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Cooperative Monitoring, Evaluation & Research (CMER)

ABSTRACTS

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Evaluation & Research (CMER)

Abstracts

TFW-AM9-94-001	TFW Ambient Monitoring Program Manual - Modules: Stream Segment Identification, Reference Point Survey, Habitat Unit Survey, Large Woody Debris Survey, Salmonid Spawning Gravel Composition, Stream Temperature, Quality Assurance August 1994, Edited by Dave Schuett-Hames, Allen Pleus, Northwest Indian Fisheries Commission. **(76)**
TFW-AM9-94-002	TFW Ambient Monitoring Program, 1993-94 Status Report, Dave Schuett-Hames, Allen Pleus, Dennis McDonald, Northwest Indian Fisheries Commission. **(79)**
TFW-AM9-96-001	Spawning Gravel Scour: A Literature Review and Recommendations for a Watershed analysis Monitoring Methodology. Dave Schuett-Hames, Bob Conrad, Allen Pleus, Northwest Indian Fisheries Commission, February 1996. **(82)**
TFW-AM9-96-002	Salmonid Spawning Habitat Availability: A Literature Review and Recommendations for a Watershed Analysis Monitoring Methodology. Dave Schuett-Hames, Allen Pleus, Northwest Indian Fisheries Commission, February 1996. **(83)**
TFW-AM9-96-003	Watershed Analysis Monitoring: Pilot Project Evaluation. Dave Schuett-Hames, Allen Pleus, Northwest Indian Fisheries Commission, February 1996. **(84)**
TFW-AM9-96-004	Winter Habitat Utilization by Juvenile Salmonids: A Literature Review. Amy Morgan, Northwest Indian Fisheries Commission, Frank Hinojosa, Grays Harbor College, February 1996. **(85)**
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TFW-AM14-94-001	A Strategy to Implement Watershed Analysis Monitoring: Assessment of Parameters and Methods, Monitoring Module Outline, Recommendations for Program Development, Dave Schuett-Hames and George Pess, Northwest Indian Fisheries Commission, May 1994. **(72)**
TFW-AM14-94-002	User Instructions: Sediment Sampling Application, Rbase Ver 1.2, Anita Sparks and Dave Schuett-Hames, June 1994. **(73)**
TFW-F3-92-001	Assessment of Cumulative Effects on Salmonid Habitat: Some Suggested Parameters and Target Conditions, N. Phil Peterson, Andrew Hendry, Dr. Thomas P. Quinn, March 2, 1992. **(46)**

TFW-F3-94-001	The Effect of Forest Practices on Fish Populations, Final Report, Dr. Thomas P. Quinn, N. Phil Peterson, May 1994. **(71)**
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TFW-IM-91-001	Information Management Coordination Project: Report to TFW Administrative Committee, Dan Cantrell, Peter T. Haug, June 30, 1991. **(24)**
TFW-SH1-92-001	Effects of Forest Cover On Volume of Water Delivery to Soil During Rain-On-Snow, Final Report, Bengt A. Coffin and R. Dennis Harr, July 30, 1992. **(54)**
TFW-SH5-91-001	Literature Search of Effects of Timber Harvest To Deep-Seated Landslides, Thomas E. Koler, June 1991. **(32)**
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TFW-SH9-91-001	Analysis of Initiation Mechanisms of Dam-Break Floods in Managed Forests, Carol Coho, Stephen J. Burges, July 1991. **(33)**
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TFW-WQ1-92-001	Proposed Surface Water Criteria for Selected Pesticides Used for Forest Management and Management of Forest Tree Seedling Nurseries and Christmas Tree Plantations in Oregon and Washington, Logan A. Norris and Frank Dost, August 20, 1992. **(60)**
TFW-WQ1-93-001	Effectiveness of Best Management Practices For Aerial Application of Forest Pesticides, Ed Rashin, Craig Graber, October 1993. **(64)**
TFW-WQ3-90-006	Evaluation of Prediction Models and Characterization of Stream Temperature Regimes in Washington, December 1990. **(2)**
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TFW-WQ11-92-001	TFW Ecoregion Bioassessment Pilot Project, Plotnikoff and Dietrich, Interim Report, July 1992. **(53)**
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TFW-000-89-007 **An Analysis of Program Integration and Development - Jim Currie, September 1989.**

Program integration can be defined as the degree to which elements of a program come together to comprise a clear, coherent whole, oriented and aligned to achieve assumed program objectives. In order for a program to be well-integrated, it must be thematically consistent, procedurally well-defined, and efficiently coordinated.

Over the course of this study, these criteria were applied in assessing CMER functions and products. The analysis, though limited in scope and duration, attempted to define key issues and program needs. It began with two important recognitions: that program integration should be viewed as a necessary but insufficient condition for program success. (A program can be well-integrated but still ineffective.) Equally important, CMER is only one element of a larger program--the TFW program, and that coherence, coordination and consistency in monitoring, evaluation and research should not be viewed in isolation.

Adaptive management, as explained in this report, is a relatively well-structured and disciplined approach to resource management and environmental assessment. It means more than simply refining resource management based upon experiment and better information. The literature on resource management characterizes it as consisting of a number of key analytical, monitoring and management components. Critical to adaptive management is a probing for appropriate policy balances between resource use and protection. The probing, however, is guided by a careful consideration of feedback from the natural environment so that each experiment can be interpreted as to actual effect.

Equally ambiguous and needing just as much clarification is TFW responsibility for implementing flexible management, and relatedly, CMER's responsibility for supporting it. Flexible management is never defined in the Agreement, but based upon context of use, it appears to mean a management system that attempts to fit resource use and protection to resource sensitivity. This may be realized through the development and application of a variety of interpretive and prescriptive tools, including but not limited to state-wide regulations.

In order to facilitate this, an attempt was made to crystallize a program framework that would combine elements of both adaptive and flexible management and otherwise bring the program into alignment with the TFW Agreement. The hypothesized approach, would reorient the program toward the evaluation and development of prescriptive and interpretive tools (including elements of the Forest Practices Act). CMER (and TFW) needs to establish a planning framework that defines expected functions, responsibilities and standards by which both internal and external products will be evaluated. It is equally critical that CMER carefully consider whether it can continue to administrate a program of the current and projected magnitude without incorporation and without at least some full-time professional staff.

TFW-000-91-001 **TFW - Cooperative Monitoring, Evaluation and Research Program Workplan, May 1991.**

TFW-000-93-002 **TFW - Cooperative Monitoring, Evaluation and Research Workplan Status Report, September 1993.**

TFW-000-94-001 **1993 Riparian Management Zone Survey; TFW Field Implementation Committee, June 20, 1994.**

The TFW Field Implementation Committee was requested to evaluate compliance to the Washington State Forest Practices regulations (WAC 222) within the Riparian Management Zone (RMZ). Ninety-four (94) sites were randomly sampled from all Forest Practices Applications submitted in 1990 and 1991. These sites were surveyed from July to October 1993 for compliance to all regulations pertaining to the RMZ. Seventy-four sites (79%) had no violations, 4 sites had major violations, 9 sites had significant violations and 7 sites had minor violations. Violations included operational violations, buffer width violations and leave tree violations (i.e., leave tree counts, leave tree size, conifer/deciduous ratios). The minimum RMZ was entered in only 28 of 86 western Washington sites. One-half (50%) of these 28 sites had violations. However, many RMZ widths were much wider than the minimum required by Forest Practices regulations.

In addition to a compliance survey, the incidence of RMZ tree blowdown was evaluated. Seventy-five of 91 sites (82%) had less than 11% of the RMZ trees blown down. Only one site exceeded 50% blowdown.

TFW-000-94-002 **CMER Research and Status Reports with Abstracts, 1988-1993, Prepared by Northwest Indian Fisheries Commission and Washington Department of Natural Resources, October, 1994.**

This document.

TFW-003-88-001 **Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat - 1988 Field Report.**

This report summarizes the 1988 field season of the Cooperative, Monitoring, Evaluation, and Research Committee research project #3 titled: "Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat".

TFW-003-90-003 **Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat - 1989 Field Report.**

This report summarizes the 1989 field season of the Cooperative, Monitoring, Evaluation, and Research Committee research project #3 titled: "Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat". In December of 1990 the Wildlife Steering Committee decided that a final report should not be produced for the 1989 field season. Instead, a summary of the 1988 and 1989 data is presented in this report. The Wildlife Steering Committee approved this report with limited editing. A cumulative report is available (TFW-WL1-91-001.)

TFW-003-90-005 **Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat - Field Procedures Handbook, May 1990.**

Description - May 1990

Work consisted of locating, establishing, and measuring physical characteristics within strip sample sites (macro plots and subplots) of Riparian Management Zones (RMZs) and Upland Management Areas (UMAs), with respect to wildlife habitat. Data was recorded on several types of field cards. The project provided a detailed information base for documenting the physical and botanical characteristics of RMZs and UMAs. Macro plots were used for measurements and tallies of sound trees, snags, and stumps. Macro plot strips were located as described in Section II. Rectangular subplots were used to measure the percentage of the shrub and the percentage of the herb canopy closure, as well as the percentage of ground cover (including downed woody material). Subplots were 5 x 10 feet and located every 10 feet along the strip centerline as described in section III. Stream measurements consisted of stream depth, width, gradient, flow direction, substrate (bed) material, large organic debris (LOD), and canopy closure as described in section IV.

TFW-009-89-005 The Effect of Elevated Holding Temperatures on Adult Spring Chinook Salmon Reproductive Success - Interim Final Report - Berman, Quinn, June 1989.

Information regarding the effects of elevated temperature on the behavior and reproductive success of spring chinook salmon is lacking. Adult spring chinook salmon enter freshwater in spring, and thus are susceptible to temperature extremes prior to spawning. While daily and seasonal fluctuations in temperature are natural characteristics of rivers, logging practices can exaggerate these fluctuations exposing mature spring chinook salmon to potentially harmful temperatures. The acute effects of elevated temperature on fishes have been well documented. However, information on the effect of long-term exposure of salmonids to sub-lethal temperatures is scarce. Recent findings suggest that alterations to tissue and blood chemistry and egg viability and survival may occur in association with prolonged exposure to elevated temperatures.

A two phase study was designed to investigate the possible link between timber harvesting practices and spring chinook salmon reproductive success. The objective of the study is three-fold: a) to characterize the thermal regimes historically tolerated by spring chinook salmon and to model the likely effects of forest practices on their success, b) to determine if temperatures experienced by adult spring chinook salmon prior to spawning influence reproductive success, and c) to determine if adult spring chinook salmon are capable of behaviorally regulating their internal temperature. Phase I, a pilot study to determine if temperatures experienced by adult spring chinook salmon prior to spawning influence their reproductive success, was completed during fiscal year 1988 (July 1, 1988 - June 30, 1989). The pilot study was conducted to assess potential problems in the Phase II adult holding study experimental design and methodology. Study site selection for the Phase II holding study and the radio telemetry study was also completed during this period. A literature and historical study to characterize the thermal regimes historically tolerated by spring chinook salmon will be ongoing throughout the study.

The pilot study was conducted at the Kalama Falls State Hatchery and the Weyerhaeuser Company's Kalama Springs facility. Twenty adult spring chinook salmon were selected from the Kalama Falls State Hatchery and were divided equally into a warm (10.0- 16.7° C) temperature treatment group maintained at the hatchery and a cool (4.4 - 6.0 C) temperature treatment group maintained at the springs. Upon reaching sexual maturity, fish from both temperature treatment groups were spawned. Unfertilized eggs and milt were transported to the University of Washington where the eggs were fertilized and incubated. The incubation unit was maintained at constant temperature to ensure the expression of only pre-spawning thermal effects. Rate of egg development, developmental stage at egg mortality, egg weight and volume, occurrence of developmental abnormalities, and hatching rate were recorded.

Interpretation of results from the pilot study was complicated by the presence of several confounding variables. Therefore, statistical analysis of the data was not deemed appropriate. However, qualitative analysis is provided. The pilot study provided useful information regarding the experimental design and methodology to be used in the Phase II adult holding study. Study site selection was determined to be the primary factor affecting the success of the holding study. Priest Rapids State Hatchery was chosen as the study site because it provides access to water of both elevated and non elevated temperatures that can be mixed to provide similar water quality in each treatment group. In addition, the Yakima River was chosen as the radio telemetry study site. Due to adjustments made to the experimental design during Phase I, the adult holding study should provide meaningful results that when combined with historical and tracking data and the temperature models will allow one to predict whether sites will experience sufficient post-logging warming to endanger the reproductive success of spring chinook salmon.

TFW-012-89-002 Sediment Dynamics in Type 4 and 5 Waters, A Review and Synthesis, June 1989.

PTI Environmental Services reviewed existing literature and interviewed regional experts regarding the status of sediment dynamics of Type 4 and 5 Waters, specifically those occurring in headwater portions of drainage basins. Field managers and other TFW participants were queried through a questionnaire and workshop regarding regional variations in sediment dynamics and the effects of forest practices on these streams. Sediment dynamics in these small channels are difficult to understand, requiring a thorough integration of local and discontinuous hillslope and fluvial processes. Much is known about the general patterns and magnitudes of sediment input to and sediment production from small channels. Less is known about the range of actual fluvial transport mechanisms in these channels. Storage and transport processes within the channel are both fluvial and nonfluvial in nature. Understanding these processes is important, because predicting sediment loads in larger channels requires quantifying the stochastic nature of sediment supply input from upstream. This report summarizes existing information on sediment dynamics in headwater channels and notes information and baseline data gaps that must be resolved within the TFW process .

Conclusions

Where runoff is exclusively derived from precipitation falling as rain, increases associated with logging or roading do not appear to be near the magnitude required to increase total geomorphic work without significant basin disturbance from roads and skid trails. Alteration in the seasonal timing of flood peaks (including those less than the annual flood) may alter routing of fine sediment (sand, silt, and clay) through headwater channels to fish-bearing streams. This effect may or may not be detrimental to fish, depending upon local conditions (Everest et al. 1987). Studies of snowfall-dominated systems, however, point to two very different and important conclusions. First, the longevity of the effect and the relative insensitivity to amount of the watershed disturbed indicate that altered snowmelt dynamics between clearcuts and forested land are responsible for increases in peak flows, while decreased summer evapotranspiration is significant in increasing low flow and total annual yield conditions. Second, increases in peak flows of 20 percent could be sufficient to entrain more of the fluvial sediment load, assuming the bankfull discharge threshold observed by Sidle (1987) holds upstream. In areas not dominated by mass wasting, such as the Okanogan Highlands, this is potentially a significant alteration to the sediment routing system that should be more fully investigated with detailed measurements of fluvial sediment transport in headwater channels.

Conclusions

Average residence time of LOD in headwater stream channels ranges from 36 to around 90 years, with that of individual pieces exceeding 100 years under natural conditions on the western Pacific slope of British Columbia, Washington and Oregon and therefore influences the channel on a time scale that may be considered geologic (Swanson and Lienkaemper 1978; Lienkaemper and Swanson 1987; Hogan 1987; Bisson et al. 1987). What little information is available suggests that the residence time of LOD in small channels is shorter in drier forests (Megahan 1982), however, this should be better constrained with data. Larger pieces of LOD provide immediate structure to headwater channels following debris flows, but controversy exists over the actual size required for stability within the channel, to provide sufficient organic material retention, and to aid recovery (Speaker et al. 1984; Robert Bilby, 13 March 1989, personal communication; Stanley Gregory, 10 April 1989, personal communication). This is a topic for future investigation as understanding of organic matter processing dynamics and channel recovery processes become better developed.

The information obtained about LOD-dominated stream channels under natural conditions in northwestern California and Oregon suggests that debris should be a significant component of streams draining second-growth forests as well (Keller et al. in press). Since debris accumulations are effective barriers to sediment movement, they are expected to have an important role in routing sediment through disturbed basins, which have high sediment loads per unit area for several years following logging and road building activities (Nolan and Janda 1981). Tally et al. (1980) suggested that debris could buffer the impact of excessive sediment input from rapidly eroding hillsides prior to delivery to trunk streams, up to an ill-defined site specific threshold. Conversely, Pitlick (1982) noted debris causing locally significant increased sediment delivery to a trunk stream, negating any buffering, even though the debris was purposely introduced to the channel during logging operations. Subsequently, Keller et al. (in press), Kaufman (1987) and Hogan (1987) found that debris both buffers and induces sediment delivery from hillslopes in steep, logged basins, and that the crucial differences between old- and second growth watersheds are direct consequences of the disturbance history.

Major disturbance of watersheds in the Pacific northwest, such as timber harvesting, can result in significant long-term changes to the morphology of streams draining them. If present, these alterations are the product of three forest practice related impacts: persistent high sediment loads to the stream channels following disturbance of the catchment; disturbance to the channel by specific activities (channel crossings, yarding timber across the channel, etc.); and alteration of the type and reduction of the size of woody debris in the channel during timber harvest and for several decades thereafter. Debris jams from this smaller debris are likely to be shorter-lived and more prone to catastrophic failure than those in undisturbed streams (Keller et al. in press).

Therefore, retaining naturally occurring jams, rather than post-harvest stream clearance, provides the best chance of maintaining a relatively natural pattern of debris loading for the next century.

Conclusions

Roads nearly always increase sediment yields in small watersheds, even with state of the art construction and erosion control practices. The effect is typically a short-term doubling of sediment yield (particularly suspended sediment); the sediment yield (particularly bedload) can rise even more catastrophically (25- ~ 100 times the average annual background yield) should a debris flow or a compressed period of intense storms occur. The contribution from roads alone, where road-related slope failures can be discounted, is on the order of 5 to 20 percent above background and is predominantly suspended sediment. The duration of this effect is not well established, but it probably remains at lower but elevated levels as long as the roads are in use. Sediment buffering by small channels may be sufficient in many locations, but the magnitude of this is not yet well established. The buffering effect is minimal with respect to silt and clay sized particles (suspended load), even at low (20 percent bankfull discharge) flows, but it increases significantly for the sand sized fraction of road sediments.

Mass wasting and severe gullying can also be associated with roads, though it can be somewhat avoided by better construction and avoiding existing mass movements. Where data exist, it appears that road related landslides are usually shallow and are more common in competent rock, indicating the importance to failure potential of steep slopes, rapid saturation of road fill, and low soil cohesion component (McCashion and Rice 1983; Sullivan et al. 1987b; Megahan et al. 1983). This suggests that vegetal erosion control on road rights-of-way could be very effective in reducing slides, depending upon local conditions (Gray and Megahan 1980).

