Chapter 5: Evaluation of the Aquatic and Riparian Effectiveness Monitoring Program

Lessons Learned While Implementing the Effectiveness Monitoring Component of the Plan

Implementing the monitoring program in the Northwest Forest Plan (the Plan) area provided an array of products and insights for successful large-scale monitoring, and ideas for how to improve the monitoring program. Our first challenge was to successfully implement the following key components described by Reeves et al. (2004).

Probabilistic Survey Design

We worked with U.S. Environmental Protection Agency statisticians to implement a probabilistic sampling strategy they developed that ensures sampling a uniform, random distribution of watersheds throughout the Plan area. The design is well established and allows using a subset of watersheds to describe the status and trend of all watersheds that meet the minimum criteria (>25 percent federal ownership) in the Plan area. Local units can use this same sample design to select sampling sites.

Field Survey Protocols

A thorough review of attributes identified in Reeves et al. (2004) was conducted to identify attributes that did not provide meaningful information, and to look for efficiencies in collecting data. The provincial specialist team's recommendations for which attributes should be included in the decision-support models were used as an initial screen for determining which attributes should continue to be collected. Data variability was also examined and sampling protocols were examined to determine if less time-consuming methods could be used for each attribute.

Concurrent with looking for sampling efficiencies, core attributes shared between the PacFish/InFish Biological Opinion (PIBO) monitoring effort and the aquatic and riparian effectiveness monitoring program were standardized prior to the 2004 field season to enable sharing of data to answer questions across all federal lands in the Pacific Northwest. Even though PIBO has different objectives for monitoring in the interior Columbia River basin, it includes similar survey attributes. Therefore, we reviewed historical data for both programs and compared performance of the different protocols in order to select the "best performing" protocol. These protocols were also designed to be consistent with the *Aquatic Ecological Unit Inventory Technical Guide* (Hixson et al. 2004). This guide is being used to create standards for characterizing aquatic resources on all national forests.

Decision-Support Models

The successful completion of decision-support models for each of the Plan's aquatic provinces provides a template for assessing watershed condition at any scale. This analysis method also makes it easy to add new information to improve the models. Future iterations of the models will incorporate advances in determining relationships among physical, biological, and chemical attributes and their effect on watershed condition. Program personnel are available to advise on applying the models at the forest, district, or even individual watershed scale.

Products Produced by the Monitoring Program

Numerous products produced by monitoring program personnel are now available for use by managers and field personnel.

Data Summaries for Local Units

Annual reports are sent to all the Forest Service and Bureau of Land Management (BLM) units where watersheds are monitored in a given year. Report data include digital photos with their spatial locations, and summaries of stream survey information. Raw data (provided upon request) are being used by fish biologists to assess restoration opportunities and priorities and to provide information for watershed analyses. Annual reports and data will be available on our Web site (http://www.reo.gov/monitoring/watershed/), starting with the 2004 field data.

Annual Technical Reports

Annual technical reports provide a road map of the monitoring program's accomplishments and changes to the program. These reports are posted on our Web site (http://www.reo.gov/monitoring/watershed).

Quality Assessment Program

We developed and implemented a field-data quality assessment program that can be easily implemented by other programs collecting field data. Our program meets criteria established in the Environmental Protection Agency quality control and quality assessment guidelines. Our field data quality assessment program has several components including training of field crews, data collection procedures, remeasurements of field indicators, data-checking procedures, and database quality control.

Field Maps

Maps we create for our field crews are available on our Web site for use by local unit managers and specialists. Area maps and watershed maps both show land ownership, road networks, stream networks, and watershed boundaries. The area maps are based on the most recent local forest or resource area map with the watershed boundary overlaid, whereas the watershed maps focus on the watershed surveyed and have the best local roads layer, ownership boundaries, topography, and the sample sites. Additionally, all data collected in the field is geo-referenced and therefore useful in ArcGIS applications outside the scope of the program.

Protocols to Prevent the Spread of Invasive Species

We proactively worked with federal, state, and tribal specialists to develop protocols to prevent the spread of invasive aquatic species and disease between watersheds by our field crews. Oregon Department of Environmental Quality experts concurred that using our techniques is the best known way to prevent the spread of New Zealand mud snails (*Potamopyrgus antipodarum*), Port Orford cedar root rot (*Phytophthora lateralis*), and sudden oak death syndrome (*P. ramorum*). Simple and easy-to-use techniques include rinsing of wading boots and sampling gear in mild bleach solution and then in boiling water (fig. 50), and using high-pressure car washes to clean vehicles prior to traveling to a new watershed. Our protocol is posted on our Web site (http://www.reo.gov/monitoring/watershed).

Kris Fausti

Figure 50—Sampling gear was cleaned by using bleach solution and boiling water to stop the spread of invasive aquatic species and disease.

Complete Coverage of Sixth-Field Watershed Boundaries

The current version of the interagency hydrologic unit code layer mapped to the sixth-field level covering Washington, Oregon, and northern California is now available for use for analysis, mapping, and maintenance at http://hydro.reo.gov/hu.html. Although this watershed coverage was created to meet the monitoring program's need, (i.e., provide a domain of sixth-field watersheds to randomly sample watersheds from), it also delineates sixth-field watershed boundaries for use at the forest and district level.

Cooperative State, Federal, and Tribal Monitoring Efforts

Cooperative monitoring efforts between state and federal agencies are a natural extension of the monitoring program as we look for ways to reduce costs and gain a better understanding of the interaction of federal, state, and private land watershed management actions within the Plan area. The monitoring program team leader initiated bringing together state agency representatives from Washington, Oregon, and California in 2001 to explore how to reduce monitoring costs by sharing data. This effort evolved to include tribal and Idaho agency representatives and is now known as the Pacific Northwest Aquatic Monitoring Partnership (hereafter referred to as the partnership).

Support for the partnership continues to build, as shown by the signing of a charter by 15 state, federal, and tribal executive signatories to date. Charter agencies also agreed to fund a full-time executive coordinator. The monitoring program team leader is the leader of the Watershed Workgroup, which is currently focused on two key areas to enable agencies to share data with each other: (1) probabilistic sample design and (2) common protocols. Use of a probabilistic sample design and using attributes with standardized sampling protocols will allow data to be combined across state, federal, and tribal lands. This will ultimately allow substantial improvements in efficiency and economy of scale for status and trend monitoring.

Sample Design

A common probabilistic sample design is being developed that any watershed monitoring effort can use. This design will facilitate (1) the creation of annual data summaries and annual report cards on the condition (based on key indicators) of riverine, riparian, and watershed resources, and (2) tracking changes and trends over time at broad regional scales (e.g., state, ecoregion, and interior Columbia River basin). The proposed sample design is based on using the same generalized random tessellation sampling strategy the monitoring program currently uses to select watersheds and stream reaches for sampling. Elements of the sample design proposal include:

- **Sample framework**—The framework will establish broad level (e.g., region, state) sampling of 50 to 100 locations annually for 5 years, with some locations monitored annually and others once during the 5-year period; then repeat the cycle for the next 5 years, and so on. This design would yield data from a total of 250 to 500 locations, which could be used to make "5-year" reports. The sample sites would be spread across federal and nonfederal lands.
- **Flexibility**—The sampling design can be modified over time as we learn more about important "subpopulations" on which to focus monitoring.
- **Scalability**—The design framework would be set up to accommodate finer scale monitoring (e.g., at the forest, district, or watershed level) embedded in the broader scale design to promote data sharing.
- **Use existing sample site information**—The design will allow incorporation of existing sample sites from ongoing probabilistic sample designs, such as data collected by the monitoring program.

