17.7	15.2	102	1	1.5	2.9	32215.2 /	10595.6 /	558.0	5254	665.2	4163	84.3
89	V4-0	10.0122	2 A	4	0.000	GREENWATER River			26	4		0.3	6676.5 /	19555.7 /	2022.0	2340	13100.0	75	
89	V4-1	51.0046	8 B	2	0.000	NORTH STAR Creek	3.4	4.9	12	1	4.7	0.3	355.8 /	859.8 /	202.5	534	0.0	0	83.9
91	V4-1	17.0034	1 A	2		S FORK TUNNEL	5.2	9.4	104	3	2.8	1.3	1570.1 /	1108.2 /	142.4	714	0.0	81	
91	V4-1	45.9999	1 A	3	6.023	MISSION	5.2	10.9	19	1	3.4	0.2	1897.4 /	5293.9 /	7104.9	4224	1538.0	4189	53.6
90	V4-1	11.0110	4 A	3	2.000	MASHEL RB TRIB	7.5	13.0	69	5	7.6	0.2	528.2 /	1668.9 /	717.0	930	0.0	8	90.6
90	V4-1	52.0042 A	8 B	3	7.961	GOLD	7.7	8.9	5	5	2.0	0.0	555.1 /	10861.5 /	2316.7	2094	0.0	0	21.5
90	V4-1	39.1128	4 B	2	4.880	NFT ANEUM	8.0	12.6	72	7	1.9	0.7	3806.5 /	4722.0 /	377.0	1923	144.0	212	68.1
89	V4-1	39.1157	4 B	3	0.000	S F TANEUM	9.6	12.5	49	10	3.3	0.5	4194.1 /	3741.4 /	5253.2	3282	1435.2	63	56.0

Year	Segment Type	WRIA	Ecoregion	Order	Discharge (cfs)	Stream Name	BFW (m)	W/D	Logs per 1000 ft	Wads per 1000 ft	Mean Grad (%)	P/R	Pool /	Riffle /	Cascade	Seg Len (m)	Mass Wasting (m^2)	Bank Cutting	Mean Canopy
90	V4-1	39.1081	4 B	4	7.950	TANEUM MAIN	10.7	11.6	6	1	0.9	0.3	2266.5 /	8314.2 /	225.3	3238	492.0	519	45.4
90	V4-1	11.0114	4 A	3	0.000	BUSYWILD	11.0	21.3	0	0	3.6		0.0 /	0.0 /	0.0	1061	0.0	338	
91	V4-1	04.1148	1 A	3	9.400	CAMP	11.0	27.5	162	1	2.0	0.9	4779.9 /	1178.5 /	4310.2	1291	4217.0	1084	
91	V4-1	39.1378	1 A	2	4.475	WF TEANAWAY	13.4	10.1	10	0	3.1	0.4	2693.0 /	4854.6 /	1724.8	1481	2625.0	38	27.0
90	V4-1	15.0356	2 A	1	1.000	GAMBLE	13.8	8.3	68	1	1.0	0.7	365.0 /	561.3 /	0.0	799	0.0	0	69.7
89	V4-1	13.0072	2 A	3	0.000	MITCHELL Creek	18.5	20.8	16	4	7.3	0.1	3533.7 /	1569.7 /	25684.6	1449	812.9	390	95.1
89	V4-1	13.0069	2 A	4	0.000	MITCHELL Creek	22.6	20.2	17	2	3.9	0.4	1793.2 /	2867.4 /	2158.4	1588	1133.4	280	85.8
89	V4-1	13.0073	2 A	0	0.000	MITCHELL Creek	23.8	26.4	11	1	10.0	0.5	434.4 /	105.2 /	781.8	493	0.0	0	96.4
90	V4-1	17.0219	2 A	4	2.296	SNOW	27.7	18.5	14	0	0.8	0.2	1649.8 /	7946.7 /	1717.0	24704	1641.0	21	85.9
89	V4-2	51.0046	8 B	2	0.000	NORTH STAR Creek	4.5	6.9	32	2	3.1	1.1	2850.3 /	1774.6 /	845.7	1436	0.0	0	67.7
91	V4-2	04.1148	1 A	2	4.600	CAMP CR	7.3	14.6	144	2	0.8	4.2	3685.3 /	795.9 /	85.8	639	0.0	213	
89	V4-2	39.1157	4 B	3	0.000	S F TANEUM	8.0	11.4	72	5	2.4	7.5	20045.7 /	2507.2 /	169.1	3361	200.6	537	57.1
90	V4-2	39.1128	4 B	2	3.545	NF TANEUM	8.7	12.6	57	8	1.9	0.5	6346.1 /	11748.8 /	1003.2	3389	6956.0	856	68.7
90	V4-2	39.1081	4 B	4	4.760	TANEUM MAIN	13.8	15.2	23	5	1.0	0.7	9625.3 /	13511.6 /	130.5	2596	1773.0	165	51.4
91	V4-2	39.1378	1 A	2	4.260	WF TEANAWAY			5	0	2.3	0.5	1989.9 /	1912.1 /	2040.6	803	14.0	0	
90	V4-3	51.0046	8 B	2	6.520	NORTH STAR	4.4	11.0	52	3	4.5	0.3	526.0 /	416.5 /	1097.2	614	0.0	0	61.0
91	V4-3	04.1148	1 A	2	5.300	CAMP	8.4	18.1	217	5	1.8	2.3	2438.0 /	679.1 /	364.7	592	2370.0	738	
90	V4-3	39.1128	4 B	2	27.490	NF TANEUM	9.1	22.8	126	2	1.5	0.7	1774.2 /	1356.9 /	1260.6	768	0.0	12	65.0
91	V4-3	39.1378	1 A	2	4.260	WF TEANAWAY	12.2	18.3	1	0	2.7	0.5	768.3 /	493.2 /	1173.1	842	0.0	0	54.0
90	V4-4	51.0046	8 B	2	2.950	NORTH STAR	15.0	10.7	35	5	4.0	0.5	351.7 /	305.7 /	441.0	439	0.0	0	69.8