Finally, the removal of vegetation from previously forested slopes may alter soil cohesion and moisture retaining properties to accelerate erosion from the hillside itself. However, this generally requires rapid input of water to the soil as well, whether from road runoff, a severe storm, or rapid snowmelt. Regrowth of vegetation is usually sufficiently rapid to avoid this situation. These studies taken together suggest that stabilization of road embankments, prevention of stream crossing failures, and proper dispersal of road drainage will bring sedimentation effects down to manageable levels in most instances.

Sediment eroded from hillslopes does not appear to be instantaneously translated to the trunk stream in the watershed; instead it is temporarily stored in tributary channels. This excess sediment fills pools and other storage compartments, including those associated with woody debris accumulations. Much, but not all of it, moves out of the tributaries within the first decade or so after timber harvest. Some remains, however, both within and below the active channel. In northern California, bed material is generally finer in streams draining cutover basins (MacDonald, unpublished data), and the relative area of the wetted channel during summer low-flow is lower than in undisturbed basins. A significant amount of the sediment stored in all watersheds discussed here and by Keller and Tally (1979) and Tally (1980) was associated with woody debris, making LOD an important aspect of sediment dynamics in small basins following timber harvesting.

TFW-16B-90-011 Evaluation of the TFW Stream Classification System: Stratification of Physical Habitat Area and Distribution, Final Report, Beechie and Sibley, July 1990.

This study was conducted to evaluate the effectiveness of the proposed TFW segment types in stratifying the physical habitat characteristics of streams. The segment types evaluated consist of four types that are commonly located in timber lands and have anadromous fish populations (C2, C3, C4, and B2), and one type that occurs in timber lands but generally does not provide habitat for anadromous salmonids (G type). As response variables we used the distribution of channel units in the segment, the percentage of pools, and the percentage of the channel area as coho spawning gravel. Additionally, we evaluated the influence of changes in discharge on the channel unit distribution, the contribution of several independent variables (bankfull discharge, gradient, wood volume, sediment size) in predicting pool percentages, and the influence of bankfull width on the percentage of spawning gravel.

Throughout this study we attempted to evaluate the sources of variability in the distributions of physical habitats in streams, and to identify those sources that provide useful information in addition to the classification system. Three sampling routines were used to address these sources of variability: (1) 16 reference sites, each 100 m in length, were established to observe the changes in channel unit distributions with changes in discharge and to examine the influence of large woody debris in segments, (2) 23 segments in the South Fork of the Stillaguamish River basin were used to examine paired B2 and C3 segments and to evaluate all B2 and C3 segments within a watershed, and (3) 32 segments in several watersheds were surveyed to compare the differences in segment characteristics within a single watershed to those in several watersheds.

We found that the segment types evaluated (B2, C2, C3. C4, and G) stratify the physical habitat characteristics of small streams with moderate success. Large rivers were not included in the analysis; they are expected to have different habitat characteristics.

Specific recommendations for the stream classification system include incorporating bankfull width as an additional variable in classification, considering the addition of an additional segment type defined as <0.5% gradient, and further investigation of such factors as LOD volume in individual segments, sub-basin geology. and position of the segment in the drainage network. These issues are to be addresses for each segment type individually. Sampling of segments requires temporal interspersion of different segment types to avoid introducing a bias in the measurement of channel units due to seasonal changes in discharge.

TFW-16E-90-004 TFW Stream Ambient Monitoring Field Manual, May 1990.

This manual describes the specific field methods to be used in this the second year pilot project for the implementation of a Timber, Fish & Wildlife (TFW) statewide stream monitoring program. The Ambient Monitoring Field Project is essential for successfully meeting many of the goals of the TFW agreement, primarily by providing reliable, consistent information on the status and trends for aquatic fisheries habitat associated with forested streams within Washington State. The ambient monitoring field project has been designed with the intention that it will ultimately provide this essential information to the process of adaptive management. Reliable, up to date data on resource condition across the state will be interpreted and the results applied to the management situation. This information will provide a direct link to evaluating the overall effect of the new forest practice regulations - a perspective needed for the judicious application of "adaptive management". Adaptive management is the process that allows us to make changes in land management actions based upon an growing understanding of the relationship between land-use activities and renewable public resources supported within streams and forests.

This field manual is written for use by field personnel, affiliated staff and interested cooperators that will be applying these methods in the field. We have included background information on key variables to be measured as well as their methods. Many of these methods have been adapted from existing literature in the hopes of providing reliable ways in which comparable data on key riparian parameters can be collected in a consistent fashion. Some methods have been modified from those presented in the first year, as these changes were felt necessary to further the reliability of the resulting data.

TFW-017-089-004 Wildlife Use of Managed Forests: Literature Review and Synthesis, NCASI, June 1989.

The 1987 Timber-Fish-Wildlife Agreement included adaptive management processes to provide for wildlife diversity on state and private forests in the State of Washington. This paper presents a literature review that provides a basis for monitoring terrestrial wildlife on managed forests. The purposes of the review included the following: (a) develop a list of parameters which influence wildlife habitat use and population dynamics in managed forests; (b) examine applicable habitat classification systems; and (c) develop a study plan for monitoring wildlife in managed forests.

The review was predicated upon emerging concepts in landscape ecology and new technology for evaluating wildlife habitats. Chapter 2 describes the scientific basis for wildlife-habitat relationships, recognizing that developing a greater understanding of wildlife response to natural and human-induced disturbances is a valid process for understanding forestry-wildlife interactions. In Chapter 3, a managed forest is defined as a shifting mosaic of dynamic forest patches subject to human-directed changes and random natural disturbance. Chapter 3 then evaluates several approaches for monitoring wildlife responses to managed forests, including indicator-species concepts, guilds, wildlife habitat models, and habitat classification systems. New research is suggested to construct management guilds as a means of monitoring wildlife responses. The management guilds would be coupled with development of an operational Geographic Information System (GIS).

The literature review on wildlife-habitat relationships provided details which were used to construct a matrix of parameters that would be useful in monitoring. The monitoring program, described in Chapter 4, will benefit by classifying managed forest mosaics using geomorphic land units, which incorporate landforms, soils, vegetation, and climatic influences on wildlife diversity and distribution. For some applications, particularly sensitive species, new technology is required for development, primarily including wildlife-habitat models that incorporate life-history attributes and risk analysis.

Chapter 5 describes adaptive concepts which employ the GIS capability and forest management practices in experiments that will result in greater understanding of wildlife-habitat relationships and provide the basis for modifying management policy. A management-experimentation program is suggested that simultaneously will evaluate management effectiveness and answer important ecological questions. The basic strategy includes a thorough quantification of variation in habitat conditions, both at the stand and landscape level. Several topics for research investigation were outlined.

TFW-AM-89-001 Valley Segment Type Classification for Forest Lands of Washington, Cupp, June 1989.

Stream channels and their associated biological components may show large variations in response to perturbations due to differences in their inherent productivity, stability, and resiliency to change. Differences in climate, flow regime, and geomorphic characteristics of drainage basins lead to significant natural variation in physical and biological characteristics of streams. The wide variety of land and associated stream conditions encountered in forested lands of Washington makes it impractical to develop stream management guidelines that would be applicable to all streams. For this reason, the need for an integrated land/stream classification system and systematic stream inventory method is widely recognized.

Stream classification can be used as an important tool to conduct stream inventories and as a foundation on which to develop basin-wide and stream-side management prescriptions. A clear system of stream classification is needed to separate natural variation among stream reaches from variation due to land management activities.

This study describes a combination and modification of several existing stream classification strategies to develop a locally adapted stream classification system applicable to drainage basins in forested lands of Washington. I adapted a subset of the diagnostic variables from existing classifications and developed classification units. These classification units can be used to stratify stream systems based on easily identifiable valley bottom and side-slope geomorphic characteristics.

The basic classification unit used to identify stream reaches is a valley segment type (modified from Frissell et al. 1986). Valley segments are defined by five general groups of diagnostic features: i) valley bottom longitudinal slope ii) side-slope gradient, iii) ratio of valley bottom width to active channel width, iv) channel pattern, and v) channel adjacent geomorphic surfaces. Valley segments are mappable classification units generally identifiable on topographic map and aerial photographs, and easily field verified.

TFW-AM3-90-010 **Quantitative Modeling of the Relationships among Basin, Channel and Habitat Characteristics for Classification and Impact Assessment, with Appendices, Orsborn, July 1990.**

This project was undertaken to develop an integrated, physical, analytical basis for its CLASSIFICATION and MONITORING programs. The heart of the project involves quantitative analyses of the components of a drainage basin system--its hydrologic, basin and stream channel characteristics. These study components include interrelationships among basin morphology, channel morphology, hydrology, streamflow, fisheries habitat and sediment transport.

This report is arranged in two major parts covering: (1) a nontechnical overview; and (2) a series of technical and non-technical appendices. These appendices describe the methodologies applied and the results developed for use by the AMC, and its cooperators and contractors, in their future work of developing management tools based on classification, monitoring and feedback.

RECOMMENDATIONS

In making these recommendations the primary purpose that guided them was to achieve improvements in the classification and monitoring programs. The initial timing of this project called for about two months of effort. This culminated in a preliminary draft report (Orsborn 1989), which evolved into a second draft report (Orsborn 1990) and which has now developed into this third version. The evolutionary process in the modeling project is mentioned because it is a model of the whole AMC/TFW process ... steps have to be taken and proven to an acceptable level before other steps can be taken in the adaptive management process.

* Contact the USGS about repeating some of the habitat investigations they completed for the Washington Department of Fisheries in the 1970s (Collings 1974):

* these studies gathered extensive and sell-documented instream flow and habitat information on some 20 streams in Western Washington;

* the streams covered a wide variety of geomorphic, hydrologic, geologic and land use conditions;

* all the study sites were established near USGS gaging stations; and

* almost 20 years have passed since the studies were completed.

Therefore, these study sites offer ideal situations in which to evaluate channel and habitat changes over time. It is recommended that the suggested study include the following activities:

* form a task committee within AMC of one-to-three people to assess this proposal.

* consider which basins might best serve AMC/TFW needs in terms of classification and monitoring tasks.

* contact the USGS office in Tacoma to ascertain:

(1) the availability of the original study records;

(2) the USGS's interest in possibly upgrading the study at certain sites on a cooperative basis with the AMC;

(3) whether the data from the first study would be available to AMC if the USGS could not conduct the new study; and

(4) whether the USGS would be able to complete the study, assist with it and/or provide the data files within a reasonable time frame to be determined by the task committee.

* The task committee would report its findings to the AMC.

* Assuming a decision is made to proceed with the project the AMC would need to: (1) select the sites which would best suit the AMC objectives;

  (2) determine which sites have good documentation of land-use changes which have occurred since the first studies were completed; and

  (3) formally request a proposal for the study, either from the USGS, or from other contractors, depending on the results of earlier inquiries.

This project would be very beneficial to the AMC program in that it would provide information on changes in stream channels, streamflow distribution and fish habitat which could be correlated with basin changes or with no changes in some basins. The results of this study could provide a solid foundation from which the monitoring program could be modified, improved and streamlined.

* There may be another instream flow data base which may not have been tapped by AMC. This consists of all the instream flow studies which have been conducted by federal and state agencies and consultants in conjunction with hydropower applications and the relicensing of projects.

  If this data base has not been assessed, it should be, to determine how it might be used to supplement the monitoring and classification program data bases.

* Forest Service instream flow, GAWS and long-term trend monitoring sites should be explored as possible supplements to the statewide monitoring and classification data bases.

With the possible inclusion of the recommended supplemental data bases (USGS, BLM, USFWS, IFIM and USFS), within two to three years the monitoring program may be on a solid enough foundation that it could be refined and adjusted to address problems which are not now apparent.

* Also, stronger interaction should be developed with the Forest Service for each Forest in each region of the state where AMC monitoring sites are located. The forests (e.g., Mt. Baker-Snoqualmie) are developing both GIS data bases, and Hydrologic Cumulative Effects Analyses. Watershed processes (activities a channel conditions) are being documented for each watershed, and IDTs are focusing on channel conditions. This information would be very helpful to the AMC for its monitoring and adaptive management processes.

* A project should be undertaken to evaluate the hydrologic data bases in each region where AMC monitoring sites are located. Part of the project would calibrate hydrologic models for each region using the methods described in Appendix III of this report.

* Also, in each monitoring region, analysis should be conducted of the calibration data for each US~S gaging station to determine changes in hydraulic geometry over time in altered and unaltered basins. The channel changes should be related to the streamflow record, and major (and cumulative) land-use changes should be documented for basins showing significant channel changes, similar to the first recommendation.

* An evaluation of the classification indices from this project (basin, streamflow and channels) should be developed for each monitoring region. These last three recommendations will help establish a stronger foundation for the AMC monitoring program, ~he stream response model and decision-making efforts.

* In developing the stream response model, the "downstream hydraulic geometry" type of model in this report can be used as a relative evaluator. For example, Figures V-7 and -8 (pages V-15 and -16) indicates that if there is a percentage change in the average flood, then there will be a certain adjustment in width.

* Consider using fault tree analysis in developing the adaptive management-decision making process (Figure 32, page 173 in preliminary draft report of July, 1989 for this project).

* Consider using Severity Factor Analysis in the Stream Response modeling project to demonstrate changes in stream channel and fish habitat characteristics as a percentage of the change in a reference flow. (Pages 186-204 of the project preliminary draft report of July, 1989).

TFW-AM9-91-002 Status and Trends of Instream Habitat in Forested Lands of Washington: The Timber-Fish-Wildlife Ambient Monitoring Project, 1989-1991 Biennial Progress Report, Center for Streamside Studies, December 16, 1991.

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 Streamside 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.

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 statewide. Particular emphasis is placed on obtaining repeatable surveys that, int he short-term, are used to evaluate present resource conditions and highlight channel character and instream 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 statewide.

TFW-AM9-94-001 **TFW Ambient Monitoring Program Manual - August 1994, Edited by Dave Schuett-Hames, Allen Pleus, Northwest Indian Fisheries Commission.**

Standard methods for:
- Stream Segment Identification
- Reference Point Survey
- Habitat Unit Survey
- Large Woody Debris Survey
- Salmonid Spawning Gravel Composition
- Stream Temperature
- Quality Assurance August

TFW-AM9-94-002 **TFW Ambient Monitoring Program, 1993-94 Status Report, Dave Schuett-Hames, Allen Pleus, Dennis McDonald, Northwest Indian Fisheries Commission. (79)**

TFW-AM9-96-001 **Spawning Gravel Scour: A Literature Review and Recommendations for a Watershed analysis Monitoring Methodology. Dave Schuett-Hames, Bob Conrad, Allen Pleus, Northwest Indian Fisheries Commission, February 1996.**

This report presents the results of a literature review conducted on the topic of spawning gravel scour. Background information on scour is presented, including the significance of scour to salmonid populations, and factors affecting the vulnerability of salmonid populations to scour. Variation in the depth and distribution of scour within stream reached, between peak flow events, and between different stream reaches is discussed. Key issues to address in developing a spawning gravel scour monitoring methodology in the context of Watershed analysis are identified, and past scour studies are examined to determine how these issues were identified. The report concludes with recommendations for developing a spawning gravel scour monitoring methodology.

TFW-AM9-96-002 **Salmonid Spawning Habitat Availability: A Literature Review and Recommendations for a Watershed Analysis Monitoring Methodology. Dave Schuett-Hames, Allen Pleus, Northwest Indian Fisheries Commission, February 1996.**

This report presents the results of a literature review conducted on the topic of spawning habitat availability prior to development of a TFW Ambient Monitoring methodology to monitor spawning habitat availability. The report summarizes information from the literature that describes the characteristics of salmonid spawning habitat, biological response to spawning habitat availability, and geomorphic and land-use factors affecting its abundance and distribution. Key issues that must be resolved to develop a methodology for monitoring spawning habitat quantity in the context of Watershed analysis are identified. Methods used in past studies to identify and measure spawning habitat availability are described and critiqued, and recommendations for a Watershed analysis monitoring method are presented.

TFW-AM9-96-003 **Watershed Analysis Monitoring: Pilot Project Evaluation. Dave Schuett-Hames, Allen Pleus, Northwest Indian Fisheries Commission, February 1996.**

This report presents the results of a pilot test of the Watershed Analysis monitoring module. In the course of the project, the TFW Ambient Monitoring Program staff provided training and assistance to five Watershed Analysis (WA) teams that used the recently complete WA monitoring module as a guide to develop follow-up monitoring plans. Following the project, we evaluated these efforts to identify obstacles encountered by teams developing Watershed analysis monitoring plans and determine improvements needed in the WA monitoring module.

Five steps in developing a monitoring plan are identifies: 1) making the initial decision to initiate a monitoring plan; 2) identifying monitoring goals and objectives; 3) preparing a monitoring plan report; 4) development of detailed sampling plans for each objective; and 5) obtaining commitments to implement monitoring plans. Factors that contributed to, or hindered, success are identified and lessons learned are documented. Four key elements to success were identified. For WA teams, these elements often represent challenges that must be overcome. The four elements are: 1) motivation to develop and implement a plan; @) an organized procedure to successfully develop and implement the plan; 3) scientific and technical know-how; and 4) adequate resources (personnel and money). Recommendations for overcoming these obstacles are provided.

TFW-AM9-96-004 **Winter Habitat Utilization by Juvenile Salmonids: A Literature Review. Amy Morgan, Northwest Indian Fisheries Commission, Frank Hinojosa, Grays Harbor College, February 1996.**

Some species of salmonids overwinter in freshwater before migrating to the marine environment. These juvenile salmonids exhibit habitat preferences that differ from the habitat used in the summer. This habitat has been identified as winter habitat. Several studies are reviewed on several different levels: species preferences, environmental effects on winter habitat selection, the features that characterize winter habitat and the geomorphic processes that affect them.

The second part of this report is a review of monitoring practices as they have been applied to winter habitat. The following aspects were surveyed: purpose of the study, parameters, study design and sampling methods, and data interpretation. From the information drawn out of these studies, a recommended monitoring approach is given.

We recommend a two-tiered approach that allows for both an office remote option and a field intensive option. The first option yields a more limited data set, but does allow for monitoring to be done in inclement weather or with limited resources. We recommend identifying the species present, and then locating the most likely winter habitat type for that species in the basin under consideration. Condition and abundance of these habitat features is then assessed to determine a baseline. Follow-up monitoring could then be done.