Common Protocols

State and federal agencies with large-scale monitoring programs have committed to participating in a side-by-side protocol comparison test in 2005.

Elements of the protocol comparison test will include:

- Identify and recommend a core set of indicators and their associated attributes and protocols that state, federal, and tribal monitoring programs use for assessing status and trends in watershed condition.
- Develop a process for determining what protocols to use (based on cost, precision and variance, trend detection capability, repeatability).
- Develop calibrations for older protocols (also known as a "crosswalk") to preserve the value of legacy data where possible.
- Recommend which physical, chemical, and biological inchannel attributes and robust protocols should be used.

Assessing Watershed Condition for All Watersheds

Determining watershed condition scores for federal and nonfederal lands over large-scale areas may become possible if sufficient data are shared among state, tribal, and federal agencies, along with completing accurate, corporate geographic information systems (GIS) data layers. For example, drivers condition scores (based on vegetation and road information) were determined for all watersheds within the Olympic National Forest and Olympic National Park (fig. 51). By sharing data with other agencies, we could potentially map the condition of all watersheds throughout the Pacific Northwest.

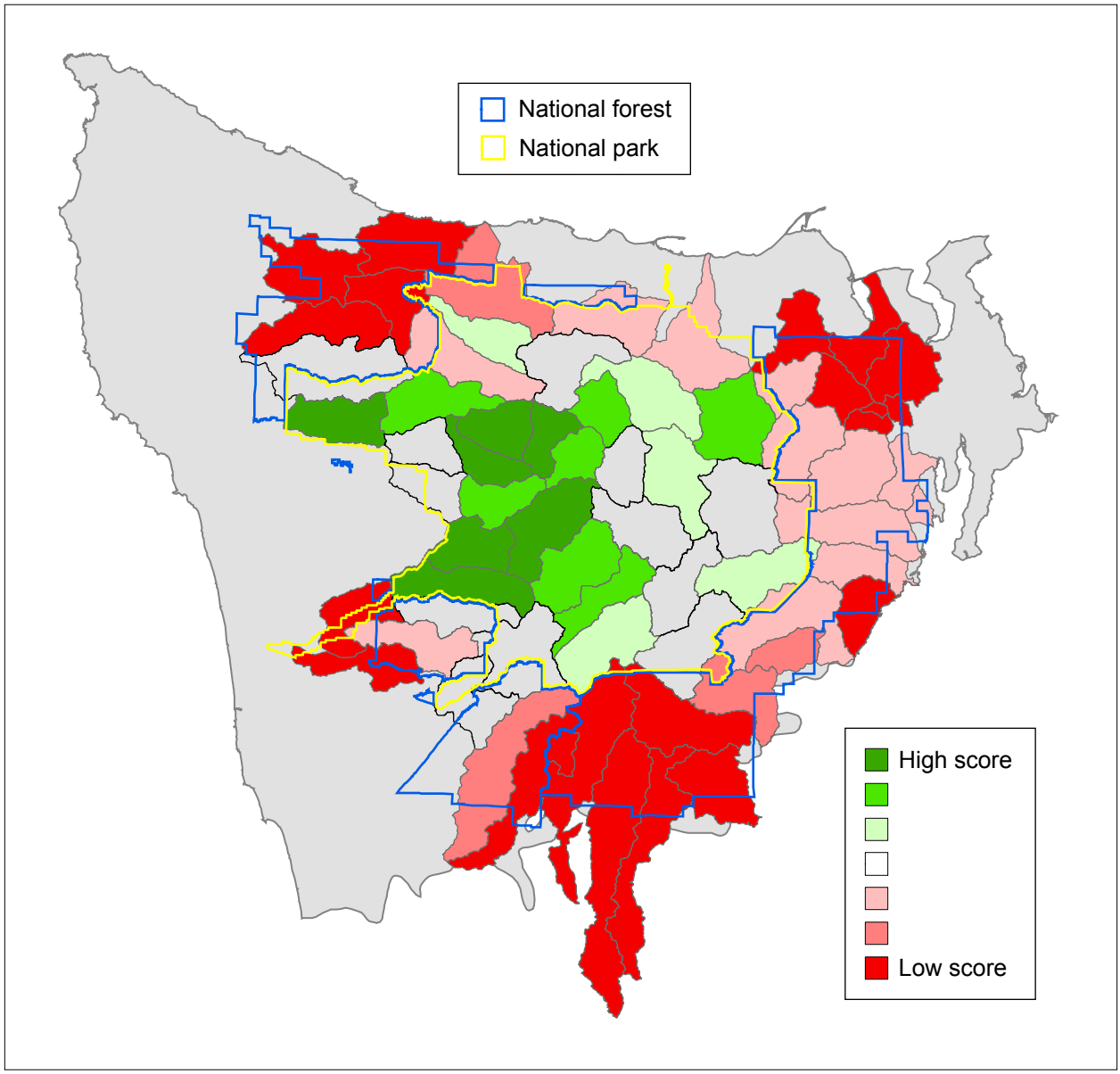

Figure 51—Drivers condition scores for all federally owned watersheds on the Olympic Peninsula. Lands are managed by the Olympic National Park and the Olympic National Forest.

Meeting Future Data Needs

The decision-support modeling process resulted in forest and district specialists identifying data needed to more accurately evaluate watershed conditions. The following additional data needs will improve both the monitoring effort and more localized monitoring efforts.

Better Tracking of Road Improvements

We currently evaluate the effect of roads on watershed condition by using a rather simplistic approach because of the lack of corporate road data. The only road information available is whether a road is present or it has been decommissioned (and is therefore assumed to be benign with respect to sediment delivery to streams). Therefore, decommissioned roads are the only "road improvements" tracked in federal agency databases. However, the term "decommissioned" can be applied to a road that has been closed by a gate or a tank trap, or to a road that has been obliterated. Because other road condition improvements (e.g., outsloping, water bars, drivable fords, hardening surfaces) can also reduce sediment delivery, we are working with Pacific Northwest Research Station scientists to recommend additional road attributes that should be tracked in federal agency databases. Availability of these data will allow future decision-support models to better reflect the effects of roads on watersheds and allow managers to take credit for those improvements. Opportunities and recommendations for how to meet these data needs are detailed in an Information Management Report (Palmer et al., in press).