TFW-AM9-96-005 **Field Comparison of the McNeil Sampler with Three Shovel-based Methods Used to Sample Spawning Substrate Composition in Small Streams. Dave Schuett-Hames, Bob Conrad, Allen Pleus, Devin Smith, Northwest Indian fisheries Commission, May 1996.**

This report presents results of a study to determine if spawning gravel composition samples collected with a shovel are comparable to those collected with a McNeil sampler. Three shovel-based methods were examined, including: a standard No. 2 round point shovel (treatment S1); a standard No. 2 round point shovel with portable stilling well (S2); and a modified shovel with side walls (S3). The study design was based on collection and analysis of a series of paired samples. Each pair consisted of adjacent samples collected with a McNeil sampler and one shovel method. Samples were collected in two stream segments in southern Puget Sound, a segment with <1% gradient in Kennedy Creek and a 1-2% gradient segment in Skookum Creek.

To compare substrate particle size composition we examined differences between the paired samples in the percentage of the total volume of material for each sieve size category, the percentage of the total volume in each of three pooled size categories (>3.35 mm; 0.85-2.00 mm; and percent fine sediment <0.85 mm), and the geometric mean particle size using a paired sample t test and the Wilcoxon test. For the comparison of individual sieve category data, there was a significant difference between the total sample volume of at least one sieve size in five of the six McNeil to shovel comparisons. In each case the average percentage of particles in the smallest particle class (<0.106 mm) was significantly higher in the McNeil samples, apparently due to the McNeil sample's plunger mechanism that captures sediment suspended in the water. Only the S2 method produced samples that were not significantly different from the paired McNeil samples in the percentage of fine sediments and geometric mean particle size at both sampling locations. The mean difference in percent fine sediment between S2 samples and the paired McNeil samples was +1.0% at Kennedy Creek and -0.7% at Skookum Creek. Bias between the S2 and the McNeil samples was not evident at either location. The S2 method exhibited precision similar to or better than the McNeil sampler, while the S1 and S3 methods were less precise. Consequently, it appears that the standard shovel <u>with stilling well</u> (S2) can be an adequate substitute for the McNeil sampler for determining the percentage of fine sediment (0.85 mm) in stream channels similar to those sampled. It is unknown if this method would produce comparable samples in other situations. We recommend limiting use of the shovel with stilling well to situations where differences of +/-3% in fine sediments will not affect data interpretation. Continued use of the McNeil sampler is recommended when a high degree of accuracy is needed.

TFW-AM9-96-006 Quantification of Stream Channel Morphological Features: Recommended Procedures for Use in Watershed Ambient and TFW Ambient Monitoring Manuals, Carlos Ramos, October 21, 1996.

The main purpose of this report is to provide guidance for the implementation of reach-scale monitoring plans that evaluate the effects of forestry practices in the morphological characteristics of low-order streams in forested landscapes of the Pacific Northwest. The methodology presented in this report was developed by conducting extensive literature reviews, interviews with practitioners, and analysis of some of the field methods. The specific objectives of this report are:

- To provide office and field-based methods to identify and delineate the spatial distribution of channel morphological types within the study area in order to help in the selection of reaches to be monitored. Channel morphological types are based on the classification developed by Montgomery and Buffington (1993).

- To provide analysts with guidelines to identify the expected sensitive diagnostic features of specific channel reaches. The identification of these diagnostic features for specific channel reaches is based on the assumption that different channel reaches belonging to the same morphological type will suffer similar morphological responses to similar changes in input processes (those are; sediment input rate, water discharge, and large organic debris loading). The general channel diagnostic features that have been identified as sensitive to forestry practices are: channel morphological type, bar characteristics, pool characteristics, pool frequency, channel dimensions (width, depth, slope), fine sediment in pools, fine sediment in riffles, channel roughness, surface particle patchiness, channel pattern, subsurface particle size, bank erosion, scour depth, and general aggradation/degradation.

- To give detailed description of the data collection and analysis methods used to characterize the sensitive channel diagnostic features.

The appendix section provides literature review discussions on the following topics: streambed surface sampling methods; subsurface sampling and analysis of stream gravels; infiltration of fine sediment and its implications on the hydraulic conductivity of stream gravels; and bank erosion measurement methods. The appendix section also includes: descriptions of different morphological channel units; guidelines on how to conduct and analyze critical boundary shear stress calculations; guidance in how to identify channel bankfull indicators; and descriptions on the criteria used to characterize large organic debris.

TFW-AM9-96-007 Proposal for a TFW Monitoring Strategy to Determine the Effectiveness of Forest Practices in Protecting Aquatic Resources, Dave Schuett-Hames, Nancy Sturhan, Kevin Lautz, Randy McIntosh, Mike Gough, Charlene Rodgers, November 12, 1996.

This report presents a monitoring strategy to evaluate the effectiveness of forest practices in protecting aquatic resources on state and private land in Washington State. The strategy was developed by the TFW Monitoring Steering Committee in response to a request from the TFW Policy water quality subcommittee. The report identifies effectiveness monitoring goals; objectives and issues; presents a framework for a monitoring strategy; discusses options for implementation and concludes with a proposal for a pilot project. A review of effectiveness monitoring goals, objectives and issues; presents a framework for a monitoring strategy; discusses options for implementation and concludes with a proposal for a pilot project. A review of effectiveness monitoring programs in other states and descriptions of monitoring approaches for eight monitoring objectives are included as appendices. Effectiveness monitoring programs in seven states and one Canadian province were examined to identify suitable models for Washington, however none were suitable because they are not tailored to two unique features of Washington's forest management system, the Watershed analysis (WA) process and the TFW cooperative management system.

The focus of the proposed effectiveness monitoring strategy is eight key monitoring objectives based on important questions monitoring should answer. These objectives address the effectiveness of: 1)riparian measures to maintain or restore stream temperature; 2) riparian measures to maintain or restore large woody debris; 3) measures to reduce or eliminate management-induced mass wasting; 4) measures to reduce management-induced surface erosion; 5) measures to reduce management-induced changes in hydrology; 6) measures to maintain or restore fish passage; 7) measures to prevent adverse impacts from forest chemicals; and 8) forest practices when applied on a watershed-scale in avoiding cumulative effects to salmonid habitat and water quality.

A monitoring strategy with an implementation element, an input process element, a resource trend element, a validation element and a supporting research element is recommended. Emphasis is placed on monitoring input processes and triggering mechanisms because they are directly affected by forest practices and can be monitored for a reasonable cost. Secondary emphasis is placed on more expensive monitoring of trends in aquatic resource conditions because resource protection and recovery is the fundamental management objective. We envision applied research where scientific investigation is needed to interpret monitoring results or determine why effectiveness varies. We propose to evaluate effectiveness by determining whether forest practices measures are successful in maintaining or restoring desired resource conditions (water quality standards or WA resource conditions indices) or avoiding adverse changes in input processes.

We recommend a multi-objective, watershed-based strategy implemented through TFW by CMER's Monitoring Steering Committee. We recommend a strong linkage with WA because many resource assessment products provide a "current condition baseline" for input process and resource conditions that can be repeated to determine changes over time. This approach will reduce monitoring start-up costs and provide information needed for the WA five year review process. We propose initial monitoring of a core sub-group of watersheds where WA has been done, selected from regions across the state. Implementation can be expanded in stages by adding other issues or watersheds needed to evaluate management programs such as standard rules, Total Daily Maximum Load agreements (TMDLs) or Habitat Conservation Plans (HCPs). We recommend tacking riparian measures, sediment, fish passage and resource conditions initially, beginning with a two-year pilot project conducted by the TFW Monitoring Steering Committee to address priority effectiveness issues. The pilot would evaluate the effectiveness of WA prescriptions in watersheds approaching the five year review and compare the effectiveness of standard rules applied under similar conditions.

TFW-AM10-91-001 Watershed Characteristics and Conditions Inventory, Pysht River and Snow Creek Watersheds, Jones & Stokes Associates, May 1991.

Jones & Stokes Associates conducted a Watershed Characteristics and Conditions Inventory (WCCI) on six watersheds within the state. The goal of the project is to provide information necessary to interpret the influence of watershed conditions on the characteristics of stream channels. This WCCI has involved the collection and compilation of information related to the natural characteristics and management-affected conditions of the designated watersheds. Stream surveys have previously been completed by AMSC trained crews on all or portions of the streams within these watersheds.

The six watersheds have been divided into three groups: West Slope Cascade Mountains, Olympic Peninsula, and East Slope Cascade Mountains group. This report presents the results of the WCCI for the Olympic Peninsula Group, consisting of the Pysht River and Snow Creek watersheds.

Part 1 of this report describes the methods of data collection and results of the inventory for the Pysht River watershed; Part 2 presents this information for Snow Creek. Part 3 consists of a comparative summary and conclusions regarding the inherent stability and harvest intensity within the study areas. A series of 1:24,000-scale maps and overlays, with attributes described on dBase data files, accompanies this report.

TFW-AM10-91-002 Watershed Characteristics and Conditions Inventory, Taneum Creek and Tacoma Creek Watersheds, Jones & Stokes Associates, June 28, 1991.

Jones & Stokes Associates to conducted a Watershed Characteristics and Conditions Inventory (WCCI) on six watersheds within the state. The goal of the project is to provide information necessary to interpret the influence of watershed conditions on the characteristics of stream channels. This WCCI has involved the collection and compilation of information related to the natural characteristics and management-affected conditions of the designated watersheds.

Stream surveys have previously been completed by AMSC trained crews on all or portions of the streams within these watersheds.

The six watersheds have been divided into three groups: West Slope Cascade Mountains, Olympic Peninsula, and Eastern Washington. This report presents the results of the WCCI for the Eastern Washington Group, consisting of Taneum Creek and Tacoma Creek watersheds.

Part 1 of this report describes the methods of data collection and results of the inventory for Taneum Creek watershed. Part 2 presents this information for Tacoma Creek. Part 3 consists of a comparative summary and conclusions regarding the inherent stability and harvest intensity within the study areas. A series of 1:24,000-scale maps and overlays, with attributes described in dBASE data files, accompanies this report.

TFW-AM10-91-003 Watershed Characteristics and Conditions Inventory, Upper Mashel River Watershed, Charley Creek Watershed, Jones & Stokes Associates, March 1991.

Jones & Stokes Associates to conducted a Watershed Characteristics and Conditions Inventory (WCCI) on six watersheds within the state. The goal of the project is to provide information necessary to interpret the influence of watershed conditions on the characteristics of stream channels. This WCCI has involved the collection and compilation of information related to the natural characteristics and management-affected conditions of the designated watersheds. Stream surveys have previously been completed by AMSC trained crews on all or portions of the streams within these watersheds.

The six watersheds have been divided into three groups: West Slope Cascade Mountains, Olympic Peninsula, and East Slope Cascade Mountains. This report presents the results of the WCCI for the West Slope Cascade Mountains group, consisting of the Upper Mashel River and Charley Creek watershed.

Part 1 of this report describes the methods of data collection and results of the inventory for the upper Mashel watershed. Part 2 presents this information for Charley Creek. Part 3 consists of a comparative summary and conclusions regarding the inherent stability and harvest intensity within the study areas. A series of 1:24,000-scale maps and overlays, with attributes described in dBase data files, accompanies this report.

TFW-AM14-94-001 A Strategy to Implement Watershed Analysis Monitoring: Assessment of Parameters and Methods, Monitoring Module Outline, Recommendations for Program Development, Dave Schuett-Hames and George Pess, Northwest Indian Fisheries Commission, May 1994.

The purpose of this project is to examine the need for a monitoring component in Watershed Analysis (WSA) and provide AMSC/CMER with information and recommendations to aid in development and implementation of the WSA Monitoring Module. Our approach was to attempt to answer six fundamental questions: 1) what is the purpose of monitoring in the context of WSA?; 2) is it possible to build a monitoring plan that fulfills these purposes using information provided in the Watershed Analysis reports?; 3) what monitoring situations are likely to be encountered in forested watersheds around the state?; 4) what parameters and methods are needed to conduct WSA monitoring?; 5) what components should the WSA monitoring module contain?; and 6) what tasks need to be integrated into the AMSC/CMER work-plan to develop and implement WSA monitoring?

Watershed Analysis Monitoring needs to be designed to fulfill three potential missions. First, it should provide feedback to assist in adaptive management. Feedback from monitoring should also help the module design teams improve WSA methods. Secondly, monitoring data should help the Department of Natural Resources in their periodic evaluation on the effectiveness of completed Watershed Analyses under WAC 222-22-090(4). Finally, monitoring data could help the Department of Ecology to evaluated the effectiveness of WSA used in the implementation of section 303(d) of the Clean Water Act.

To accomplish these missions Watershed Analysis Monitoring must focus on two areas. First, triggering mechanisms and input processes must be monitored to evaluate the effect of WSA prescriptions. This type of input monitoring is important because it provides valuable feedback on the performance of "prescriptions" and allows early identification of potential problems before they are translated into detectable adverse channel and resource effects. Next, the response of stream channel, habitat and water quality conditions should be monitored to determine if the resource protection objectives of WSA are being met. Development of a channel/resource recovery prognosis will help to evaluate the response of systems that have been disturbed by past management or natural events.

A completed Watershed Analysis makes an excellent foundation for developing a monitoring plan, because each "causal mechanism report" provides a monitoring hypotheses that links input processes with channel and resource responses and can be used to identify appropriate monitoring parameters and specific monitoring locations. The WSA causal mechanism reports (supplemented by resource assessments) are the key source of information for developing a monitoring plan, however they must be thoroughly written with input from all assessment team members to provide adequate detail. Most causal mechanism reports (CMRs) contain adequate information on triggering mechanism. Treatment of channel effects was less consistent, and many CMRs lacked adequate information on specific habitat effects. This problem could be prevented by providing better guidance in preparing CMRs.

About 100 causal mechanisms were examined from WSAs completed in 1993 to identify potential monitoring situations and parameters. We condensed this information into seven input/response "hypothesis" that occurred frequently in the CMRs. Three hypotheses focused on mass wasting, and there was one each for surface erosion, large woody debris (LWD) recruitment, stream temperature, and peak flows. We used these to identify the potential monitoring parameters we predict will be in greatest demand, however other less common situations occur and will need to be addressed on a case-by-case basis.

Based on this analysis, we identified 29 basic monitoring parameters, including 7 for triggering mechanisms, 7 for channel effects, and 15 for habitat. No water quality parameters are listed because they were infrequently identified in the CMRs due to lack of a water quality module. Water quality parameters will be better identified when the Water Quality Module is completed. Potential monitoring parameters were evaluated based on estimated demand and the amount of work required to develop an acceptable method. Based on estimates of future demand and the amount of work required to develop a suitable method, we recommended development in the next year of the following high priority parameters; slope stability, road assessment, surface erosion, channel substrate size (fining or coarsening), channel aggradation or degradation, channel widening, braiding, lateral migration and bank erosion (aerial photo method), sediment storage features, spawning gravel availability and macro-invertebrate production. We also recommend initiating work on the following parameters (high demand/extensive work): fine sediment delivery, site-specific peak flow runoff monitoring, channel widening, braiding, lateral migration and bank erosion (field methods), spawning gravel scour, pool refuge habitat, and LWD accumulations.

Our next task was to scope out information that would need to be included in the monitoring module. We determined that the most effective WSA monitoring approach would have local stakeholders develop and implement watershed-specific monitoring plans based on the WSA causal mechanism and resource assessment reports. The role of the Watershed Analysis Monitoring Module will be to provide information and guidance in preparation and documentation of the monitoring plans. Specific issues that need to be addressed in the plans include identifying goals and objectives, developing a sampling plan, quality assurance, and data processing and interpretation.

Technical assistance from the TFW Ambient Monitoring Program is necessary to support the local monitoring efforts and ensure consistent data collection on a state-wide basis. The role of the TFW Ambient Monitoring Program in implementing Watershed Analysis Monitoring will include developing standard methods, conducting training, providing quality assurance, assisting with data processing and analysis, and maintaining the state-wide database.

The tasks that need to be done to successfully implement WSA Monitoring include writing the monitoring module, developing standard methods, providing support services (training, quality assurance, etc.), clarifying procedures for use of WSA monitoring data in adaptive management, improving linkages with other WSA components, improving capability to interpret monitoring information, and developing future funding sources. Recommendations for incorporating these tasks into the AMSC/CMER work-plan are provided.

TFW-AM14-94-002 User Instructions: Sediment Sampling Application, rBASE Ver 1.2, Anita Sparks and Dave Schuett-Hames, June 1994.

The Sediment Sample Application provides a two-part system to allow input, update, export and analysis of sediment sample data. This two-part system is built in Ingres and r:Base. The Ingres part, which includes the main sediment database, is located on the NWIFC's SUN system/Bulletin Board. Copies of the R:Base part will be sent to those organizations involved in data collection.

The Ingres part of the application will allow the import, input, and maintenance of the sediment tables. It will also give access to a variety of reports through the report menu. The reports are sent to files (filename specified by the user). The system currently works with Ingres reports. A later enhancement will include the ability to call reports created in SPSS.

The R:Base application will allow input of data, one error-checking report and export of the data in the proper format to be used in the Ingres import. It will also allow transfer of data to disk for storage of long term data.

These user instructions will serve as a guide for the new user and as a lookup manual for basic operation and special features for the experienced user of the Ingres part of the system.

TFW-F3-92-001 Assessment of Cumulative Effects on Salmonid Habitat: Some Suggested Parameters and Target Conditions, N. Peterson, Andrew Hendry, Dr. Thomas P. Quinn, March 2, 1992.

Cumulative Effects (CEs) as used in this paper refer to changes in watershed and channel conditions caused by multiple forest practices. These effects may be additive or multiplicative in nature and are functionally linked to watershed processes.

The concept of linking threshold values for selected in-stream habitat parameters to the intent and degree of forest practice regulation, has gained favor among many resource managers and is now being considered for adoption into the Forest Practice Rules and Regulations.

Thresholds have been variously called decision criteria, performance standards, habitat goals, target values, and most recently "indices of resource condition". Whatever their name, their purpose is the same: to describe a level of stream habitat condition that would trigger specific management responses. A description of these responses is still under development in the draft rules for "Cumulative Effects and Watershed Analysis", Washington Administrative Code (222-31-030 to 222-32-100). We prefer the term "target condition" because it connotes a condition that may be surrounded by considerable variability but that can be actively managed for.

The objectives of this paper are: 1) to provide an evaluation of the "threshold" approach as it might apply to the regulation of forest practices across diverse landscapes and stream channels in Washington, 2) identify in-stream parameters that are closely linked to forest practices, fluvial processes and salmonid habitat life history requirements, 3) suggest threshold or target conditions to determine habitat condition, and 4) recommend quantitative field methodologies for parameter measurement.

The organization of this paper is intended to serve readers of various interest levels and disciplines. Important conclusions and recommendations are presented first, followed by an increasingly detailed discussion of supporting information.

Conclusions and Recommendations

1) Reliance on in-channel parameters and resource based target conditions will not prevent CEs from occurring. In effect, this approach permits CEs to occur before corrective actions are undertaken. Such a system is helpful only in assessing channel condition and it philosophically continues to place the burden of proof on fishes and other aquatic resources to show damage. This is not appropriate in view of the lag time between some watershed activities and their expression in the channel, and it is not entirely consistent with the goals of Federal legislation such as the Clean Water Act and the Endangered Species Act.

2) A better approach to the prevention of CEs is an early warning system of hillslope thresholds that would deal directly with the causes of CEs on forest lands, i.e. those things that upset the balance of basic channel inputs of wood, water and sediment. These include clear cut logging on steep unstable terrain; road density, location, construction and maintenance; and patterns and rates of timber harvest that disrupt normal basin hydrology.

3) Approaches to the prevention of CEs, that do not deal with the proximal causes of stream habitat deterioration as the first level of warning, fail to provide adequate resource protection and do not serve forest managers because they provide a false sense of security and ultimately limit management flexibility to deal with the problem.

4) A suite of in-channel parameters and target conditions is a needed channel assessment procedure that could help identify specific needs to address through forest practice regulation. This system would be a useful adjunct to a hillslope threshold approach and could provide needed corroborative links for monitoring the effectiveness of management practices over long periods.

5) We have elected to use the conditions indicative of the streams draining unmanaged forests as the standard by which to set target conditions. This approach does not seek to optimize the stream environment for a particular species or age class, but assumes naturally functioning and ecologically intact channels will provide long term sustainability for diverse fish assemblages.

6) We have elected to set a single target condition for two reasons, first we do not think it is necessary to designate a lower level for the purposes of channel assessment and secondly the data does not exist to do this in a consistent fashion.

7) This scientific literature does not support a "one size fits all" approach to the establishment of target conditions. We believe a stream classification system linked to important physical variables such as gradient, stream size, and bank material must be developed to group streams and stream reaches that may respond similarly to disturbance. We support the establishment of target conditions appropriate to local settings for assessment purposes.

8) We recommended the following in-channel parameters for inclusion in a detailed monitoring program; 1) LWD frequency (pieces per channel width), b) average LWD volume (cubic meters per piece), c) percent pool area, and d) substrate composition (% fines < 0.85 mm).

9) Target conditions established at this time are:

A) LWD frequency by channel width. From 4 to 19 meters bank full channel width, 2.44 to 2.03 pieces respectively (see Table 2a). Data based on regression of Bilby and Ward (1989).

B) LWD average volume per piece by channel width. From 4 to 19 meters bank full channel width, 0.25 to 3.70 cubic meters per piece respectively (see Table 6). Data based on regression of Bilby and Ward (1989).

C) Percent pool area. For streams less than 3% gradient, the target condition is for 50% of the total wetted surface area to be comprised of pools at the low flow period.

D) Substrate composition. The target condition is for no more than 11% of the particle size distribution to be comprised of the <0.85 mm fraction. This target condition applies broadly to streams of different sizes and gradients but as a general rule would be most applicable to streams <3% gradient and between 5 and 30 meters bank full channel width.

TFW-F4-91-001 Patterns of Flow, Temperature and Migration of Adult Yakima River Spring Chinook Salmon, Thomas P. Quinn, June 1991.

To better interpret the recent TFW-sponsored research on adult Yakima River spring chinook salmon (Berman and Quinn 1990), this report provides data on river flows, temperatures and salmon migratory timing. First, it presents graphical summaries of flow records from five gages on the Yakima River and three tributary gages for 1989. It also provides summaries from the earliest period of record (1907 or 1909 to 1911), during the mid-late 1970s and during the late 1980s for the Cle Elum and Umtanum gages. It provides yearly and mean June flows for these gages for the complete periods of record. These flow records must be viewed in the context of temperature regimes, and records are presented for the relevant months in 1989 for the Columbia and Yakima rivers (four stations on each river). Finally, the migratory timing patterns of adult chinook salmon at Prosser Dam in 1989 and Bonneville Dam from 1980-1989 are presented.

TFW-F4-94-001 The Effect of Forest Practices on Fish Populations, Final Report, Dr. Thomas P. Quinn and N. Phil Peterson, May 1994.

Studies were conducted in field and laboratory settings to investigate aspects of the physical and biological effects of forest practices on fish populations in Washington streams. The incubation environment of chum salmon was studied in Kennedy Creek, where we examined the architecture of the egg pocket as created by the female salmon, and the patterns of gravel scour and fill, sediment deposition and dissolved oxygen during the period of embryonic development. Background levels of fine sediment were greatly altered by the female salmon but fine material infiltrated into the egg pocket during incubation. Dissolved oxygen levels varied greatly among egg pockets and over time but were not correlated with fine sediment concentrating in the egg pockets. Scour of egg pockets is likely to be a major source of mortality for chum salmon fry in this and similar streams, though the modifications in the stream channel morphology and surface bed composition by the salmon themselves may reduce the likelihood of scour.

TFW-IM-91-001 **Information Management Coordination Project: Report to TFW Administrative Committee, Dan Cantrell, Peter T. Haug, June 30, 1991.**

Information management issues throughout the Timber/Fish/Wildlife (TFW) process share many common characteristics. These need to be approached systematically, first to ensure that data and information are of consistently high quality, and second, to facilitate storage, retrieval, and exchange of data and information. This project addresses a need to develop a directory of data and information generated by, or of interest to, TFW participants, and possibly others outside the TFW community.

This report (1) reviews and evaluates TFW information and the way it has been handled to date; (2) recommends ways to improve organization, maintenance, and access of TFW data and information; (3) identifies tasks and deliverable items for a comprehensive information management and coordination program within the TFW process, and (4) provides a TFW information database accessible through printed copy or personal computer. The database includes:

- A master directory of TFW products.
- A bibliography of reports and other products generated by CMER projects, TFW cooperators, and other TFW activities.
- A file of annotations about these products.
- An index to variables measured in research and monitoring projects and to other key words associated with TFW products

RECOMMENDATIONS

This report, though not comprehensive, illustrates the breadth and scope of data and information associated with TFW. As the TFW process continues, the amount and complexity of this information and data are certain to grow apace. The following recommendations are designed to organize this complexity and provide managers with better information to make decisions quickly.

We therefore recommend that the TFW Administrative Committee and Policy Group:

- Assign clear responsibility for receiving and keeping TFW products; for maintaining the database of TFW data and information developed in this project; and for refining the information management procedures and database itself to make data and information more accessible to end users.
- Authorize a full-time information management coordinator position, under the auspices of the IMC, to continue the process begun in this project and expand the ideas presented in this report.
- Direct IMC to develop a detailed proposal, with budget, to implement the second recommendation above.

- Recognize and encourage continuing efforts to further the TFW process with more in-kind support and initiatives among TFW participants, and document these efforts through the medium of information management. This study unearthed several such efforts, and we have a sense that several more remain unsung.

Examination of the stream ecology of juvenile coho salmon in Big Beef Creek revealed that the complexity of the stream environment and the size of the fish at the end of the summer have strong, interacting influences on survival to the smolt state. Variation in survival between years, among reaches of the stream, and among size classes was evident. Experiments in an artificial rearing channel indicated that the brushy material was no attractive to juvenile coho salmon in early summer and its presence (in pools 0.5 m deep) did not influence survival or growth. However, experiments conducted later in the summer with more complex fish communities revealed a clear interaction between depth and brushy cover in the distribution and survival of juvenile salmonids. Shallow pools without cover were under utilized and fish confined to them suffered higher mortality that those in deeper pools without cover or shallow pools with cover, and deep pools with cover were most attractive and beneficial.

Analysis of long-term data sets from Big Beef Creek revealed a freshwater carry capacity for juvenile coho salmon that was affected by the summer low flow period (lower flows, fewer smolts) but density did not seem to affect smolt size. Interannual variation in marine survival was poorly explained by smolt size or physical oceanographic variables examined (sea surface temperature, salinity and upwelling), though marine growth was positively correlated with salinity. While these date revealed complex interactions between density-dependent and climate-dependent factors affecting coho salmon, our ability to integrate this information with land use practices was hampered by the absence of habitat date at this site.

Examination of stream fish communities in a series of Washington streams over several years revealed changes in composition associated with season but considerable resilience in the streams after flood events but the timing of floods may be more important than their magnitude. Species richness was positively correlated with indices of habitat complexity and the abundance of coho salmon and speckled dace was positively correlated with the amount of pool habitat in the study sections.

TFW-SH1-92-001 Effects of Forest Cover on Volume of Water Delivery to Soil During Rain-On-Snow, Final Report, Bengt A. Coffin and R. Dennis Harr, July 30, 1992.

Most of the highest stream flows in western Washington have had a snowmelt component, and the high rates of water input to the soil during rain-on-snow have triggered landslides on steep, marginally stable slopes. State and Federal laws require analyses of the cumulative effects of forest management activites on the environment. These laws and the perception of increased flooding in western Washington have perpetuated the concern about the effects of logging on streamflow, particularly that resulting from snowmelt during rainfall. Modelling efforts attempting to predict streamflow based on precipitation and landuse require empirical data at the plot scale that show how much water would be available for runoff from forested and non-forested sites during rain-on-snow.

This study was undertaken (1) to test the hypothesis that forest cutting has no effect on water outflows from mature forest stands and open areas during rain-on-snow.

Snow lysimeters were installed under each of three cover types including a mature forest, forest plantation, and clearcut or open area. A total of 24 study plots were established at three elevations and at two locations in northwest Washington. A weather station at each non-forested plot monitored weather conditions during snowfall and snowmelt, and between rain-on-snow events. Water outflows from snow lysimeters were compared to determine differences among cover types during 13 rain-on-snow events.

Open plots exhibited greater outflows than their corresponding forested plots during 29 plot-events in 13 rain-on-snow events over three winters. (A plot-event is one rain-on-snow event at one plot; one rain-on-snow event measured at each of four plots would equal four plot-events.) Differences in outflows between forest and open plots were generally the greatest for rain-on-snow events exhibiting relatively high air temperatures and wind speeds and low rainfall intensities. During the parts of rain-on-snow events when air temperatures and wind speeds were relatively high and rainfall intensities were low, outflows from open plots were much greater than corresponding outflows from forest plots.

During many events, plantations monitored in this study did not appear to be hydrologically recovered with respect to snow accumulation and subsequent melt during rainfall. Outflows from 18-42-yr old forest plantations were often intermediate between those from corresponding forested and non-forested sites, but sometimes were less than from corresponding forest plots. Plantations typically accumulated snow around the crown margins of individual trees because spindly, flexible branches were incapable of holding as much snow and allowing it to melt in the crowns as mature forest stands did.

Results from this study suggest timber harvest (or any other activity or event that replaces forest with open area) can increase outflow of water from snowpacks during many rain-on-snow conditions by reducing snow interception and increasing heat transfer to the snow. Specifically:

1. Over a number or rain-on-snow events, a wide range of conditions, and at a number of different sites, this study showed greater water delivery to soil (as indexed by lysimeter outflow) in open plots than forested plots during rain-on-snow. Increased outflows from open plots in this study were generally much greater than those reported in similar studies elsewhere. Except for the extreme rainfall in November 1990, storms monitored in this study were not considered extraordinary in terms of weather conditions, so snowmelt processes and volumes of water outflow should not be considered extraordinary.

2. Differential snow accumulation and rate of melt during rain-on-snow both appeared to be involved in greater outflows from open plots. Differential snow accumulation and subsequent rate of melt during rainfall did not appear to be of equal importance in every rain-on-snow event nor at every location. Since snow accumulation was not measured, the relative importance of snow accumulation and melt could not be determined.

3. Analyses of individual rain-on-snow events show water delivery to soil increased most when greater accumulation of snow in an open (logged) area was followed by moderate rainfall at relatively high air temperatures and wind speeds that combined to increase the transfer of sensible and latent heats to the snow. These weather conditions are common during late fall and winter months in western Washington.

4. Maximum differences in outflows between open and forest plots occurred during periods when air temperatures and wind speeds were both relatively high. Even though some plot-events did not exhibit large differences in outflow between open and forest plots over the duration of individual rain-on-snow events, there were commonly 7- to 12-hr periods during individual rain-on-snow events when outflow from the open plots exceeded that from the forest plot by 50% to more than 400%.

5. When snow fell at temperatures above freezing and was intercepted and melted in tree crowns, outflows form forest plots exceeded those from open plots. Given the high conductivities of forest soils, the steep slopes, and the rapid subsurface flow of water in

western Washington, the small differences in outflow probably have little effect on differential antecedent soil moisture or streamflow. The hydrologic significance of these events is likely based on their determining how much snow water equivalent would be on the ground under forest when a future rain-on-snow event occurred.

6. Analyzing precipitation-frequency in view of this study's results reveals that increased water input to soil following timber harvest could double return period of 24-hr water input events, i.e. larger water input events would become more frequent.

7. Outflows from the plantation plots were often intermediate between outflows from the forest and open plots, but at times were actually less than the outflow measured from the forest. Outflows from plantation plots ranged from 30 mm (21%) less to 43 mm (96%) greater than from corresponding forest plots. The wide range of outflow responses reflect variability between storm events, but also the variability among the stands and within individual stands.

8. The wide range of outflow differences observed during this study emphasizes the extremely complex and highly variable nature of the biologic and meteorologic systems monitored during rain-on-snow.

TFW-SH5-91-001 Literature Search of Effects of Timber Harvest to Deep-Seated Landslides, Thomas E. Koler, June 1991.

Published literature concerning the effects of timber harvesting (road construction, logging, and burning) to deep-seated landslides is sparse. Some authors have provided descriptions of conditions affecting deep-seated landslides, most notably Sidel (1985) and Swanston and Swanson (1976), but few authors have collected field data for analysis that specifically addresses how timber harvesting effects deep-seated landslide stability. Research completed by Swanston, Lienkaemper, Mercer and Levno (1988) is the only exception. These scientists evaluated, monitored, and analyzed the effects of road construction, logging, and slash burning to these large landforms in southwestern Oregon. Two other research projects did not specifically look at the cause/effect relationship of timber harvesting to deep-seated landslides, but their collective work is important to understanding better the role of the ground water regime of these geomorphic features. These two projects were completed in western Oregon by Pyles, Mills, and Saunders (1987); and in northwestern California by Iverson and Major (1987). Understanding the ground water regime in deep-seated landslides is considered by slope stability scientists the most important factor in evaluating them. In addition to the lack of documented research, two other issues were found: 1.) the documented research listed above were completed in areas that were not modified by continental glaciation, a common geomorphic process in Washington State; and, 2) no one has examined the relationship of timber harvesting to deep-seated landslides located in rock slopes, such as would be found in the Olympic, Cascade, and Okanogan Mountain Ranges of Washington. Because there is a lack of literature on this topic, much work remains to be done to understand how timber harvesting effects deep-seated landslides in Washington.

TFW-SH6-91-001 TFW Road Questionnaire: Analysis and Compilation of Responses, Cogan Sharpe Cogan, February, 1991.

A questionnaire on forest roads was developed by the Sediment, Hydrology and Mass Wasting Subcommittee (SHAMW) of the TFW Cooperative Monitoring, Evaluation, and Research Committee (CMER) as a first step in determining the effectiveness of forest road construction methods and regulations in Washington.

Roads associated with forest practices can have significant impacts on water quality and aquatic habitat, and contribute to mass wasting. A significant portion of Washington's forest practices rules and regulations involve various aspects of roads and landings, including design and maintenance of the surface and drainage structures, placement of fill and waste material from excavation activities, and reduction of organic debris from clearing operations.

This questionnaire was developed to provide road construction engineers, regulators, and other individuals involved with forest roads an opportunity to provide information to TFW cooperators on what's working and not working in the field; to identify information needs; to offer suggestions for further research; and to identify any needed changes in regulations governing forest roads. The results of this questionnaire will be used to create a catalog of workable techniques and to establish a network of successful operators.

The questionnaire was originally distributed in August, 1990 to personnel working within TFW as well as to forest road engineers at National Forests in Washington. The original response due date of September 30 was extended several times to encourage wider distribution among agencies and the timber industry and to obtain as many responses as possible. In late 1990, there was severe flooding in many areas of the state and damage to or failure of a number of forest roads. Additional questionnaires were distributed and the response deadline extended to January 15, 1991, to respond to an anticipated increase in interest in forest road design, maintenance and closure issues as a result of these events.

All questionnaires received as of February 11, 1991 are tabulated and analyzed in this report.

TFW-SH7-91-001 Sediment Transport Processes in Steep Mountain Streams in Forested Watersheds on the Olympic Peninsula, Washington: Interim Final Report, Matthew O'Connor, R. Dennis Harr, August 6, 1991.

TFW-SH7-94-001 Bedload Transport and Large Organic Debris in Deep Mountain Streams in Forested Watersheds on the Olympic Peninsula, Washington: Final Report, Matthew O'Connor, September 1994.

TFW-SH8-91-001 Watershed and Stream Channel Cumulative Effects Analysis Using Aerial Photography and Ground Survey Data - Interim Report, Dave Somers, Jeanette Smith, Robert Wissmar, 1991.

This document is intended to serve as an interim report on the "Watershed and Stream Channel Cumulative Effects Analysis Using Aerial Photography and Ground Survey Data" project. This report provides a description of approach taken in the study, particularly for watershed cumulative effects analysis, and presents information and experience gained through the project to date.

We have tried to prepare the report to provide information relevant to the current activities of TFW and the Washington Forest Practice Board, specifically the design and implementation of watershed screening, watershed analysis, and stream condition thresholds. At the time this project was originally funded, these issues were not a part of any formal regulatory process, although similar issues had been discussed at length within TFW. Recent legal and political events have moved watershed level analysis towards adoption within existing regulatory processes. It is our hope that our project experiences will assist in the development of watershed analysis which is technically well grounded, efficient, and effective in providing resource managers with appropriate and interpretable information regarding watershed conditions. The scope of this study is limited to factors influencing the abundance and quality of anadromous and resident fisheries habitat.