Landslide Assessments

Monitoring program personnel are leading a multiagency effort to determine the relationship between landslides and topographic features in order to identify areas that have high risk for landslides (fig. 52). The results of this effort will be used in decision-support models to help determine the relationship between management activities (harvest and roads) and frequency of landslides. These results will also provide a valuable watershed analysis tool for land managers.

USDA Forest Service

Figure 52—Landslides are a natural process that brings wood and sediment to streams. However, excessive landslides caused by management activities (harvest and roads) can be detrimental to stream habitat.

Using Biological Data to Assess Watershed Condition

The monitoring program is unique because of the diverse biological information we collect for fish, aquatic and terrestrial amphibians, macroinvertebrates, and periphyton (fig. 53), along with inchannel physical and chemical attributes. A partnership of Pacific Northwest Research Station scientists, university specialists, and monitoring program specialists is examining the monitoring program's biological data to determine (1) what biological species and associated metrics are most valuable for determining watershed condition and (2) how to incorporate biological metrics into decision-support models. The results of this effort will help guide forest and district biologists in interpreting their own biological data.

Exploring New Cost-Effective Technologies

Efforts are underway to find more cost-effective methods for collecting data about watersheds. For example, new technologies such as LIDAR (Light Distance and Ranging–aerial flights with lasers) are being explored as a mechanism for collecting information on vegetation (upslope and riparian), roads (existing, decommissioned, and lost), landslides (volume and direction of movement), and stream channel morphology (gradient, sinuosity, and bankfull width).

Brian Neilson

Steve Lanigan

Steve Lanigan

Figure 53—Fish, aquatic and terrestrial amphibians, macroinvertebrates, and periphyton will be used to develop metrics describing the biological health of watersheds.

Reconciling Sample Design With Funding Limitations

The general technical report that guides the monitoring program recommends sampling a minimum of 50 watersheds a year over a 5-year repeat cycle for a total of 250 watersheds (Reeves et al. 2004). This design was intended to balance our ability to estimate status in the greatest number of watersheds with the repeat sampling required to assess trend. Reeves et al. (2004) also recommend convening a group of survey statisticians to develop a final sampling design that accounts for budgetary and other constraints under which the program is implemented.

The original estimate of the costs to fully implement the monitoring program was $1.8 million each year. Thus far, funding has allowed us to sample about 25 watersheds each year, including resampling one site per watershed as part of our quality assurance/quality control (QA/QC) program and the sampling of "trend sites" (revisits to QA/QC sites sampled the previous year). Expected declines in overall USDA Forest Service and USDI Bureau of Land Management budgets for 2005 and 2006 make any dramatic increases in funding to the monitoring program unlikely.

Given budget constraints, monitoring program personnel are working with statisticians and scientists from the U.S. Environmental Protection Agency, U.S. Geological Survey, and USDA Forest Service Pacific Northwest Research Station to review 3 years of cost and attribute data to determine the best type of sample design to use given probable funding levels and also to determine which attributes provide meaningful status and trend data. Five options are presented for the future monitoring program structure. We will conduct analysis of the data collected by the monitoring program to date to assist in selecting an option. Selection will be based on the cost to implement the option, the time it will take to detect changes in the condition of watersheds, and the power to detect changes. The results of the assessment will be published in a general technical report.

Option 1—Field-based program that relies heavily on detailed stream channel measurements that will be conducted in 25 watersheds per year.

In this option, the current program structure will remain largely unchanged. An evaluation of the attributes and sampling protocols will be conducted, and attributes will be dropped and protocols simplified when possible.

Pros

- Little change will be required to the sampling protocol, training program, or decision-support model.
- No loss of data owing to changed protocols.
- High-quality field data will be produced across a large spatial scale that can be used by managers for watershed analysis and Endangered Species Act consultation.

Cons

- Assessing baseline condition of 250 watersheds will take 10 years instead of 5.
- Time required to measure trend will increase.

Option 2—Field-based program that relies heavily on stream channel measurements that will be conducted in 50 watersheds.

In this option, the current monitoring program will be scaled back in order to sample 50 watersheds. Several alternatives exist for scaling back, including:

- Sampling seventh-field rather than sixth-field watersheds, assuming fewer sites will be needed to characterize seventh-field watersheds.
- Sampling fewer sites in watersheds.
- Sampling fewer inchannel attributes.
- Decreasing the level of detail of the inchannel sampling.
- Reducing the data quality assurance program.
- Reducing the number of trend sites revisited each year.
- Using data collected by other programs where available (and quality is known).

Steinacher Road, Six Rivers National Forest, California

Road decommissioning—
Six Rivers National Forest, in cooperation with the Karuk Tribe of California, decommissioned 7.3 mi of the Steinacher Road. This 30-year-old road was identified as the highest priority for decommissioning in a spring Chinook (*Oncorhynchus tshawytscha*) recovery plan because sediment from the road was being deposited in Steinacher Creek, Wooley Creek, and the Salmon River. All these rivers provide spawning, rearing, and migration habitat for coho (*O. kisutch*) and chinook salmon, as well as steelhead (*O. mykiss*) and native trout.

A partnership consisting of a private foundation, and tribal, state, and federal agencies contributed funding for this project.

The Karuk Tribe also initiated a comprehensive watershed restoration training and implementation program for tribal members and staff. Sixteen Karuk tribal members were trained in heavy equipment application, prescription planning, surveying, and supervision of project sites. This workforce participated in the Steinacher Road decommissioning work and will help decommission more than 65 mi of road in the East Ishi Pishi watershed area. Contact Jerry Boberg (jboberg@fs.fed.us) for more information.

Adam Dresser

Road decommissioning efforts included removing 200,000 yd^3 of fill material.

The pros and cons of this option depend on which of the alternatives are selected to scale back the sampling program.

Pros

- Able to sample 50 watersheds.
- Use of data collected by other programs will facilitate sharing of data among agencies.

Cons

- Sampling fewer sites in a watershed will reduce our ability to characterize watershed condition with respect to inchannel attributes.
- Decreasing the level of detail in the sampling could result in data useful only to the Aquatic and Riparian Effectiveness Monitoring Plan and not to managers or other programs.
- Changing sampling protocol could result in the loss of data collected in previous years.
- Reducing the data quality assurance program could result in collecting lower quality data or in the inability to describe the quality of the data.
- Reducing the number of sites revisited will increase the time required to detect trend.

Option 3—GIS/remote sensing-based program that relies on upslope and riparian indicators as surrogates for watershed condition.

In this option, relationships between attributes such as vegetation, roads, and landslides that can be evaluated by using GIS or remote sensing techniques and watershed condition will be developed. When the relationships are known, these indicators will be used as surrogates for watershed condition. Field sampling will be reduced to validation of the relationships and the GIS layers.

Pros

- Will be able to sample 250 watersheds easily, and could potentially sample all watersheds in the Plan area.
- The relationships between upslope/riparian attributes and watershed condition could help managers make decisions about management activities because they will have a clearer understanding of the consequences (positive or negative) of the proposed management action.

Cons

- Will have to spend money up front updating/improving GIS layers (especially road and stream layers).
- Have to develop relationships between upslope/riparian attributes and watershed condition. We may have to collect additional inchannel data before this can be done.