TFW-SH9-91-001 **Analysis of Initiation Mechanisms of Dam-Break Floods in Managed Forests, Carol Coho, Stephen J. Burges, July 1991.**

This is the first of two reports that examine dam-break floods. This first report describes the general physical characteristics of dam-break floods described occurred in the Cascade and Olympic Mountains of Washington and Oregon during the last decade. The second report, expected to be completed by December 1992, will include quantitative analysis of the dam-break flood process that focuses on that aspect of the floods that leads to increasing magnitudes with distance travelled (migrating organic dams). The aims of that analysis will be to produce a better understanding of the dam-break flood process and develop qualitative and quantitative descriptions of initiation and travel distance of dam-break floods that can be used by forest managers.

This report describes the initiation mechanisms of twenty dam-break floods, the geometry of the valley floor at each of the initiation and deposition sites of the floods, and their lengths of travel. The stream types and stream orders, and resources impacted by the floods are discussed.

TFW-SH9-93-001 **Dam-Break Floods in Low-Order Mountain Channels, Carol Coho and Stephen J. Burges, June, 1994.**

Flood waves produced from dam breaks attenuate with distance traveled downstream (Costa 1985). Flood waves produced from dam breaks in low-order mountain channels, however, mobilize significant amounts of organic debris within the stream valley and may cause the formation of a moving dam composed almost exclusively of organic material. This dam.is propelled downstream in a manner often destructive to riparian vegetation, fish habitat, and downstream dwellings, until riparian conditions, channel geometry, or supply of organic debris are altered causing the movement to cease. Initiation mechanisms, movement, and ultimate deposition locations of debris from dam-break floods are described for twenty locations in the Pacific Northwest. Four low-order mountain channels that experienced destructive dam-break floods are described in greater detail. A strategy for evaluating the potential for destructive dam-break floods in low-order channels is provided.

TFW-SH10-91-001 **Geomorphological Watershed Analysis: A Conceptual Framework and Review of Techniques, Lee Benda and Lynne Rodgers Miller, June 28, 1992.**

This report presents a conceptual framework and technical guidelines for evaluating present watershed conditions, and for predicting the response of hillslopes and channels to landuse. The goal is to provide a rational scientific approach for anticipating and solving problems related to forest management in mountain drainage basins. The framework and guidelines we present respond to and are consistent with the directives of the CMER taskforce on cumulative effects.

The conceptual framework is based on a single important concept: each level of analysis builds upon information acquired from the preceding step. Collectively, the analyses are referred to as a geomorphological watershed analysis (GWA).

The GWA consists of methods for measuring and interpreting erosion and channel processes in managed watersheds, and therefore for examining the relationship between watershed conditions and landuse activities. Its structure provides a variety of analyses to accommodate numerous watershed management concerns. For example, the GWA can determine whether erosion and sedimentation is produced by natural causes or by landuse (diagnosing present watershed conditions), screen for environmental thresholds, evaluate and predict influences of forestry activities on erosion and sedimentation (predicting future watershed conditions), and address habitat recovery and restoration. The protocol for applying these analyses to watersheds remains a policy decision for the participants of TFW. The analyses employed will depend on the specific environmental conditions found in a watershed, on the management questions asked, and on the education and experience of the user.

In this report we review technical methodologies for conducting a GWA. The guidelines are brief and consist of short narratives describing published techniques. We discuss relative merits and shortcomings of each. The GWA pertains primarily to hillslope and fluvial geomorphology, fisheries, and implicitly accounts for certain aspects of subsurface and surface hydrology.

This report is not a procedural handbook on how to conduct a GWA. Individuals trained in geomorphology and fishery science should, however, be able to conduct various levels of GWA using this document as a guide.

TFW-SH10-91-002 Proposal for Research in Geomorphological Watershed Analysis, Thomas Dunne and David Montgomery, July 15, 1991.

We propose to continue a project begun in January 1991 that involves a coordinated set of geomorphological studies to address the quantitative relationships between channel morphology and watershed conditions of hydrology, sediment supply, and large channel obstructions in forested mountainous watersheds. Because sediment supply and channel obstructions (such as woody debris, coarse-sediment dams, and active deep-seated landslides) depend on hillslope processes, our coordinated research will be organized into a channel component and two hillslope components (see Figure 1).

The results of the research will include basic advances in the understanding of mountain watersheds and river channels, as well as methods, derived from these improvements, for assessing the effects of forest management on hillslopes and channels. The assessment methods will be usable by M.S.-level personnel trained in earth-science fields such as geomorphology, hydrology, or geotechnical engineering.

The studies have been designed after extensive consultation with the resource-management community in Washington and Oregon. We accomplished this consultation during the six-month start-up period.

The overall goal of the study is to provide the scientific basis and methods for predicting the response of hillslopes and stream channels in forested mountains to (1) long-term average conditions (such as climate, geology, topography, and forest type) and (2) to short-term episodic perturbations (such as fires, extreme weather conditions and particularly timber harvest).

We propose to make progress toward this goal by first dividing the entire complex, watershed problem into three related sub-problems: (1) the channel system; (2) hillslopes from which the sediment supply to channels is from shallow sources (such as surface wash from roads, debris avalanches, and debris flows); and (3) complex terrains that are unstable to great depth and supply sediment to streams by either catastrophic or chronic, slow landsliding, creep, or seepage erosion mechanisms. The main body of this proposal is organized into three sections which detail our various plans for each of these topics.

TFW-SH10-93-001 Geomorphological Watershed Analysis Project, Biennial Report For The Period From 10/1/91 to 6/30/93, David R. Montgomery, Thomas Dunne, William E. Dietrich.

This work includes the following papers:

Montgomery, D.R., and Foufoula-Georgiou, E., Channel network source representation from digital elevation models, EOS, Transactions of the American Geophysical Union, v.74, no.16, p.152, 1993.

Dietrich, W.E., Wilson, C.J., Montgomery, D.R., and McKean, J., Analysis of erosion thresholds and land surface morphology using a digital terrain model, EOS, Transactions of the American Geophysical Union, v.74, no.16, p.194, 1993.

Montgomery, D.R., Buffington, J.M., and Massong, T., Channel classification and prediction of channel response in mountain drainage basins, EOS, Transactions of the American Geophysical Union, v.73, no.43, p.230-231, 1992.

Buffington, J.M., and Montgomery, D.R., Effects of hydraulic roughness and sediment supply on bed surface textures in gravel-bed streams, EOS, Transactions of the American Geophysical Union, v.73, no.43, p.231, 1992.

Schmidt, K.M., and Montgomery, D.R., Mountain-scale strength properties, deep-seated landsliding, and limits to local relief, EOS, Transactions of the American Geophysical Union, v.73, no.43, p.227-228, 1992.

Dietrich, W.E., and Montgomery, D.R., A digital terrain model for predicting debris flow source areas, EOS, Transactions of the American Geophysical Union, v.73, no.43, p.227, 1992.

Dietrich, W.E., Wilson, C.J., Montgomery, D.R., McKean, J., Analysis of Erosion Thresholds, Channel Networks and Landscape Morphology Using a Digital Terrain Model, Journal of Geology, v.101, p.259-278, 1993.

Dietrich, W.E., Wilson, C.J., Montgomery, D.R., McKean, J., and Bauer, R., Channelization Thresholds and Land Surface Morphology, Geology, v.20, p.675-679, 1992.

Montgomery, D.R., and Buffington, J.M., Channel Classification, Prediction of Channel Response, and Assessment of Channel Condition, TFW-SH10-93-002, Washington State Timber/Fish/Wildlife Agreement, 84p.

Montgomery, D.R., and Dietrich, W.E., Landscape Dissection and Drainage Area/Slope Thresholds, in "Process Models and Theoretical Geomorphology" edited by M.J. Kirkby, John Wiley & Sons.

Montgomery, D.R., and Foufoula-Georgiou, E., Network Source Representation from Digital Elevation Models: Water Resources Research.

Zhang, W., and Montgomery, D.R., Digital elevation model grid size, landscape representation and hydrologic simulations: Water Resources Research.

Montgomery, D.R., and Dietrich, W.E., A Physically-Based Model for the Topographic Control on Shallow Landsliding: Water Resources Research.

Montgomery, D.R., Impact of road drainage concentration on the stability of natural landscapes, submitted to Water Resources Research.

Montgomery, D.R., and Buffington, J.M., A process-based channel classification, submitted to Environmental Management.

Bauer, R., Evaluating digital elevation models, submitted to Water Resources Research.

Montgomery, D.R., Peterson, N.P., Buffington, J.M., Schuett-Hames, D., and Quinn, T., Channel Bed Coarsening by Salmonid Spawning: Feedback Mechanism for Population Stability.

Schmidt, K.M., and Montgomery, D.R., Mountain-scale strength properties, deep-seated landsliding, and limits to local relief.

Miller, D., Big Dirt: deep-seated mass wasting project report.

Schmidt, K.M., Deep-seated bedrock landslides and rock mass strength analysis.

Buffington, J.M., Fluvial processes and interpretation of stream-bed surface textures.

TFW-SH10-93-002 Channel Classification, Prediction of Channel Response, and Assessment of Channel Condition, David R. Montgomery and John M. Buffington, June 24, 1993.

A process-based landscape and channel classification is proposed as a framework for assessing watershed response to natural and anthropogenic environmental change. Our proposed classification is based on a hierarchy of process-regimes at several spatial scales: i) geomorphic province, ii) watershed, iii) valley segment, iv) channel, reach and v) channel unit. The geomorphic province level identifies watersheds developed in similar materials, topography, and climates, reflecting comparable hydrologic, erosional, and tectonic processes. The watershed level distinguishes hillslopes from valleys, defining fundamental differences in transport processes within a contiguous drainage basin. Valley segment morphologies further distinguish transport processes and general relations between transport capacity and sediment supply of both channeled and unchanneled valleys. At the reach level, distinct morphologies may be identified based on sediment transport characteristics, channel roughness configuration. Channel reaches, in turn, are composed of finer-scale channel units.

Within this framework, our discussion focuses mainly on the valley segment and channel reach levels. Valley morphology and sediment transport characteristics define colluvial, alluvial, and bedrock valley segments. Unchanneled valleys (hollows) are characterized by a lack of fluvial processes, resulting in a transport-limited accumulation of colluvium that is periodically excavated by mass wasting processes. Channeled colluvial valleys are those in which fluvial sediment transport maintains a channel, but in which the transport capacity is insufficient to mobilize all of the colluvium delivered from the surrounding hillslopes. In mountain drainage basins, colluvial valleys are dominantly carved by mass wasting processes. Alluvial valleys contain predominantly alluvial fills and are characterized by fluvial transport of sediment over a variety of alluvial bed morphologies. Alluvial valley segments may be either confined or unconfined, reflecting general relations between transport capacity and sediment supply. Bedrock valley segments lack a continuous alluvial cover due to high transport capacities. Valley morphology generally reflects the relation between sediment supply and transport capacity.

At the channel reach-level of the classification, bed morphology is coupled with both the potential for debris flow impacts and the role of large woody debris loading to characterize channel processes and provide a framework within which to examine potential channel response. Colluvial and bedrock channels occupy corresponding valley segments, but we recognize six alluvial channel types; regime, braided, pool-riffle, plane bed, step-pool, and cascade. We hypothesize that observed systematic and local downstream changes in alluvial channel morphology and channel roughness correlate with changes in channel slope, sediment supply (size and amount of material available for transport) and transport capacity (a function of the available shear stress). These differences provide the basis for interpreting the potential response of different areas of the channel network to perturbation. In general, steep alluvial channels (step-pool and cascade) tend to maintain their morphology while transmitting increased sediment loads. In contrast, low-gradient channels (regime and pool-riffle) typically respond to increased sediment loads through morphologic adjustment. In essence, steep channels effectively act as sediment delivery conduits connecting zones of sediment production on hillslopes to downslope low-gradient channels. Such distinctions allow recognition of source, transport, and response reaches. Channel morphology thus reflects the local and watershed-integrated processes influencing sediment supply and transport capacity. Evaluation of channel response potential within the context of morphologically-characteristic processes allows distinction of different response potential for different portions of a channel network.

While the proposed channel classification provides insight into potential channel response that can guide impact assessment, changes in sediment supply and transport capacity may result in either similar or opposing effects. This highlights the reality that changes in discharge and sediment supply cannot be examined in isolation; both need to be considered when assessing either watershed conditions or the potential for future impacts. In particular, it is necessary to focus on aspects of channel morphology and dynamics that are sensitive indicators of perturbation and to consider the specific channel type and position in the channel network. A number of quantitative and qualitative approaches provide insight into evaluating watershed impacts and predicting potential responses to continuing or anticipated watershed disturbance.

TFW-SH10-95-001 Mountain Scale Stength Properties, Deep-Seated Landsliding, and Relief Limits, Kevin Michael Schmidt, December 9, 1994.

TFW-SH10-95-002 Effects of Hydraulic Roughness and Sediment Supply on Surface Textures of Gravel-Bedded Rivers, John M. Buffington, March 8, 1995.

Textural response to sediment supply and other hydraulic roughness elements in gravel-bedded rivers is examined by comparing reach-average median surface grain sizes (D_{50s}) with those predicted from a simple threshold channel model. An extensive literature review of bedload transport studies indicates that sediment transport in gravel-bedded channels is to a first approximation bankfull threshold. Using Shields' equation D_{50s} is predicted from bankfull depth and slope, providing a theoretical reference point for examining textural response. The model, however, requires specification of a dimensionless critical shear stress parameter ($\tau^{*}c_{50s}$) values currently available 0.032 is the most appropriate for natural channels.

Previously documented textural response to sediment supply is examined within the bankfull-threshold framework, showing that increased sediment loading causes a systematic textural fining and deviation from model predictions. Textural response to bedform and large woody debris (LWD) roughness is investigated through a field study of gravel-bedded channels in forest environments of western Washington and southeast Alaska. Surface textures are examined in three distinctly different channel morphologies representing an increasing complexity of channel roughness: plane-bed, LWD-poor pool-riffle, and LWD-rich pool-riffle. Results show that textural fining in response to hydraulic roughness features occurs at both reach and local scales and that the number of spatial complexity of textural patches increases with greater complexity of channel roughness. Within the bankfull-threshold framework, reach-average median surface grain sizes segregate by channel type into distinct zones of textural response, with plane-bed channels showing the least deviation from model predictions and LWD-rich pool-riffle channels the most. Median values of textural response distributions reveal that roughness caused by bedforms and minimal LWD result in a two-and-a-half-fold decrease in D_{50s} relative to model predictions, while pool-riffle channels with abundant LWD exhibit a four-and-a-half-fold decrease.

In the channels studied, non-catastrophic levels of sediment loading are apparently subordinate to the controls on surface texture caused by bedform and LWD roughness. Although there is the potential for severe sediment impacts (and hence sediment-induced textural fining) in the study areas, such occurrences tend to be infrequent pulsed events compared to the pervasive influence of stable bedforms and LWD. Consequently, bedforms and LWD provide long term influences that dominate surface textures of the study sites, while sediment supply effects are either relatively less significant or transient.

Coupled with subsurface grain size sampling, the bankfull-threshold model allows evaluation of the degree of textural fining within the theoretical grains size limits and is proposed as a management tool for assessing channel textural-response condition. Naturally large degrees of textural fining in LWD-rich pool-riffle channels generally correspond with small capacities for further surface fining. The bankfull-threshold model and empirically determined response ranges also offer an opportunity to examine geomorphic controls on the availability of salmonid spawning gravels. Textural fining due to sediment supply and hydraulic roughness elements significantly increases spawning habitat availability.

TFW-SH11-91-001 A Process-Based Stream Classification System for Small Streams in Washington, Jeffrey B. Bradley and Peter J. Whiting, April 1992.

A fundamental pre-requisite in the application of environmental regulations to the natural domain is an identification of those parts of a landscape that are sensitive and warrant various degrees of protection. This is particularly true in the evaluation of forest practices which depending on the geometry of a hillslope, the character of the stream channel, and the history of the drainage basin have notably different consequences upon fish, wildlife and water quality. This report outlines a geomorphically process-based stream classification system for small forest streams which provides the framework for building rational regulations.

The present stream typing system is based on an assortment of factors including size, use and fisheries. Type 4 and 5 waters are defined as those not containing anadromous fisheries (WAC 222-16-030) whereas Types 1-3 do contain anadromous fisheries. The present system does not consider stream process or geomorphology except as size is associated with stream type. Best Management Practices (BMPs) vary significantly between Types 1-3 and Type 4 and 5 streams. BMPs for forests in Washington include activities conducted on or directly pertaining to forested lands and relating to growing, harvesting, or processing of timber. Specific issues of concern to TFW include roads, timber harvest, silvicultural practices, and riparian management zones. Of particular significance is that riparian zone practices vary dramatically between Type 3, 4, and 5 streams, yet have not been predicated on a good process based classification scheme. Hence, downstream effects on beneficial uses (fisheries, water quality, et. al.) are not tied to physical process. The ability to correctly identify the appropriate boundary between Type 3 and 4 waters using a process based, geomorphic classification is particularly needed for TFW managers. A 1989 (MacDonald and Ritland) review for the Sediment, Hydrology, and Mass Wasting Steering Committee (SHAMW) revealed a definite need to improve descriptive techniques for small streams.

To date, only limited research information on stream processes, forest practices, and related effects on downstream beneficial uses is available for Type 4 and 5 waters within Washington. Debris flows and debris avalanches are the dominant physical processes in such streams in the western Cascades, the northwest coast and, on a less frequent basis, in the eastern Cascades, Blue Mountains and southwestern Washington. Bank erosion, channel bed erosion and transitional slides are important sediment sources throughout Washington. Sediment storage in headwater streams is strongly tied to channel obstructions, often woody debris including Large Organic Debris (LOD). Channel recovery is generally thought to be rapid with significant reduction in sediment source after the first two to three years following a disturbance. Sediment delivery to downstream areas, affecting beneficial use, is normally episodic and is a result of debris flow, debris avalanche, or "dambreak" floods as woody debris "dams" fail.

The first section of this report is a timely overview of stream classifications. The next section develops a process-based, geomorphic classification system for small streams and discusses a break point between the presently used Type 3 and 4 streams. The effects of mass wasting and its downstream impact related to stream class is then presented. In conclusion, a field assessment work plan is presented to test the validity and applicability of the classification scheme.

TFW-SH12-96-001 Simulation of Water Available for Runoff in Clearcut Forest Openings During Rain-On-Snow Events in the Western Cascade Range of Oregon and Washington, by Marijke van Heeswijk, John S. Kimball, and Danny Marks, U.S. Geological Survey (Water-Resources Investigations Report 95-4219), 1996.