Option 4—Coordinate monitoring efforts with other federal and state agencies to enable the sharing of data and reduce overall costs.

In this option, state, federal, and tribal monitoring groups would agree to use a common probabilistic sampling design and standardized protocols for a core set of attributes. This will allow each agency or group to answer questions at the appropriate scale for the questions being asked, while contributing data to other monitoring efforts.

Pros

- Will result in greater precision by increasing the amount of data available to each agency.
- Alternatively, it would allow agencies to reduce individual data collection efforts by supplementing their data with data collected by other agencies, while still maintaining the current level of precision.
- Allows data to be aggregated at multiple spatial scales.
- The Pacific Northwest Aquatic Monitoring Partnership is working to make this a feasible option.

Cons

- It is dependent on monitoring programs agreeing to use a common probabilistic sampling design.
- It is dependent on monitoring programs agreeing to use the same protocols for a core set of attributes.
- There is a need to determine how to effectively share data among monitoring programs.
- Standardizing protocols may make it more difficult to answer questions for a specific project.
- Using other agencies' data may result in a watershed's reach condition being determined by only one or two sampled reaches.
- The entire set of attributes used in the decision-support model is not collected by other agencies.

Option 5—Use models to estimate the historical range of variability of vegetation condition and mass wasting across the Plan area. Use this distribution as the "desired" distribution and assess the differences (if any) between the current distribution and the desired distribution.

In this option, we would use models such as those developed by Wimberly et al. (2000) and USDA Forest Service (2002) to estimate the historical range of variability of forest conditions and landslide rates. The monitoring program would rely on GIS to determine whether the current conditions deviate from the desired distribution.

Pros

- Will be able to sample 250 watersheds easily, and could potentially sample all watersheds in the Plan area.
- We will have a desired distribution or a goal to work toward achieving with our land management strategies.

Cons

- Will have to spend money up front updating/improving GIS layers (especially road and stream layers).
- Models that describe the historical range of variability have been developed and validated for the Oregon coast area only. We would need to expand these models or build new ones to describe the entire Plan area.

Eliminate redundant attributes—
Gallo et al. (2002) searched for correlations between attributes that would allow for the reduction of attributes and/or development of models to be used in a predictive sense. Little correlation was detected beyond what was expected; e.g., average bankfull width and stream length (the former was used to determine the latter). Gallo et al. (2002) concluded that the attributes sampled were not redundant and did not recommend dropping any attributes from the sampling effort.

Simplify and eliminate protocols that do not provide needed information—
A thorough review of all protocols was done to identify attributes that were not providing meaningful information and to look for efficiencies in collecting data. The provincial specialist team recommendation for which attributes should be included in the decision-support models was used as an initial screen for suggesting which attributes should continue to be collected. Data variability was examined and protocols were examined to determine if less time-consuming methods could be used for each attribute.

Concurrent with looking for sampling efficiencies, core attributes shared between the PacFish/InFish Biological Opinion monitoring effort and the monitoring program were standardized prior to the 2004 field season to enable sharing of data to answer questions across all federal lands in the Pacific Northwest. These protocols are also designed to be consistent with the *Aquatic Ecological Unit Inventory Technical Guide* (Hixson et al. 2004). This guide is being used to create standards for characterizing aquatic resources on all national forests.

Chapter 6: Emerging Issues

Issues related to the condition of watersheds are expected to emerge as our understanding of processes affecting watershed condition evolves. These issues will be incorporated into future iterations of decision-support models as needed information becomes available. Information management considerations for each of these issues can be found in Palmer et al. (in press). The following highlights some current emerging issues.

- **Distribution of watershed condition scores**—The desired distribution of watershed condition scores was not identified by the strategy. Consequently, we are unable to determine whether goals of the strategy were achieved. This information would allow field unit specialists to determine if planned disturbances will move watershed conditions outside the range of natural variation.
- **Links between management and inchannel habitat and biological indicators**—Thus far, research has yet to determine how management activities in upslope and riparian areas affect fish and other aquatic- and riparian-dependent species.
- **Fire**—The effect of fire suppression and stand-replacing burns on vegetation and stream reach conditions is unknown. Fire condition class, which identifies how vegetation conditions have deviated from historical fire conditions, is likely to be one tool used in future iterations of the decision-support models. Fire condition class is currently being mapped for all federal lands in the Plan area.
- **Restoration projects**—A link between restoration projects and the monitoring program has yet to be established. For example, the decision-support models are sensitive only to road decommissioning, because such improvements are not tracked consistently in a database. Assigning and tracking other road attributes (such as water bar installation and culvert replacement) is needed to better reflect how roads affect the condition of watersheds. A fish-passage barrier (i.e., culverts; fig. 54) database for federal and nonfederal lands is also needed. If these data were available, decision-support models could reflect improved conditions as fish passage barriers are removed. Current efforts are underway to create a fish-passage barrier database for Forest Service lands in the Pacific Northwest.

Al Doelker

Figure 54—Culverts with steep drops at the outlet can be barriers to upstream fish passage.

- **Invasive aquatic species**—The effects of invasive and exotic aquatic species on the aquatic biotic community are usually detrimental to native species. Future biological indices used in the decision-support models will include invasive species.
- **Adequate flow**—Dams and irrigation practices have altered flow regimes in many watersheds. Altered flow regimes include changes in timing and magnitude of peak flow and dewatering that result in insufficient flow during summer.

Wind River, Gifford Pinchot National Forest, Washington

Stream restoration—

The Wind River Watershed Council, a partnership of landowners, businesses, logging companies, government agencies, conservation groups, and schools, encourages the use of land management practices that sustain and improve water quality, fish habitat, and other natural resources, while contributing to long-term economic and community sustainability within the Wind River watershed. Their efforts are focused on accelerating the recovery of riparian, instream habitat, and water quality in which native steelhead evolved. Since 1992, about 100 mi of road has been stabilized or storm-proofed, 35 mi of road has been decommissioned, 120 ac of flood plain has been reclaimed, about 600 ac of riparian area has been planted, and 4,000 pieces of large wood have been placed in 11 river mi of stream.

Progress to date—

Monitoring in Trout and Layout Creek, where most stream restoration work was done during 1995–98, showed encouraging results:

- Large wood (>12 in diameter) increased 333 percent, from 36 to 120 pieces per mi.
- Bank stability increased from 60 to 93 percent.
- Coarse and fine sediment input from eroding banks decreased by 73 percent.
- Six hundred feet of relief and side channel habitat was reconnected to the flood plain.
- Subterranean flow was reduced by 80 percent.

Brian Bair

Brian Bair

The Trout Creek old-growth channel was disconnected from the main channel in 1981 when a logjam that was thought to be a migration barrier was removed (top). The removal of the logjam initiated the main channel to down-cut and leave the old-growth channel high and dry. After a logjam was restored in 1998 (bottom), the streambed aggraded more than 4 ft and again flowed through 0.8 mi of pristine river habitat in the old-growth channel. Contact Brian Bair (bbair@fs.fed.us) for more information.