Rain-on-snow events are common on mountains slopes within the transient-snow zone of the Pacific Northwest. These events make more water available for runoff than does precipitation alone by melting the snowpack and by adding a small amount of condensate to the snowpack. In forest openings (such as those resulting from clearcut logging), the amount of snow that accumulates and the turbulent-energy input to the snowpack are greater than below forest stands. Both factors are believed to contribute to a greater amount of water available for runoff during rain-on-snow events in forest openings than forest stands. Because increased water available for runoff may lead to increased downstream flooding and erosion, knowledge of the amount of snowmelt that can occur during rain on snow and the processes that control snowmelt in forest openings is useful when making land-use decisions.

Snow accumulation and melt were simulated for clearcut conditions only, using an energy-balance approach that accounts for the most important energy and mass exchanges between a snowpack and its environment. Meteorological measurement provided the input for the simulations. Snow accumulation and melt were not simulated in forest stands because interception of precipitation processes are too complex to simulate with a numerical model without making simplifying assumptions. Such a model, however, would need to be extensively tested against representative observations, which were not available for this study.

Snowmelt simulated during three rain-on-snow events (measured in a previous study in a clearcut in the transient-snow zone of the H.J. Andrews Experimental Forest in Oregon) demonstrated that melt generation is most sensitive to turbulent-energy exchanges between the air and the snowpack surface. As a result, the most important climate variable that controls snowmelt is wind speed. Air temperature, however, is a significant variable also. The wind speeds were light, with a maximum of 3.3 meters per second during one event and average wind speeds for all three events ranging from 1.7 to 2.1 meters per second. For observed and estimated conditions, the average simulated snowmelt ranged form 0.2 to 0.8 millimeter liquid water per hour, and turbulent-energy exchange provided 51 percent of the energy that led to snowmelt during the largest of the three rain-on-snow events. When wind speeds were multiplied by a factor of 4, the simulated snowmelt ranged from 1.0 to 2.5 millimeters per hour. Similarly, when wind speeds were multiplied by a factor of 6, the simulated snowmelt ranged from 1.6 to 3.7 millimeters per hour. Turbulent-energy exchange provided a dominant 88 and 92 percent of the energy input to the snowpack during the largest rain-on-snow event when average wind speeds were multiplied by factors of 4 and 6, respectively. During the same event, the contributions to the melt by the sum of net solar and net thermal radiation (net all-wave radiation) was roughly equal to the contribution of sensible energy carried by the precipitation itself (advective heat).

Estimates of snowmelt resulting from rain on snow for climate conditions other than those observed and estimated in the simulated plot-scale data were expanded by simulating snowmelt for 24-hour presumed rain-on-snow events extracted from the reconstructed, long-term historical climate records for Cedar Lake and Snoqualmie Pass National Weather service stations in Washington State. The selected events exceeded 75 millimeters of precipitation in 24 hours. When clearcut conditions were assumed to be identical to those at the H.J. Andrews Experimental Forest site and a ripe snowpack that never completely melted was assumed to be available, simulated 24-hour snowmelt ranged from 4.2 to 47.0 millimeters (0.2 to 2.0 millimeters per hour) for low wind speeds (1.5 meters per second) and from 10.3 to 178.8 millimeters (0.4 to 7.5 millimeters per hour) for high wind speeds (8.2 meters per second). The ranges in melt for a given wind speed resulted from the different combinations of air temperature, dewpoint temperature, and precipitation depth that were characteristic of the synthetic events. The average of the median 24-hour snowmelt at Cedar Lake and Snoqualmie Pass was 15.1 millimeters (0.6 millimeters per hour) at low wind speeds and 49.6 millimeters (2.1 millimeters per hour) at high wind speeds. Condensation could increase water available for runoff by a small percentage of the melt. The climate conditions used to generate the range in melt estimates are representative of the transient-snow zone of the western Cascade Range of the Pacific Northwest because Cedar Lake and Snoqualmie Pass are located near the bottom and top of the zone, respectively.

Hourly plot-scale data available from previous studies for clearcut, forested and plantation conditions in the western Pacific Northwest could not be used to simulate snow accumulation and melt over extended periods of time to investigate the effects of different climate and physical conditions. Measurements of snowpack properties were too infrequent; precipitation-density information was absent; and water-available-for-runoff measurements on vegetated plots were not considered representative of larger areas because lysimeters were too small to account for the lateral variability of snow accumulation and melt due to interception processes in the canopy. Lack of representative data for vegetated land precluded the testing of a numerical model that would simulate precipitation-interception processes in the forest canopy. Even for the plot-scale simulations that were done, basic data had to be estimated, and as a result, the three plot-scale rain-on-snow events, as well as the 24-hour events, could be considered synthetic.

To ensure adequate data sets for future studies of climate and physical factors in snowmelt generation during rain on snow, data-collection efforts would include frequent (at least every few days) visits to obtain measurements of snowpack thickness, density, liquid-water content, and temperature and to verify that climate data suitable for use in energy-balance numerical models are being collected. In addition to climate variables such as average hourly wind speed, incoming solar radiation, air temperature, and dewpoint temperature, variables such as incoming thermal radiation, reflected solar radiation, and precipitation density would be measured. Soil temperature would be measured, except at study sties at altitudes where snowpacks remain close to isothermal at 0 degrees Celsius, where those measurements could be optional.

Studies of melt generation during rain on snow on forested land could be designed to account for the lateral variability of snow accumulations and melt that occurs below the vegetative canopy. Plot-scale studies that use small lysimeters to measure water available for runoff are not appropriate for the study of rain on snow in forested settings; instead, a combination of data collection at both the plot and catchment scale could be used. At the plot scale, water available for runoff would need to be measured in a few extremely large lysimeters, or many small ones. At the catchment scale, water available for runoff would have to be computed from streamflow measurements by correcting it for such variables as baseflow, interflow, soil-moisture storage, evapotranspiration, and bank storage. Plot- and catchment-scale data could be analyzed simultaneously, because a nested, duplicate approach is more likely to produce useful results for simulating water available for runoff during rain on snow in forest stands than analysis of either data type alone.

TFW-SH13-91-001 Design of a Slope Hazard Assessment System for Washington's Forested Land, Phase 1, Draft Report, June 1991, Golder Associates.

Golder Associates Inc. provides these guidelines for the evaluation of mass movement on forested land. Our proposal dated January 25, 1991, presented our technical and philosophical approach to the project including the delineation of two separate work phases. Phase 1 was proposed to consider primarily the development of field methods for slope stability hazard assessment. Phase 2 of the project was intended to develop a field verification method for the assessment methods and to develop a decision analysis methodology.

This draft report presents the results of the Phase 1 study and makes recommendations for the second phase.

The specific objective of Phase 1 of the project as identified in the agreement was "to provide methods to identify and rate potential site specific slope stability problems associated with proposed or existing forest roads, including an objective and accountable methodology for collecting and organizing road system information that encourages preventive road management." In conducting the Phase 1 program to meet this objective, we have:

* Attended meetings with SHAMW
* Conducted interviews with technical personnel
* Developed the preliminary slope hazard assessment data sheet and manual
* Drafted a detailed slope hazard assessment data sheet and manual
* Made recommendations for implementing the assessment

For ease of reference, the report has been structured so that Sections 2 and 3 summarize background information collected from an extensive literature search, by way of an internal technical forum, and through interviews with forestry personnel. Section 4 describes the rationale behind the development of a two stage slope assessment methodology. Sections 5 and 6 deal, respectively, with the preliminary and detailed slope hazard assessments. Section 7 summarizes several alternatives for the application of decision analysis techniques to the preventive maintenance of forest road systems. A work plan for Phase 2 of the project is outlined in Section 8 while Section 9 summarizes the salient points of the Phase 1 study. Supplementary data and draft assessment sheets and companion user's manuals are contained in Appendices A through G.

TFW-SH14-91-007 A Road Damage Inventory for the Upper Deschutes River Basin, Steven Toth, January 1991.

In early January, 1990, a 100+ year storm event hit the upper Deschutes River basin causing extensive road damage. This study examined a number of road damage sites to evaluate the factors that contributed to road system problems. Physical terrain feature, road construction standards, and road maintenance levels were analyzed for each damage site. A landslide inventory for the basin was also done using air photos. Roads built in the last fifteen years survived the storm with minimal damage, but roads built 16-45 years ago had very high damage rates. The majority of problems occurred because of steep cutslopes and blocked culverts. Since culvert problems cause the most amount of environmental damage, first priority should be given to replacing older culverts and developing a better inventory of their condition. Another recommendation is to base road maintenance levels on sensitivity to problems rather than on amount of use. Finally, better organization of and access to accumulated data would allow engineers to utilize this information for planning road system maintenance and reconstruction.

TFW-SH15-90-001 Slope Stability in the Transient Snow Zone, T.H. Wu and Carolyn J. Merry, March, 1990.

Landslides are a main source of sediments that affect water quality and fish and wildlife habitats. In the Cascade Mountains of Washington, landslides occur frequently after rapid snowmelt. Particularly serious are landslides during rain-on-snow events in the transient snow zone (Berris and Harr, 1987). For the purpose of landslide hazard zonation, the first task is to map the transient snow zone. This report describes the work accomplished during the first six months of the project for mapping the transient snow zone.

Conclusions

The results of this preliminary study show that AVHRR data may be used to identify snowlines. The elevation variation along the AVHRR snowlines show the spatial component of snow cover, which is a reflection of local conditions. At the Snoqualmie site, we identified the south-facing slopes as locations where the snowline is higher than the mean snowline. The AVHRR snowlines provide a measure of the spatial component that can be used to modify the average snowline as estimated form Brunengo's relation. A methodology was developed to map the mean and variance of snow depth on a given day by combining AVHRR data and snow depth measured for that day with Brunengo's statistical data predicting the average snowline and snow depth. This was done for February 1989 at the Snoqualmie site as an illustration. Interpretation of some AVHRR snowlines is handicapped by a lack of measured snow depth, unknown effects of vegetation and local topography.

The Corps of Engineers model requires input data that are available from weather records. It was found to give reasonable results when compared with snowmelt measured by Harr et al. (1989). Therefore, it provides a practical means for estimating snowmelt. It was shown that this model could be combined with the snow depth map to obtain a probability map of rain plus snowmelt. This probability map is a measure of the severity of rain-on-snow events and it is recommended that the transient snow zone be defined in terms of this probability. It was also shown that this probability map could be used to estimate probable infiltration and landslide hazard.

TFW-SH15-93-001 **Landslide Hazard Mapping, Part 1: Estimating Piezometric Levels; Tien H. Wu, Carolyn J. Merry, Christopher P. Benosky, and Mohamed Abdel-Latif, Revised June 1993.**

This project concentrated on mapping the piezometric levels following rain-on-snow events. This report begins with a review of available methods for computing infiltration and groundwater changes (the hydrology model), for computing slope stability (stability model), and for estimating failure probability. The results obtained will be used to produce landslide hazard maps.

The lumped-parameter model of Reddi and Wu (1991) was used for the hydrology model. A sensitivity analysis was made, and it was found that the important input variables were rainfall, soil thickness, soil porosity, and soil permeability; the piezometric level was found to be insensitive to slope dimensions. Effects of variations in topography, uncertainties about soil properties and geologic anomalies, and rainfall and snow depth were evaluated.

A plot of piezometric level versus return period was constructed for the average site condition, representative of the focus township. Maps of piezometric level for a 10-year period were constructed for Glenoma and Mineral quadrangles. A preliminary landslide hazard map was constructed for Glenoma quadrangle.

TFW-SH15-97-001 **Prediction and Mapping of Landslide Hazard, Tien H. Wu and Mohamed A. Abdel-Latif, December 1996; revised June, 1997.**

The report outlines a mechanics-based methodology for prediction and mapping of landslide hazard for hillside slopes. The principal components are: estimation of rain and snowmelt, estimation of infiltration and groundwater response, and estimation of failure probability.

Brunengo's (1989) statistical data on rainstorms and snow-on-ground were used to predict the rainfall-plus-snowmelt, which constitutes the infiltration at the ground surface. The lumped-parameter groundwater model of Reddi and Wu (1991) was used to predict overall infiltration and drainage from catchments. The finite-difference solution (Lee, 1986) was used to estimate the variations of groundwater levels within catchments. The infinite-slope model was used to predict slope failure and hazard. Predictions with the models are made by using the best estimates of the input parameters and the associated uncertainties. This allows us to account for different levels of accuracy in the available information and judgment based on field observations.

The method allows mapping of landslide hazard at different scales and with various degrees of refinement. In this project, mapping was done at two different levels: a macro-map made with regional site conditions and simplified groundwater profile, and a micro-map made with local site conditions and a groundwater profile that accounts for catchment shape. Macro- and micro-hazard maps were produced for Glenoma and Mineral quadrangles.

TFW-SH17-91-001 **Effects of Landslide-Dam-Break Floods on Channel Morphology, Adelaide C. Johnson, June 1991.**

Landslides are known to temporarily dam channels in mountainous regions of the Pacific Northwest, England, Scandinavia, and Japan, resulting in impoundment of water. Subsequent breaching of these dams initiate dam-break floods. These sudden releases of water, sediment, and woody debris produce flood flows which surpass those of normal floods resulting from snowmelt and rainfall. Dam-break floods have significant effects on downstream valleys and river channels. These impacts vary according to location of the event in the landscape, and they have implications for natural resource scientists and managers.

Dam-break foods that occur in second- through four-order channels are more common than dam-break floods that occur in stream channels that are larger than fourth order. Occurrence and effects of large-scale, low-frequency floods are better understood then the small-scale, higher-frequency dam-break floods that may occur in remote mountainous regions. Smaller-scale dam-break floods in mountainous regions have often been included in the general class of soil mass movements termed "debris torrents".

Debris torrent is a confusing term because it includes a spectrum of stream events that range from sediment flows or debris flows to floods. Dam-break floods result from failure of instream dams composed of sediment and woody debris. Dam-break floods typically decrease in magnitude as they travel downstream unless a wedge of woody debris blocks the flow of water. The wedge of organic debris may move and create a mobile organic dam which enables the flood height to increase as it travels downstream. Catastrophic gullying due to rapid erosion by fluvial processes has also been considered a debris torrent process. Different debris torrent processes may have different patterns of initiation, runout, and deposition. Previous studies of debris torrents processes describe impacts of these events of the dam-break flood as a mechanism that can be differentiated from the general class of debris torrent processes.

TFW-SH20-96-001 Implications of Forest Practices on Downstream Flooding, Phase 2, Final Report. Pascal Storck, Dennis P. Lettenmaier, Brian A. Connelly, Terrance W. Cundy, July 1, 1995.

Field studies have shown that substantial changes in snowmelt during rain-on-snow events can occur due to removal of forest cover. These changes are attributable to differences in snow accumulation as a result of canopy interception changes, and to differences in latent and sensible heat associated with increased wind at the snow surface when vegetation is removed. However, the field studies are of necessity point observations; at the watershed scale, the effects of vegetation changes on any particular flood are complicated by variations in antecedent snow accumulation, spatial differences in temperature and precipitation during the storm, and the area-elevation distribution of the watershed.

At the watershed scale, physically realistic computer simulation models offer the best hope for understanding the effects of forest harvesting on hydrologic response, and on flood peaks in particular. The Distributed Hydrology-Soils-Vegetation Model (DHSVM) was modified for the purposes of evaluating the effects of forest harvesting on flooding. Changes and enhancements to the model include: a) incorporation of a module to estimate topographic effects on precipitation, b) modification of the original single layer snow model to incorporate a thin surface layer, c) inclusion of a channel routing scheme, and d) certain changes to the representation of vegetation effects on aerodynamic resistance under the forest canopy.

Following testing of the modified version of DHSVM, it was applied to produce a 46 year simulation (1948-93) of the Snoqualmie River at Carnation, with vegetation fixed at 1989 conditions. The residuals (difference between simulated and observed peak flows) were analyzed for trends. Because the residuals series is effectively adjusted for climatic variations that might have been associated with the specific storms associated with the floods, any trends should be the result of vegetation changes.

Based on the residuals analysis, the major conclusions of this study are:

1) No significant trend has occurred during the period of analysis in the annual maximum flood series, while the smaller floods in the peaks over threshold series (less than 650 cms) showed statistically significant increases;

2) The amount of forest harvesting that has actually occurred in the Snoqualmie River watershed is not enough to explain the observed trend in the smaller floods in the peaks-over-threshold series;

3) Land use effects not represented by DHSVM, such as forest roads, may have a greater effect than ROS physics, which are represented by the model;

4) The largest changes in peak streamflows were found to occur from spring peak flows, most of which are significantly smaller than bankfull capacity. While this result is not of practical significance in terms of flood changes in the Snoqualmie basin, it may have important implications for changes in flood peaks resulting from forest harvesting in eastside catchments, where spring snowmelt peaks dominate the flood series;

5) Observed changes in the smaller floods of the peaks-over-threshold series are much larger than those predicted given the magnitude of historical land use changes. This result suggests that some mechanism other than changes in ROS runoff is the cause.

A sensitivity analysis was conducted of changes in selected events in the peaks-over-threshold series that would have occurred for three alternative harvest strategies, with harvested areas distributed spatially based on visual impact considerations. The three strategies resulted in 10 percent of the basin being cut at elevations below 300 m, between 300 and 900 m, and above 900 m, respectively. The peaks-over-threshold for the period 1948-55 with the alternative strategies, and for prescribed complete forest cover, were compared using DHSVM. Increases in the peaks-over-threshold were predicted to be small, averaging under 2 percent (maximum 10 percent) for harvest below 300 m, about 2 percent (maximum 5 percent) for harvest between 300-900 m. Even smaller changes were predicted when the harvest was concentrated above 900 m.

TFW-SH20-97-001 Evaluation of the Effects of Forest Roads on Streamflow in Hard and Ware Creeks, Washington, Laura C. Bowling and Dennis P. Lettenmaier, September 1997.

Road networks in mountainous forest catchments may increase peak streamflow by replacing subsurface flow paths with surface flow paths. Forest roads affect runoff generation via two mechanisms: capture of subsurface water by road incisions, and generation of infiltration excess runoff from road surfaces. The quantity of runoff intercepted by the road network was monitored in two small Western Washington catchments, Hard and Ware creeks (drainage areas 2.3 and 2.8 square km, respectively). Road densities in both catchments are approximately 5.0 and 3.8 km/square km, respectively. Observations indicated that the highest peak culvert discharges in Hard and Ware Creeks are associated with subsurface flow interception rather than road surface runoff. A total of 111 culverts in the two catchments were located using GPS. For each of the road segments defined by the culverts, road widths, slopes and the fraction of the road surface draining to the culvert were measured, and each of the culvert outlets was field checked to determine whether the culvert was hydraulically connected to the channel system. Based on the field study, the effective channel network density was found to have increased by 64% in Hard Creek and 52% in Ware Creek due to road construction.

The Distributed Hydrology-Soil-Vegetation Model (DHSVM) is an explicitly distributed hydrological model that simulated the land surface water and energy balance at the scale of a digital elevation model (DEM). DHSVM represents water movement through the unsaturated zone and the vegetation canopy in one dimension, as well as subsurface and surface lateral flow. It accounts for interception of precipitation as both rain and snowfall in the forest canopy. a new scheme represent s the effects of forest roads on runoff generation in DHSVM via two mechanisms: capture of subsurface water by road incisions, and generation of infiltration excess runoff from road surfaces. Runoff produced by both mechanisms is routed through an expanded (roads plus pre-existing channels) channel network using a Muskingum-Cunge scheme. DHSVM-simulated lows with and without roads were compared to continuous recording gauges at the outlets of each of the basins, and to cres-recording gauges installed on 12 culverts for selected storms during the winter of 1995-96. Simulated basin conditions indicate that the roads redistribute soil moisture throughout the basin, resulting in drier areas beneath the road right-of-way relative to the simulation without roads. Based on retrospective simulations using eleven years of data, the mean annual floods in Hard and Ware Creeks were predicted to have increased by 11%, and the mean of 4 peaks over threshold were predicted to have increased by 8 and 9%, respectively.

TFW-WL1-91-001 1988-90 Cumulative Report, Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat, Washington Department of Wildlife.

This project, Characterization of the Physical and Botanical Characterizations of Riparian Management Zones (RMZs) and Upland Management Areas (UMAs) with Respect to Wildlife Habitat, was designed to provide detailed information on RMZs and UMAs. The project provides a "snapshot" view of RMZs and UMAs as they occur throughout the state of Washington.

Although originally not the intent of the project, data were interpreted where possible to determine the value of habitat provided for wildlife in RMZs and UMAs, and compared to the Washington Forest Practices Rules and Regulations where possible. Although originally planned for six years, monitoring was discontinued after three years because enough data had been collected to accomplish project goals and objectives.

RMZs are defined in the Washington State Forest Practices Regulations, WAC 222 (1988) as a specified area along Type 1, 2, or 3 waters where specific measures are taken to protect water quality and fish and wildlife habitat. Riparian zones are among the most heavily used wildlife habitats in the forests of Washington (Thomas et al., 1979). They occur along rivers, streams, intermittent drainages, ponds, lakes, reservoirs, springs, and wetlands.

UMAs are areas of naturally occurring trees and vegetation where specific silvicultural activities have been designed to provide wildlife habitat (Forest Practices Board Manual, 1988). UMAs are voluntary under the TFW agreement. They are intended to increase habitat diversity by providing vegetative conditions that would not normally occur in harvested areas. The TFW intent was for UMAs to provide increased diversity through irregular scattering or dispersion of habitats for a broad spectrum of wildlife species. This project provides an information base for more detailed studies on the value and use of RMZs and UMAs for wildlife.

TFW-WL1-91-003 1988-90 Cumulative Report, Characterization of Riparian Management Zones and Upland Management Areas with Respect to Wildlife Habitat, Washington Department of Wildlife

Data documentation for TFW-WL1-91-001.

TFW-WL1-93-001 Wildlife Use of Riparian Habitats: A Literature Review, compiled by Margaret A. O'Connell, James G. Hallett, Stephen D. West; March 1993 .

This paper provides a review and synthesis of the literature on wildlife use of riparian habitats in the Pacific Northwest that has served as a cornerstone in the design of an adaptive management study that examines the effectiveness of RMZs in providing habitat for wildlife.

The literature synthesis is organized around the following components. In the background section, an overview of riparian ecosystems is presented. In this section the structure and function of riparian zones with respect to the major elements of a riparian zone, the interaction of terrestrial and riparian environments in the riparian zone, and the role of disturbance in shaping riparian habitats are examined. The overview addresses general considerations of wildlife use of these habitats. Reviewed next are theoretical considerations of habitat fragmentation that are relevant to understanding how wildlife species might respond to changing habitat conditions as a result of timber management practices under the RMZ guidelines.

The second section provides a review of empirical studies on wildlife use of riparian habitats and response to habitat variation in riparian forests. The focus is on studies from the Pacific Northwest (PNW), but include other studies that deal with general considerations of wildlife/riparian relationships. The literature was examined to address the following types of questions: 1) What are the relative dependencies of PNW species on riparian habitats? 2) What are the critical habitat components that riparian habitats provide for wildlife? 3) How do different silvicultural activites, including road building, in riparian areas affect wildlife? 4) What is the potential response of wildlife species to the establishment of riparian buffer zones?

The third section is a review of the methodologies used to examine these issues. First considered are field methods used to sample vertebrate populations. Next considered were the field methods used to describe habitat, determine population parameters of species, and determine community composition. The importance of using multiple metrics to examine wildlife use of riparian areas is stressed. Wildlife communities are expected to exhibit temporal and spatial variability. For example, one might use species diversity. However, in riparian fragments, species diversity characteristic of the riparian habitat might be lost. Population and community parameters are then reviewed.

The fourth component develops a ranking system for Washington's riparian wildlife species. Recently, Millsap et al. (1990) developed a system which ranked Florida's wildlife taxa according to biological vulnerability, population status, and management needs to prioritized conservation efforts. The ranking system was based on a biological score, an action score, and a supplementary set of scores dealing with taxonomic, biogeographic, and political concerns. The biological score was a compilation of 7 variables measuring aspects of a species' distribution, abundance, and live history. The action score was based on 4 variables measuring the current state of knowledge the taxon's distribution, population trend, and limiting factors as well as current experience of wildlife biologists. Millsap et al. (1990) tested their ranking system by examination of how the system ranked species of known status in Florida and found close agreement. The methods of Millsap et al. (1990) were modified to rank riparian wildlife species of Washington. The ranking system presented here is an initial exercise that will be fine-tuned as more information is collected on these riparian species.

Online searches were conducted on BIOSIS (Biological Abstracts) and Cambridge Life Sciences, AGRICOLA (data base of the National Agricultural Library, CRIS (Current Research in agriculture and related science). Current literature was reviewed by consulting publications such as Current Contents and by reviewing relevant journals. In addition to standard library research procedures, relevant reports were obtained from appropriate government agencies and TFW cooperators. All citations have been entered into a bibliographic database. This has allowed sorting of citations by selected keywords and periodic updating through the life of the project.

TFW-WL3-94-001 Effectiveness of Riparian Management Zones in Providing Habitat for Wildlife: Pre-Harvest Interim Report, Stephen D. West and Kathryn A. Kelsey, June 30, 1994.

The objectives of the study were threefold: 1) to determine whether current RMZ habitat specifications provide adequate habitat to maintain wildlife as specified in the TFW wildlife goal (TFW Agreement 1987. Wildlife Action Plan 1990), 2) if they do not, to identify those habitat conditions created by current RMZ management practices that adversely affect species assemblages, and 3) to provide recommendations for improving RMZ guidelines. These objectives were approached in an experimental fashion by monitoring the population responses of selected wildlife species and species groups within riparian zones and nearby upland habitats on a total of 18 sites of harvestable age (Figure 1 and Table 1). Six sites would be harvested according to current RMZ guidelines, six according to modifications of the guidelines, and six would remain unharvested as controls. Wildlife monitoring would be for two years prior to and two years immediately after harvest. This strategy would establish the baseline conditions from which to compare future changes in the RMZ.

Due to the highly integrated nature of this research project, progress has been possible only with an extraordinary measure of involvement from cooperators. This has been manifest from funding through the planning phases of the work to implementation in the field. This is an unprecedented research project in Washington, and it represents one of the largest efforts in this country to understand the effects of forest management on wildlife communities in riparian zones.

Site selection for this project was difficult. Avian sampling could not be done during the first year because of the lack of sites. Thirteen sites were available for wildlife censusing during the fall sampling period of the first year. Trapping for small mammals and terrestrial amphibians was completed for all sites; stream surveys for aquatic amphibians were conducted on 12 sites; and bat echolocation surveys were conducted on 10 sites. During the winter the full complement of 18 sites were located. Avian censusing was completed the following spring and early summer on all sites.

Completion of the fall sampling for the second year had several important effects. In terms of the usefulness of the data set, the second sample provided 1) a two-year average for the baseline condition which allows for the statistical comparisons for all wildlife groups (except birds) between sites and over time, 2) the opportunity to make comparisons within sites from the current data set, i.e., riparian vs. upland comparisons, 3) all of the vegetation/habitat measurements which were scheduled for the second year; and 4) give information for birds, small mammals, stream-dwelling amphibians, terrestrial amphibians, and bats for all 18 sites.

Sites are in the process of being harvested. With delays in harvesting on four of the sites, there will be no sampling in 1994.

TFW-WL4-91-001 Wildlife Use of Managed Forests - A Landscape Perspective, Stephen West, James Hallett, June 28, 1991.

The managed forests of Washington State encompass approximately 17,305,000 acres of which about 63% are on State and private lands (Card et al. 1985). A critical question facing TFW resource managers is how to balance the TFW wildlife goal to "provide the greatest diversity of habitats (particularly riparian, wetlands and old growth), and to assure the greatest diversity of species within those habitats for the survival and reproduction of enough individuals to maintain the native wildlife of Washington forest lands" with the timber resource goal of "...continued growth and development of the State's forest products industry..." (Timber Fish and Wildlife 1987).

The May 1991 workshop resulted in a number of recommendations to modify the objectives stated in the Request for Proposals (RFP). The objective of determining habitat relationships affecting long-term population viability was dropped with the realization that population viability analysis was beyond the scope of this rather broad exploratory project. Rather, data collection would focus on defining as yet unknown habitat relationships in managed forests at the stand and landscape levels. A second objective to produce a highly-structured, predictive computer model with widespread application to forest wildlife management was also dropped as unrealistic within the scope of the project. We agreed, however, that the research team would develop methods for analyzing landscape and stand-level impacts on wildlife in managed forests. Some of those methods will certainly include modelling efforts and the use of GIS, but may not be a highly structured and rigorously validated simulation model. The revised objectives of the project are to:

- describe the species composition and abundance levels of wildlife and plant communities occurring in forest stands of varying seral stages, size-classes and landscape configurations in watershed managed primarily for timber production;

- develop methods for analyzing wildlife responses to landscape-level habitat conditions in managed watersheds.

TFW-WL4-96-003 Wildlife Use of Managed Forests - A Landscape Perspective, A Workshop. Stephen West, Keith B. Aubry, James G. Hallett, Margaret O'Connell, David A. Manuwal, Janet L. Erickson, Scott F. Pearson, Angela B. Stringer, Levon P. Yengoyan, Matthew W. Frazier, Deborah Beutler, Lori A. Campbell, Robert E. Griffith, Douglas R. Call, Stephen G. Mech, Jason A. Thomas, October 1996.

TFW-WQ1-92-001 Proposed Surface Water Criteria for Selected Pesticides Used for Forest Management and Management of Forest Tree Seedling Nurseries and Christmas Tree Plantations in Oregon and Washington, Logan A. Norris and Frank Dost, August 20, 1992. (Replaces TFW-WQ1-91-001.)

Surface water quality standards for pesticides used in forestry are needed to (1) permit evaluation of the effect of pesticide use on aquatic organisms and on humans and animals which consume water from forest areas, (2) determine the effectiveness of strategies used to protect water quality, and (3) provide a basis for evaluating adherence to regulatory rules which govern the use of pesticides in forestry in Washington and Oregon. The purpose of this report is to provide surface water quality criteria which provides the basis for selecting standards to meet these goals. This effort was undertaken at the request of the Oregon Department of Forestry and the Washington Department of Natural Resources. The report has been extensively reviewed and revised in response to reviewer's comments.

Water quality standards for forest pesticides are usually developed to assure protection of human health and prevent adverse toxic effects on aquatic organisms, or terrestrial animals which may reside in or consume the water. This report identifies specific pesticides in surface water which will achieve these goals in connection with the following two broad patterns of pesticide use:

(a) forest management, and
(b) forest seedling nursery and Christmas tree plantation management.

These criteria in turn can provide a basis for establishment of water quality standards.

This report is in three major sections. Section 1 deals with concentrations to protect human health. Section 2 focuses on protection of freshwater aquatic organisms. Section 3 combines information from Sections 1 and 2 to identify potential water quality standards which we feel will protect humans, aquatic organisms, and other animals.

TFW-WQ1-93-001 Effectiveness of Best Management Practices for Aerial Application of Forest Pesticides, Ed Rashin, Craig Graber, October 1993.

Forest practices, including the use of pesticides, are conducted in accordance with Best Management Practices (BMPs) established in the Washington Forest Practices Rules and Regulations. This project was undertaken to evaluated BMP effectiveness through intensive field monitoring of forest pesticide applications. Determination of BMP effectiveness is based on interpretation of various provisions of state water quality standards (WQS), forest practice rules, pesticide registration labels issued by the U.S. Environmental Protection Agency (EPA), and Department of Agriculture pesticide regulations.

This study employed intensive sampling of streams that flow through or adjacent to units treated by aerial (Helicopter) applications of forest pesticides to monitor the entry of chemicals into surface waters. Seven of these case studies served as representative examples of BMP implementation, and were used to determine BMP effectiveness for the application scenarios represented. We sampled dormant and early foliar herbicide operations conducted during April and May, late foliar herbicide sprays conducted in September, and an insecticide/fungicide spray conducted in early June of 1991. The silvicultural operations included five conifer release herbicide sprays (one dormant spray, two early foliar sprays, and two late foliar sprays), one site preparation herbicide spray (late foliar), and one Christmas tree pest control spray. Pesticides applied included 2,4-D, triclopyr, glyphosate, imazapyr, metasystox-R, and chlorothalonil.

Pesticides were detected in streams following applications at all seven sites, with peak levels ranging from 0.02 to 7.55 μg/L. Pesticides were also detected in runoff at the four sites where runoff events were sampled. Runoff sampling occurred 2 to 25 days following the applications, and concentration ranged from 0.17 to 2.49 μg/L. Maximum instantaneous concentrations found were 1.29, 2.49, 7.55, 1.15, 1.72, and 2.80 μg/L, respectively, for triclopyr, 2, 4-D, glyphosate, imazapyr, chlorothalonil, and metasystox. Excluding runoff events, peak concentrations occurred within the first three hours following the spray in all cases. Maximum 24-hour average levels were 0.13, 0.69, 0.56, 0.36, 0.18, and 3.25 μg/L, respectively, for the same six pesticides. Based on the timing of peak concentrations, the majority of pesticide introduction to streams was attributed to off-target swath displacement and drift from spray areas near streams. The overall distribution of pesticide levels indicated that overspray of small headwater streams (which the applicator had incorrectly assessed as not having surface flow) also contributed to levels found at some sites.

The BMPs were determined to be partially effective or ineffective based on three tests of effectiveness. First, water quality standards regarding toxic levels of pesticides were not met in at least one of the case studies. Second, the BMPs were not effective at avoiding drift causing direct entry of pesticides into surface waters or Riparian Management Zones, as required by the Forest Practice Rules. And third, the BMPs were not effective at complying with certain pesticide product label restrictions regarding entry to surface waters and avoidance of off-target drift. Recommendations for improving the BMPs include revised stream buffer requirements, specifications for spray nozzle configurations, and improved procedures for determining whether small streams must be buffered. Recommendations for stream buffers include minimum buffers of 15 to 25 meters for downwind applications and 75 to 90 meters for upwind applications along all flowing streams.

TFW-WQ3-90-006 Evaluation of Prediction Models and Characterization of Stream Temperature Regimes in Washington, with Data Appendix, December 1990.

A temperature study was undertaken in 1988 to develop a method to address temperature sensitivity on a site and basin scale. The temperature study was designed to generate information for two primary purposes: data was collected from forest streams extensively (92 sites) throughout the state to develop a temperature sensitivity screening method and intensively at a smaller number of sites (33) to evaluate the predictive capabilities of existing reach and basin temperature models. Study sites represented type 1-3 streams located in all regions of the state having a variety of riparian shading conditions ranging from mature conifer forest to sites completely open and devoid of shade.

This report documents the results of the Temperature Study and recommends a method to TFW. In addition, a preliminary evaluation of the effectiveness of riparian management regulations is provided based primarily on temperature modeling.

Many of the 92 study sites were found to exceed water quality temperature criteria including most reaches with less than 50% shade but including some reaches with mature forest canopies along larger rivers. Where timber harvest had occurred, activities at all sites except one had been conducted *prior* to the TFW Agreement and did not reflect riparian conditions left according to the regulations adopted in 1987. Of all sites, 62% were found to be temperature sensitive according to the Forest Practice temperature standard and 72% exceeded the DOE water quality temperature standard. This large number of sites exceeding biologically-determined criteria confirm that past riparian management practices had significantly affected temperature in forest streams.

Although many characteristics were shown to correlate with stream temperature, two factors were of such overwhelming importance that they could be used to reliably predict temperature sensitivity--shading and elevation (which probably indicates air temperature regime). A simple graphic model (the temperature "screen") based on these characteristics correctly identified the temperature category according to water quality criteria of 89% of the sites.

Shading specified by the regulations was found to be generally inadequate for protecting temperature of type 1-3 waters. Based on study results, *total* stream shading of 50-75% after cutting is needed to maintain water temperature in most streams within water quality standards (rather than the 50-75% of the *existing* shade as specified in current rules). However, because the importance of shade varies with elevation, a shading guideline based on elevation of the site is recommended.

The temperature sensitivity screen based on site elevation and shading forms the basis for the recommended TFW temperature method. The screen can be used to estimate temperature conditions of a reach before and after timber harvest based on an easy to measure shading parameter with good reliability. Where greater precision may be needed, a temperature prediction model requiring more carefully conducted field measurement may be used.

The effectiveness of temperature prediction models was analyzed to identify models that could be used where needed. Four reach temperature prediction models (Brown's Model, TEMP-86, U.S. Fish & Wildlife Service SSTEMP, and TEMPEST) were rigorously evaluated for prediction accuracy and practicality of use. A sensitivity analysis was performed to determine each model's sensitivity to key input parameters of importance to stream temperature (for example, shading, air temperature, solar radiation, and stream depth). Several of the models were found to predict water temperature with reasonable reliability, even when input data is estimated, although models varied in predictive capability and practicality. One reach model was selected that satisfied both prediction accuracy and practicality criteria developed with TFW field managers in mind. The computer model is simple to use by anyone.