Chapter 7: Summary

Introduction

The primary objectives of this report are to describe the status of aquatic and riparian resources and changes in their condition under the Northwest Forest Plan's (the Plan) aquatic conservation strategy. We present a preliminary assessment of the condition of watersheds in the Plan area—the first quantitative assessment conducted since the Plan was implemented in 1994. The status assessment is based on road, vegetation, and inchannel data from 55 watersheds in the Plan area. The trend assessment is based on road and vegetation data from 250 watersheds.

We also present the analytical approach used to assess the condition of watersheds in the Plan area. The approach presented is based on a statistically valid sampling design that enables us to make inferences about watersheds in the Plan area, combined with a decision-support model that incorporates indicators of watershed condition in a way that is consistent and repeatable across time and space (Reeves et al. 2004).

The aquatic conservation strategy (hereafter referred to as the strategy) is a comprehensive, regionwide strategy designed to maintain, restore, and protect those processes and landforms that create good ecological conditions in watersheds, such as high-quality habitat for aquatic and riparian organisms and good water quality (FEMAT 1993). Because watersheds are dynamic systems, evaluating the effectiveness of the strategy is based on measuring changes in the distribution of watershed condition scores through time, rather than looking at average conditions. The strategy does not describe the baseline condition of watersheds nor does it define a desired distribution. Thus, we infer that if the strategy has been effective in achieving its goal of maintaining or improving the condition of watersheds, then the distribution of watershed condition scores should either stay the same through time or it should shift in a direction that indicates improvement.

Study Design

Monitoring was conducted in 250 randomly selected sixth-field subwatersheds (hereafter called watershed) that contained a minimum of 25 percent federal ownership (USDA Forest Service, USDI Bureau of Land Management [BLM], or USDI National Park Service) along the total length of the stream. The Plan area contains 2,631 watersheds, of which 1,912 contain some land that is federally owned and 1,372 have at least 25 percent federal ownership. The ownership criterion excludes about 10 percent of the federal lands in the Plan area from this analysis.

According to Reeves et al. (2004), 50 watersheds should be sampled each year for 5 years. On year 6, the watersheds sampled the first year will be revisited. Watershed monitoring officially began in 2002, although funding was about half of the amount identified as needed to fully implement the program. As of fall 2003, 55 of an expected 100 watersheds were sampled. Because of this limitation, we have data from only 22 percent (i.e., 55 of 250 watersheds) of the watersheds needed to build a baseline distribution for use in evaluating the effectiveness of the strategy. Also, none of the watersheds was sampled more than once; therefore, we have no inchannel data to support the trend analysis.

We relied on road and vegetation data from the 250 watersheds and inchannel data from the 55 watersheds that have been sampled to describe the current status of the different attributes. For the trend analysis, we relied only on the road and vegetation data in the 250 randomly selected watersheds from two periods.

Assessment of Watershed Condition

The definition of watershed condition developed by the monitoring program was based on the goals of the strategy and on guidance provided by Reeves et al. (2004). The condition of a watershed was defined as "good" if the physical attributes were adequate to maintain or improve biological integrity, including diversity and abundance of species—particularly, native or desired fish species. Specific physical attributes included intact upslope and riparian habitats that were biologically and structurally diverse and functioning properly—i.e., banks were stable, large wood was present in the stream channel, and sediment and nutrient inputs were similar to natural levels. Flows should have been adequate to maintain or improve riparian and inchannel habitat. Chemical characteristics and water temperature must have

been in a range that maintained biological integrity. Further, the system should have been able to recover to desired conditions when disturbed by large natural events or by land management activities.

Decision-support models were used to assess the condition of individual watersheds by using locally relevant evaluation criteria. These models are computer-based models that capture evaluation procedures and apply a consistent decision or evaluation process across time and space. Criteria were developed by expert panels to evaluate individual data parameters. Data were compared to the criteria and given an evaluation score between -1 and 1. The evaluation score is positively related to the condition of watersheds, such that the attributes (or watersheds) in good condition should receive an evaluation score of (or near) +1. Evaluation scores for the attributes were aggregated into an overall assessment of watershed condition.

A decision-support model was built, refined, and peer-reviewed for each province (n = 7) during workshops attended by local agency professionals. Models were built at the provincial scale to account for the ecological differences that exist between aquatic provinces. For example, precipitation and the availability of water in the creeks is an important consideration on the east side of the Cascade crest and in many parts of California and southern Oregon. However, water is rarely a limiting factor in coastal watersheds.

The workshops consisted of an informal group process through which participants came to consensus on the model structure and evaluation criteria. After the workshops, models were built and run and the results returned to the workshop participants. Participants compared the results of the model to their knowledge of the condition of the watersheds and suggested refinements to the model as necessary. Changes were made to the model and the results were reevaluated.

Methods

The evaluation of upslope and riparian conditions in watersheds was tailored to specific physiographic provinces. In individual watersheds, roads and vegetation data in upslope and riparian areas were collected across the entire watershed by using geographic information systems (GIS) data sets.

Upslope and Riparian Attributes

Roads—

In each of the 250 watersheds, road density in upslope and riparian areas and the frequency of road-stream crossings were determined. For riparian road density analyses, the road layer was laid over the riparian buffer and miles of road inside the buffer were counted. Miles of road outside the buffer were used to determine upslope road density. To estimate the number of road-stream crossings, we counted road and stream intersections. Road layers were not available from 1994 when the Plan was implemented; however, current road layers identify roads that have been decommissioned. Therefore, to obtain road data from 1994 (time 1) and the present (time 2) to analyze change, we used total road miles (existing + decommissioned) as the time 1 data point and the existing roads as the time 2 data point.

Vegetation—

The GIS layers developed by the Interagency Vegetation Mapping Project (IVMP) were used in Oregon and Washington, and CalVeg in California to assess vegetation characteristics. In each of the 250 watersheds, the vegetation layer and the 1:24,000 stream layer were clipped to the watershed boundary. A fixed-width buffer was generated from the stream layer to designate the riparian area. The area outside the buffer was defined as upslope.

For change analysis, data from the IVMP or CalVeg layer were used as the time 1 (around 1996) data point. For the time 2 (2002) data, the vegetation change layer developed for the late-successional and old-growth (older forest) vegetation monitoring program (Moeur et al. 2005) was used to update the baseline IVMP or CalVeg layer. The change layers were laid over the IVMP or CalVeg layer, and the vegetation inside polygons that indicate post-1994 disturbance was classified as early seral. These change layers describe stand-replacing events resulting from harvest and fire, but they do not capture partial losses owing to thinning or surface fire, nor do the layers show tree growth.

To account for vegetation growth, we used data from the Forest Inventory Analysis and the Current Vegetation Survey plots. We calculated the average percentage of area with trees in one size class in time 1 (e.g., <20 in) that transitioned to the next size class in time 2 (>20 in) since the Plan was implemented. We calculated this percentage for each vegetation type (e.g., pinion-juniper, Douglas-fir forest) in each province. This change rate was used to calculate change factors for each watershed by using the change rate for each of the vegetation types in the watershed, weighted according to the area of the watershed covered by the vegetation type.