The recommended method includes an easy to apply temperature screen based on elevation and shade of a site. From this, the amount of shade needed to maintain temperature within water quality standards can be determined. This temperature screen can adequately predict temperature of most sites. In some cases, more careful design of riparian leave trees with shade in mind may be warranted. The computer model may be used at sites where unusual situations suggest that screening results may be inaccurate or to verify predictions made with the screen. Widespread need for the computer model is not foreseen. (It is likely that a temperature sensitive type 4 streams can be identified in a manner similar to that of the temperature screen for type 1-3 waters.)

TFW-WQ3-90-007 The Physics of Forest Stream Heating: A Simple Model, by Terry N. Adams and Kathleen Sullivan, 1989.

The basic physics of forest stream heating is investigated. Expressions for the individual energy transfer modes are developed in a simple and direct manner so that the parametric influence of various environmental conditions can be established. The environmental conditions include the daily average solar insolation, local air temperature, shading by riparian vegetation, air velocity and relative humidity, and groundwater intrusion. A mathematical model is developed and applied over a broad range of conditions. The predicted stream temperature is broken into two components, the daily mean stream temperature and the stream temperature fluctuations about the mean. The actual stream temperature is the sum of these tow. Three major conclusions are drawn from the model results. First, the daily mean stream temperature is always very near the daily mean air temperature when the stream is in equilibrium with the environment. Other environmental parameters including solar insolation are shown to have relatively little influence on the daily mean stream temperature after an initial transient heating period. In contrast, the fluctuations in stream temperature about the mean are strongly influenced by solar insolation, riparian vegetation, and diurnal fluctuations in air temperature. Second, stream depth is the primary geometric parameter characterizing stream size for energy transfer purposes. Stream depth affects both the response time and magnitude of the fluctuations in stream temperature. Third, groundwater influx is an important factor in the temperature of small streams.

The full energy transfer model is then linearized so that an analytical solution is possible, and both the mean stream temperature and the fluctuating component of stream temperature are expressed as algebraic functions of only ten important environmental parameters. Comparison between the linearized model and the full model is shown to be very good. The basic results of the full model are confirmed by the linearized model.

TFW-WQ4-91-002 TFW Stream Temperature Method: User's Manual, Doughty, Caldwell, & Sullivan, June 1991.

T/F/W identified key management issues to focus for further research efforts, including: (1) criteria for identifying temperature sensitive streams (2) a method for describing their geographic extent, and (3) a reliable method of predicting water temperature keyed to riparian management.

1988-1990 T/F/W Temperature Study

A study was undertaken in 1988 by the Temperature Work Group (TWG) to develop a method to investigate temperature on a site and basin scale. The temperature study was designed to generate information for two primary purposes: data was collected from forest streams extensively (92 sites) throughout the state to develop a stream temperature screening method and intensively at a smaller number of sites (33) to evaluate the predictive capabilities of existing reach and basin temperature models. Study sites represented Type 1-3 streams located in all regions of the state having a variety of riparian shading conditions ranging from mature conifer forest to sites completely open and devoid of shade.

Application of this Manual

This manual is based upon the results and recommendations of the above mentioned study. The manual presents a step-by-step method for determining shade levels necessary to meet the Washington water quality criteria of the state water quality standards.

T/F/W managers likely to use this method include state, private and tribal foresters, fisheries biologists and water quality regulators. The method relies on a graphical temperature screen and a computer model that can be used to predict temperatures within a stream reach. The temperature screen is a simple tool to predict temperature category dependent upon site elevation and stream shading. The temperature screen does not require a computer, while using the computer model requires an IBM-compatible personal computer with a minimum 512K RAM

TFW-WQ4-91-003 Management Trials Testing Plan for the TFW Stream Temperature Methods., Caldwell, Sullivan, & Doughty, July 1991.

A stream temperature study was undertaken in 1988 by the Temperature Work Group (TWG) to develop a method to address stream temperatures and the impact of harvest practices at both a site and basin level. The results of that study are presented in the 1990 Temperature Report (Sullivan and others, 1990). A method for identification of temperature-sensitive streams and appropriate shade requirements to meet Water Quality temperature standards was presented to T/F/W.

The Temperature Study identified that current regulations for shading of riparian zones may not meet water quality standards in all stream locations, and provided an initial recommendation on where and how to determine appropriate alternative shade levels. These conclusions appear to be verified by a current riparian temperature study conducted by the Dept. of Ecology, which evaluates the regulations (E. Rashin, Dept. of Ecology, pers. comm.)

The recommended method includes an simple graph which classifies stream reaches based on their elevation and shading levels. Using this, the amount of shade needed to maintain water temperatures within the Water Quality standards can be determined. As a backup, a computer model is also presented, to be used at stream sites where circumstances suggest that additional temperature evaluation is necessary. Widespread use of the computer model is not foreseen at this time. The current version of the recommended method is presented in the Stream Temperature Method Users' Manual (Doughty and others, 1991).

This document is a companion to the Temperature Method Users' Manual. Together, they present a method for field testing the recommended temperature method. Recommendations for two avenues of additional investigation are also made. The first is an assessment of current information regarding typical levels of riparian shade on Washington streams, and the second is an investigation of the Water Quality standard's stream classification system and ambient stream temperatures.

At this time, no definite plans are in place to proceed further with the management trials. This project was one of the first T/F/W research products to approach this field testing phase. Some policy questions and administrative concerns encountered by the Temperature Work Group and the CMER/FIC Implementation Subcommittee are discussed, in order to aid future investigators.

TFW-WQ4-93-001 TFWTEMP Computer Model: Revisions and Testing; Kent Doughty, J. Smith and J. E. Caldwell, June 1993.

In 1988 a study of available stream temperature models was initiated by TFW cooperators. The TEMPEST model was found to perform well and be the most practical stream temperature model available. Although less restrictive than many other models the TEMPEST model requires substantial site specific information including hourly air temperature data. The TFWTEMP model is an adaptation of the TEMPEST model to reduce the data input requirements for modelling stream temperatures. The TFWTEMP model uses regional climate data and estimates of stream channel characteristics to internally generate values for input variables necessary to solve the energy balance equations for stream heat exchange. The model user simply provides information readily available from maps (location, elevation, water quality classification, distance from watershed divide) along with estimates of riparian shade conditions.

The product of this project is TFWTEMP version 7.0. this model, available on diskette, runs on IBM compatible computers. It is designed to evaluate if the incremental increase in stream temperature associated with the harvest of riparian shade trees complies with the Washington water quality standards. The model is applicable to Washington streams only. Modifications in the latest version include improvements to the user interface computer screen prompts and a physical process model for estimating summer climatic conditions at sites to be modelled. Testing of the model at 75 sites throughout Washington indicated average model precision to be 1.9°C, 1.6°C, and 2.7°C for coastal, western, and eastern Washington ecoregions respectively.

TFW-WQ5-91-004 Evaluation of Downstream Temperature Effects of Type 4/5 Waters.

Stream Types 4 and 5 are generally small headwater streams that do not support significant fish populations. Current forest practices regulations do not require any riparian trees to be left after harvest on Type 4 and 5 streams, as they do on stream Types 1-3. The possibility of temperature impacts from removal of riparian trees along Type 4 waters on downstream, salmonid-bearing waters has remained a concern. This study investigates the effect on stream temperatures of forest practices along Type 4/5 waters in Washington. Consideration is given to both stream temperature effects within the Type 4/5 water as well as potential downstream temperature effects in fish bearing waters.

This study supplements a previous study (Sullivan and others, 1990) which investigated stream temperatures for larger Type 1-3 rivers and streams in Washington. It was anticipated that stream temperatures in Type 4/5 streams would behave similarly with respect to two basic principles reported for larger streams. First, stream temperature tends towards equilibrium with the surrounding environmental conditions. The interaction between temperature and environmental conditions occurs in a complicated yet predictable manner. Second, the maximum equilibrium temperature for a stream reach (the hottest temperature reported for a stream reach) can readily be categorized with minimal information; specifically shade and elevation. However, we would also anticipate temperatures in smaller streams to be much more responsive to localized factors such as groundwater.

Three primary objectives of this study were:

1) Characterize temperature regimes in Type 4 waters of Washington.

2) Assess the magnitude and extent of downstream effects related to water temperatures of upstream Type 4 waters.

3) Provide recommendation for management of riparian areas on Type 4 waters relevant to potential downstream temperature impacts.

All study objectives were met, except that the streams surveyed were limited to western Washington. In summer 1990 air and water temperatures were monitored at multiple points along the 4/3 water type interface for nine locations in western Washington. The conclusions and recommendations within this report are based upon the results of this monitoring.

The conclusions and recommendations for the management of riparian areas along Type 4 streams are only based on stream temperature concerns. Numerous other factors also must be considered in the management of forest practices along type 4 streams. Though downstream temperature impacts are negligible, erosion and other factors are still relevant to the management of Type 4 streams.

TFW-WQ6-92-001 Effectiveness of Washington's Forest Practice Riparian Management Zone Regulations for Protection of Stream Temperature, Ed Rashin and Craig Graber, Washington Department of Ecology, July 1992.

The Forest Practices Rules and Regulations contain Best Management Practices (BMP) which include requirements for Riparian Management Zones (RMZ) on certain water types affected by timber harvest activities. The purpose of this study was to test the effectiveness of the BMPs (i.e., RMZs) at achieving water quality standards for temperature.

Recording thermographs were deployed upstream and downstream of thirteen RMZs statewide during the summer of 1990 to monitor stream temperature response to timber harvests. Streams and riparian zones were characterized to evaluate factors influencing the observed temperature conditions.

Maximum observed water temperatures ranged from 12.8°C to 19.9°C. Maximum water temperature change between upstream and downstream monitoring sites ranged from 0.3°C to 5.2°C. Definitive determinations of whether applicable water quality criteria were met or exceeded were not possible for many of the study sites due to uncertainties related to thermograph accuracy and/or representativeness of the monitoring period. Water temperature criteria were met or judged likely to be met at three of the thirteen study sites. These RMZs were considered effective. Temperature conditions at five of the thirteen study sites exceeded applicable criteria for maximum allowable temperature, with conditions at an additional three sites possibly exceeding criteria. The BMP was considered ineffective at six of the sites where maximum temperature criteria were exceeded or possibly exceeded. At two of the five sites where maximum allowable temperature criteria were exceeded, the exceedances were attributed to factors other than timber harvesting at the study site, and the BMP was considered effective. Possible exceedance of the criteria for allowable temperature change due to timber harvesting was indicated by the monitoring results at two of 13 sites. At one additional site, exceedance of the temperature change criteria was suspected based on spot field checks.

The primary factors influencing BMP effectiveness appear to be site elevation, post-harvest shade levels, groundwater flux within the reach, and stream morphology. Stream modification by beavers was a significant factor influencing the effectiveness of RMZs at some sites. The proposed new TFW method for identifying temperature sensitive streams takes the most important factors into account, and is expected to correctly identify streams where enhanced RMZs are needed in a majority of cases. To optimize the effectiveness of RMZs, procedures to identify and address site specific anomalies which result in temperature sensitivities that would not be identified by the new TFW stream temperature screen and/or model should be incorporated into the BMPs.

TFW-WQ8-91-008 Methods for Testing Effectiveness of Washington Forest Practices Rules and Regulations with Regard to Sediment Production and Transport to Streams, Pentec Environmental, Inc., June 28, 1991.

The purpose of this project is to develop a methodology to test how effectively the Washington Forest Practice Rules and Regulations (Washington State Forest Practice Board, 1988) minimize sediment production and delivery of sediment to streams. Washington statute 173-202 WAC identifies specific forest practice regulations as Best Management Practices (BMPs), which are required to protect water quality from impacts caused by forest management activities. The Washington Department of Ecology (WOE) is required by State and federal statute to assess how effectively the BMPs maintain water quality.

The methodology for testing the forest practice rules' effectiveness developed in this report is based on a multidisciplinary approach ranging from geomorphology to forestry. The method is based on several supporting tasks including a literature review of the sources and severity of sediment production in managed forests, the geographical variation of erosion processes and magnitudes across Washington State, and an analysis of the conceptual or theoretical effectiveness of the forest practice rules at preventing erosion.

This document reports on four different tasks. The first task is a review of the literature on effects of forest practices on erosion and measures to mitigate erosion. It also includes a review of previous methods used to assess the effectiveness of BMPs at protecting water quality.

The second task is an assessment of the relative severity of erosion and sedimentation impacts in different regions of Washington State.

The third task is an assessment of the theoretical or conceptual effectiveness of forest practice rules in minimizing sediment production caused by forestry activities. The focus is on the expected effectiveness of the rules rather than their actual effectiveness as determined by field evaluation. The task also includes recommendations for improving rule effectiveness.

The fourth and final task is the development of a method to be applied by the State Department of Ecology for an assessment of the effectiveness of existing BMPs in minimizing sediment production and delivery of sediment to streams.

TFW-WQ8-93-001 Effectiveness of Forest Road & Timber Harvest Best Management Practices With Respect To Sediment-Related Water Quality Impacts, Interim Report 1, Ed Rashin, Johanna Bell, Casey Clishe, June 1993.

This study to evaluate the effectiveness of certain forest road and timber harvest best management practices (BMPs) is being conducted as a part of the Timber/Fish/Wildlife Cooperative Monitoring, Evaluation and Research Program. The purpose of this first Interim Report is to describe the sampling design for the study, the study sites established to date, survey methodologies employed, and to present our field survey protocols. The project is employing a case study approach to evaluating BMP effectiveness. A total of 75 to 90 examples of typical BMPs, implemented under varying degrees of landscape hazard, will be selected from six of the nine physiographic regions of Washington. General BMP categories targeted in the study include road construction practices, road maintenance practices, and timber harvesting practices. A number of qualitative and quantitative survey techniques are being employed to assess erosion and sediment delivery to streams, aquatic habitat conditions, and biological communities. In most cases, two or more survey techniques are applied to each BMP example studies. The different survey techniques will provide different kinds of evidence on forest practice effects, leading to a weight-of-evidence approach to determining BMP effectiveness. Thirty-six study sites have been identified so far in the project, at which 79 specific BMP examples are being evaluated. These include 37 harvesting BMPs (tractor/wheeled skidding, Riparian Management Zones, and Riparian Leave Tree Areas), 38 new road construction BMPs (road drainage design, culvert installation, and construction techniques), and four road maintenance BMPs (active haul road maintenance). Six physiographic regions of the state are represented in the sample.

TFW-WQ8-94-001 Effectiveness of Forest Road and Timber Harvest Best Management Practices with Respect to Sediment-Related Water Quality Impacts - Interim Report 2, Ed Rashin, Casey Clishe, Andy Loch, May 1994. (Companion to Interim Report #1, TFW-WQ8-93-001)

This study to evaluate the effectiveness of certain forest road and timber harvest best management practices (BMPs) is being conducted as a part of the Timber/Fish/Wildlife Cooperative Monitoring, Evaluation, and Research Program. The purpose of this second Interim Report is to provide an overview of the study design, summarize study site information, and report on progress to date. The project is employing a case study approach under varying degrees of landscape hazard, have been selected from six of the nine physiographic regions of Washington. General BMP categories targeted in the study include road construction practices, road maintenance practices, and timber harvesting practices. A number of qualitative and quantitative survey techniques are being employed to assess habitat conditions, and assess biological communities. In most cases, two or more survey techniques are applied to each BMP example studies. The different survey techniques will approach to determining BMP effectiveness. Thirty-six study sites have been identified for the project, at which 90 specific BMP examples are being evaluated. These include 47 harvesting BMPs (tractor/wheeled skidding, Riparian Management Zones, and Riparian Leave Tree Areas), 39 new road construction BMPs (road drainage design, culvert installation, and construction techniques), and four road maintenance BMPs (active haul road maintenance.)

TFW-WQ11-92-001 T/F/W Ecoregion Bioassessment Pilot Project, Robert W. Plotnikoff, July 1991.

Biological assessment of benthic macroinvertebrate communities was completed at forested stream reference sites in three ecoregions of Washington State: Puget Lowlands, Columbia

Basin, and Cascades. Characteristic chemical and biological patterns were explored through reference sites within each ecoregion. Physical characteristics of the reference sites within an ecoregion were reflective of mid-order stream types and conformed, as closely as possible, to the predefined site selection criteria.

Habitat and biological conditions in each ecoregion were determined by using a modified version of the Environmental Protection Agency's Rapid Bioassessment Protocols (RBP). Habitat condition determined through the qualitative RBP scoring system indicated specific seasons that habitat availability to benthic macroinvertebrate communities was reduced due to changing wetted stream bottom surface areas. Each region had characteristic natural disturbances that determined timing of habitat instability.

Benthic macroinvertebrate communities and surface water conditions were examined for uniqueness by ecoregions and change by calendar seasons. The benthic macroinvertebrate information was initially examined by detrended correspondence analysis (DCA), and best distinctions among ecoregions occurred during the fall, spring, and summer seasons. Two-way indicator species analysis (TWINSPAN) produced lists of genera that were considered unique to each ecoregion. The functional attributes of these "unique assemblages" were used to relate to each ecoregion. The functional attributes of these "unique assemblages" were used to relate water quality and physical habitat influences that were thought to shape community patterns. Seasonal taxonomic lists were also constructed for each ecoregion that included macroinvertebrates assumed to appear in streams similar to those used in this project.

Seven RBP biometrics were used to define ecoregion macroinvertebrate conditions. Each of the biometrics was examined individually during each calendar season. Three of the metrics commonly used by benthologists were problematic. The "shredders/total abundance of sample organisms" ratio had consistently low values in each ecoregion during the fall and winter. The "EPT/Chironomidae abundance" ratio was not useful for Cascades ecoregion reference streams because of highly variable results. The "scrapers/collector-filterer abundance" ratio was least use during winter 1991 in this ecoregion, also.

Surface water information was examined through use of principal components analysis to define parameter relationships among the three ecoregions. Many of the parameters measured in this project revealed close associations between the Columbia Basin and Puget Lowland reference sites. The Cascade streams maintained distinct surface water conditions from the other two regions, probably due to increased streamflows and higher gradients. Biological, chemical, and physical instream information surveyed in this project contrasted the mountain ecoregion streams with the valley/plains ecoregion streams.