Inchannel Attributes

Inchannel data (physical and water chemistry attributes) were collected at three to eight randomly selected sites in each watershed. Sites are sections of the stream channel that differ in length from 175 to 525 yd, depending on the width of the channel. Sites located in unwadeable water or private land were not sampled. Field data were collected to provide information on physical and chemical characteristics of the reach. Physical habitat indicators include bankfull width-to-depth ratio and entrenchment ratio calculated from cross-sectional profiles; pool frequency, sinuosity, and gradient, calculated from longitudinal profiles; wood frequency; percentage of fine sediments; and substrate D_{50} (median particle size). Chemical data were collected for dissolved oxygen, conductivity, pH, and water temperature.

Statistical Analysis

To test for the direction of change between the time 1 and time 2 distributions, we used a one-tailed Wilcoxon signed rank test. This test examines the differences between the time 1 and time 2 condition scores for individual watersheds and determines whether more watersheds increased or decreased in condition than would be expected by chance. The Wilcoxon test is a nonparametric that does not assume a normal distribution of the data. To avoid type II error, we set $\alpha = 0.10$ in all of the analyses conducted.

Results

Results of the assessment were presented for the entire Plan area and by land use allocation, based on a poststratification of the 250 watersheds. Information on the current status of inchannel attributes was presented for the Plan area only because the number of watersheds measured (55) was not sufficient to divide into multiple land use allocation categories. The land use allocation categories presented here are the same as those identified in the Plan; however, we added a key watershed category and a nonfederal category. Watersheds were classified according to the predominant land use allocation (>50 percent of the watershed area). Condition scores range from -1 to 1, and are positively related to resource condition.

Plan Area

Current status—

Overall, condition scores for riparian attributes were lower than upslope attributes, riparian vegetation, in particular. When evaluating riparian vegetation, we looked for the percentage of the riparian area that has conifers >20 in d.b.h. In the 250 randomly selected watersheds, the riparian area with large trees ranged from 0 to 93 percent. The evaluation criteria for most of the provinces indicate that watersheds in good condition with respect to riparian vegetation have large conifers in at least 50 percent of the riparian area, and watersheds in poor condition have only 30 percent. The median value for percentage of riparian area with large conifers is 40 percent. Nearly 38 percent of the 250 randomly selected watersheds have large conifers in at least 50 percent of the riparian area. Twenty-nine percent of the watersheds have large conifers in less than 30 percent of the riparian area.

The density of riparian roads in the 250 randomly selected watersheds varies from 0 to 0.41 mi of road per mile of stream. The evaluation criteria for most of the provinces indicate that zero mi of road in watersheds suggests that the watershed is in good condition with respect to riparian roads and that watersheds with 0.1 mi of road per mile of stream are in poor condition. The median riparian road

density was 0.15 mi of road per mile of stream. Nearly 4 percent of the watersheds have no riparian roads. More than two-thirds of the 250 watersheds had riparian road densities greater than 0.1 mi of road per mile of stream.

The frequency of road-stream crossings in the 250 randomly selected watersheds differs ranging from 0 to 4.2 crossings per mile of stream. The evaluation criteria indicate watersheds with no road-stream crossings are in good condition and watersheds with 1 to 3 crossings per mile of stream (depending on the province) are in poor condition. Just over 4 percent of the watersheds contain no road-stream crossings. Nearly 53 percent of the watersheds have more than 1 crossing per mile of stream, and 15 percent have more than 2 crossings per mile of stream.

Reach condition scores, which are aggregates of the inchannel attributes including wood, pools, and substrate, tended to be fairly high; fewer than 15 percent of the 281 reaches sampled had condition scores less than 0, which is the center point of the possible range of condition scores. The median reach condition score was 0.4, and about 75 percent of the reach condition scores fell in the 0 to 0.6 portion of the range.

Many of the sampled reaches had high condition scores with respect to pools; nearly 75 percent of the reaches received a condition score of 1. Substrate condition scores were also generally high. Thirty-eight percent of the sample reaches had condition scores equal to +1, which suggests that these reaches had low levels of fine sediment and median particle sizes that are suitable for spawning habitat. In contrast, 12 percent of the sample reaches had condition scores equal to -1. These reaches either had high levels of fine sediment or were scoured down to bedrock. Wood condition scores tended to be very low; nearly 70 percent of the sample reaches had scores of -1, suggesting that low levels of large wood in stream channels are prevalent throughout the Plan area.

Changes since the implementation of the Plan— Condition scores were generally higher in time 2 than in time 1; however, the magnitude of change was very small. The drivers condition score (which is the aggregate of roads and vegetation attributes) increased in 161 of the 250 watersheds (64 percent) by an average of 0.09 (SD 0.19). This level of change represents a significantly higher percentage of watersheds than would be expected if the changes were random. Of the remaining watersheds, 18 (7 percent) had drivers condition scores that were the same in time 1 and time 2, and 71 (28 percent) had scores that were lower in time 2 (table 4). The average decrease in condition scores for those 71 watersheds was 0.14 (SD 0.3). The overall net change in drivers condition score across all 250 watersheds was 0.02 (SD 0.1).

Most of the watersheds changed little during the last 10 years; however, 7 of the 250 watersheds had drivers condition scores that changed by more than 0.2 from time 1 to time 2 (4 decreased and 3 increased in condition). Wildfires that burned 31 to 55 percent of the watershed area explain the decrease in drivers condition scores. The three watersheds with higher condition scores in time 2 were targets of road decommissioning. Nine to sixteen miles of road was decommissioned in these watersheds, a significant portion of which was in riparian and hazard areas (i.e., prone to mass wasting).

The small changes in the drivers scores were largely due to higher vegetation scores in the watersheds. Two to four percent of the trees moved from a size class that was less than 20 in d.b.h. to the size class of trees greater then 20 in across the Plan area since 1994. Stand-replacing harvest in watersheds in Oregon and Washington has decreased on federal lands to 15 percent of the 1991 level. Although the area harvested in riparian areas has decreased since the implementation of the Plan, riparian harvest as a portion of total harvest remained fairly constant since 1972, with an average of 25 percent of total harvest in riparian areas of federal lands (range 17 to 35 percent over the time periods) and an average of 30 percent riparian harvest on nonfederal lands (range 23 to 36 percent). The net decrease in road miles on federal lands was about 4,300 mi, out of about 91,000 mi of road that existed in 1994. The effort was spread out across the Plan area; consequently, the miles of roads in the 250 watersheds changed very little.

Key Watersheds

Current status—
Currently, key watersheds tend to be in better condition overall than non-key watersheds. The range of riparian road densities extends from 0 to about 0.4 mi of road per mile of stream for both key and non-key watersheds. However, riparian road densities generally tend to be lower in key watersheds. Nearly half of the key watersheds have riparian road densities lower than 0.1 mi of road per mile of stream, compared to 24 percent of non-key watersheds. Road-stream crossings also tend to be fewer in key watersheds than in non-key watersheds. Just over 60 percent of key watersheds have road crossing frequency less than one crossing per mile of stream, compared with 40 percent of non-key watersheds. Just over 20 percent of the key watersheds have <30 percent of the riparian area covered by conifers greater than 20 in d.b.h., compared with 33 percent of non-key watersheds.

Changes since the implementation of the Plan—
Small shifts in the drivers, roads, or vegetation distributions were detected for key watersheds or non-key watersheds. Drivers condition scores in 74 percent of key watersheds and 48 percent of non-key increased by at least 0.1 in time 2 (table 4). Fewer than 4 percent of the watershed declined by that amount in the last 10 years in either key or non-key watersheds.

The primary difference between key and non-key watersheds was attributed to roads rather than vegetation. Not only did key watersheds have higher road condition scores than non-key watersheds at time 1 and time 2, more than twice the miles of roads were decommissioned in key watersheds than in non-key watersheds in the last 10 years. Vegetation condition scores increased more in key watersheds than non-key watersheds (table 4). Harvest rates were historically lower in key watersheds than in non-key watersheds. This trend continued after the Plan was implemented.

Land Use Allocations

Adaptive management areas—
Adaptive management areas had drivers condition scores that ranged from -1 to 0.3. The density of roads in adaptive management areas is among the highest of those on federal lands. Riparian road densities in adaptive management areas ranged from 0.07 to 0.28 mi of road per mile of stream. Eighty-eight percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.6 to 2.0 crossings per mile of stream. Seventy-eight percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 10 to 70 percent in adaptive management watersheds. Twenty-eight percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Small positive changes in the distribution of condition scores were detected for drivers, roads, or vegetation. Drivers condition scores increased by at least 0.1 in 72 percent of the watersheds in the last 10 years. None of the watersheds decreased in condition. The miles of roads decommissioned in adaptive management areas was the lowest of any watersheds. No decommissioning occurred in nearly 70 percent of the watersheds. Of those watersheds that did have roads decommissioned, about 1 mi was decommissioned in riparian areas and 2 mi in upslope areas. Harvest levels in adaptive management areas were low in the past 10 years. Mean harvest rates in adaptive management areas dropped from about 63 ac per watershed per year prior to 1995 to 5 ac per watershed per year after 1995.

Congressional reserves—
Drivers condition scores range from -0.8 to 1. Condition scores in congressional reserve watersheds are generally higher than all other watersheds, more than 60 percent of the congressionally reserved watersheds had scores higher than 0.5. Road densities in congressional reserves are the lowest of any of the land use allocations. Riparian road densities in congressionally reserved watersheds ranged from 0 to 0.28 mi of road per mile of stream. Fourteen percent of

these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0 to 2.2 crossings per mile of stream. Eight percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 0 to 93 percent. Twelve percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Fifty-six percent of the watersheds had higher drivers condition scores in time 2, about 3 percent decreased in condition, and the remainder stayed the same. The average number of road miles decommissioned in congressional reserves was the lowest of any watersheds, consistent with the low road densities in congressionally reserved watersheds. Less than 0.25 mi of road was decommissioned in riparian areas and 0.5 mi in upslope areas. Harvest rates were also very low. Mean harvest areas declined from 30 ac per watershed per year to 3 ac per watershed per year.

Late-successional reserves—
Drivers condition scores in late-successional reserve watersheds were generally higher than the scores of other federally owned watersheds, with the exception of congressional reserves. About half of the late-successional reserve watersheds had drivers condition scores greater than 0. Riparian road densities in late-successional reserve watersheds ranged from 0.01 to 0.41 mi of road per mile of stream. Sixty-three percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.02 to 4.26 crossings per mile of stream. Forty-three percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 0.4 to 92 percent in late-successional reserve watersheds. Twenty-four percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Nearly 80 percent of the watersheds had drivers condition scores that were at least 0.1 higher in time 2 than they were in time 1. Road decommission was conducted in about 40 percent of the watersheds, at an average rate of 2.6 mi of road per watershed. These average rates were the highest of any on federal land. Harvest area was fairly high in late-successional reserves, comparable to those on matrix lands. Mean annual harvest rates declined in late-successional reserves from 67 ac per watershed per year to 11 ac after the Plan was implemented.

Matrix—
Drivers condition scores ranged from -0.9 to 0.5 on matrix lands. Matrix lands generally had low condition scores compared with other federally managed lands, about 60 percent of the watersheds had scores less than 0. Riparian road densities in matrix watersheds ranged from 0.07 to 0.33 mi of road per mile of stream. Ninety-three percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.5 to 2.6 crossings per mile of stream. Eighty-three percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 1.2 to 83 percent in matrix watersheds. Seventeen percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

Just over half of the watersheds in matrix lands had higher drivers condition scores in time 2 than they did in time 1. None of the watersheds had lower condition scores in time 2 than they did in time 1. Road decommissioning was conducted in about 40 percent of the watersheds in matrix lands. Average decommissioning rate within these watersheds was about 2.5 mi in the last 10 years. The number of acres harvested was the highest in matrix lands when compared with the other federal land use allocations, as would be expected under the Plan. Mean harvest rate was 21 ac per watershed per year, down from over 70 ac per year prior to implementation of the Plan.

Nonfederal lands—
Drivers condition scores in watersheds that are predominantly nonfederal ranged from -1 to 0.2. Only 5 of the 45 watersheds had drivers condition scores higher than 0. Overall, nonfederal watersheds had the lowest condition scores of the land use allocation categories. Watersheds that contained more than 50 percent nonfederal lands had

the highest road densities of the watersheds. Riparian road densities in nonfederal watersheds ranged from 0.05 to 0.41 mi of road per mile of stream. Ninety-six percent of these watersheds had riparian road densities greater than 0.1 mi of road per mile of stream. Road crossing frequencies ranged from 0.3 to 3.1 crossings per mile of stream. Eighty percent of the watersheds had road crossing frequencies greater than 1 crossing per mile of stream. Riparian area with conifers >20 in d.b.h. ranged from 3 to 74 percent in nonfederal watersheds. Sixty-two percent of the watersheds had less than 30 percent of the riparian area containing large conifers.

One-third of the predominantly nonfederal watersheds had higher drivers condition scores in time 2 than in time 1. Drivers condition scores did not change in the remainder of the watersheds. The number of road miles decommissioned in the nonfederal watersheds averaged about 2, which was consistent with the average across the Plan area. More acres of timber were harvested on nonfederal watersheds than in any of the other land use categories.

In general, watersheds that are predominantly nonfederal have the lowest condition scores of all of the watersheds, notably worse than predominantly federal watersheds. The percentage of federal land appears to have little effect on drivers condition scores from the present period. Although the relationship is statistically significant, the percentage of federal ownership explains only 25 percent of the variance in drivers condition score. When land use allocation is added to the analysis as a covariate, federal ownership explains 37 percent of the variance in drivers condition scores. These results suggest that drivers condition scores are influenced by factors other than the management applied to the watershed.

Discussion

The authors of the Plan recognized the complex and dynamic nature of watersheds. Human activities in the past century have altered the processes that create healthy ecosystems (Bisson et al. 1992, Naiman et al. 2000). These processes occur on the scale of decades or centuries. Given the temporal scale of these ecological processes and that degradation of watershed processes has probably occurred gradually for decades, it is unlikely that restoration activities will restore habitat in a short period (Larsen et al. 2004). From this perspective, it is not surprising that changes observed here in the roads and vegetation were very small, except in a few watersheds.

Most of the watersheds had higher condition scores in time 2 than in time 1 across the entire Plan area and in each of the land use allocations except nonfederal. Relatively few watersheds decreased in condition. Given that (1) the growth rate of trees exceeded harvest rates, (2) more roads were decommissioned than were constructed, (3) the watersheds that had large increases in drivers condition scores were all targets of road decommissioning, and (4) those watersheds that had lower condition scores were all exposed to wildfire (and not management activity), it appears that the strategy has had positive effects on the condition scores of watersheds in the Plan area. Further, over 70 percent of key watersheds, which were supposed to have first priority for restoration activities, increased in condition. Less than 50 percent of the non-key watersheds increased in condition.

Currently the watershed condition evaluations include only road construction and decommissioning and tree growth and stand-replacing harvest or fire. Overall, road attributes are weighed more heavily in the decision-support models than are the vegetation attributes. Also, riparian attributes carry heavier weights than upslope attributes. Therefore, decommissioning roads in riparian and hazard areas will have the greatest positive effects on watershed condition scores. A reduction in the number of road-stream crossings often accompanies riparian road decommissioning, so removing a road in the riparian zone can have a large effect on the condition score. Management activities that increase the density of large (>20 in) conifers in riparian areas will also have strong positive effects on the condition of watersheds and will be a good step toward strengthening the wood input processes in these watersheds.

Implementing the monitoring program in the Plan area provided many products and insights for successful large-scale monitoring, and ideas for how to improve the monitoring program. Our first challenge was to successfully implement key components of the program including:

- Implementing a probabilistic survey design.
- Developing field survey protocols, including standardizing field protocols with the PacFish/InFish Biological Opinion (PIBO) monitoring effort.
- Developing the decision-support models.
- Implementing a data quality assessment program.
- Developing and implementing protocols to prevent the spread of invasive species.

Cooperative monitoring efforts between state and federal agencies are a natural extension of the monitoring program as we look for ways to reduce costs and gain a better understanding of the interaction of federal, state, and private land watershed management actions within the Plan area. The monitoring program team leader initiated bringing together state agency representatives from Washington, Oregon, and California in 2001 to explore how to reduce monitoring costs by sharing data. This effort evolved to include tribal and Idaho agency representatives and is now known as the Pacific Northwest Aquatic Monitoring Partnership.

The monitoring program team leader is the leader of the Pacific Northwest Aquatic Monitoring Partnership Watershed Workgroup, which is currently focused on two key areas to enable agencies to share data with each other: (1) probabilistic sample design and (2) common protocols. Use of a probabilistic sample design and using attributes with standardized sampling protocols will allow data to be combined across state, federal, and tribal lands. This will ultimately allow substantial improvements in efficiency and economy of scale for status and trend monitoring.

The general technical report that guides the monitoring program recommends sampling a minimum of 50 watersheds a year over a 5-year repeat cycle for a total of 250 watersheds (Reeves et al. 2004). This design was intended to balance our ability to estimate status in the greatest number of watersheds with the repeat sampling required to assess trends. Thus far, funding has allowed us to sample about 25 watersheds each year, including resampling one site per watershed as part of our quality assurance/quality control (QA/QC) program and the sampling of "trend sites" (revisits to QA/QC sites sampled the previous year). In light of budget constraints, monitoring program personnel are working with statisticians and scientists from the U.S. Environmental Protection Agency, U.S. Geological Survey, and USDA Forest Service, Pacific Northwest Research Station to review 3 years of cost and attribute data to determine the best type of sample design to use given probable funding levels and also to determine which attributes provide meaningful status and trend data. Five options are presented for the future monitoring program structure. We will analyze the data collected by the monitoring program thus far to assist in selecting an option. Selection will be based on the cost to implement the option, the time it will take to detect changes in the condition of watersheds, and the power to detect changes. The options include:

- A field-based program that relies heavily on detailed stream channel measurements that will be conducted in 25 watersheds per year.
- A field-based program that relies heavily on stream channel measurements that will be conducted in 50 watersheds per year.
- A geographic information system/remote sensing-based program that relies on upslope and riparian indicators as surrogates for watershed condition.
- Monitoring efforts coordinated with other federal and state agencies to enable the sharing of data and reduce overall costs.
- Using models to estimate the historical range of variability of vegetation condition and mass wasting across the Plan area. This distribution would be treated as the "desired" distribution to assess the differences (if any) between the current distribution and the desired distribution.

Issues related to the condition of watersheds are expected to emerge as our understanding of processes affecting watershed condition evolves. These issues will be incorporated into future iterations of decision-support models, as needed information becomes available. The following highlights some current emerging issues.

- **Distribution of watershed condition scores**—The desired distribution of watershed condition scores was not identified by the strategy. Historical and current watershed condition scores will allow field unit specialists to determine if planned disturbances will move watershed conditions outside the range of natural variation.
- **Links between management and inchannel habitat and biological indicators**—Thus far, research has yet to determine how management activities in upslope and riparian areas affect fish and other aquatic- and riparian-dependent species.
- **Fire**—The effect of fire suppression and stand-replacing burns on vegetation and stream reach conditions is unknown.
- **Restoration projects**—A link between restoration projects and the monitoring program has yet to be established.

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Metric Equivalents

When you know:	Multiply by:	To find:
Inches (in)	2.54	Centimeters
Inches (in)	25.4	Millimeters
Feet (ft)	.3048	Meters
Miles (mi)	1.609	Kilometers
Acres (ac)	.405	Hectares
Square miles (mi^2)	2.59	Square kilometers
Miles per square mile	.62	Kilometers per square kilometer

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Appendix 1: Objectives of the Aquatic Conservation Strategy[1]

Forest Service and Bureau of Land Management-administered lands within the range of the northern spotted owl will be managed to:

1. Maintain and restore the distribution, diversity, and complexity of watershed and landscape-scale features to ensure protection of the aquatic systems to which species, populations, and communities are uniquely adapted.
2. Maintain and restore spatial and temporal connectivity within and between watersheds. Lateral, longitudinal, and drainage network connections include flood plains, wetlands, upslope areas, headwater tributaries, and intact refugia. These network connections must provide chemically and physically unobstructed routes to areas critical to fulfilling life history requirements of aquatic and riparian-dependent species.
3. Maintain and restore the physical integrity of the aquatic system, including shorelines, banks, and bottom configurations.
4. Maintain and restore water quality necessary to support healthy riparian, aquatic, and wetland ecosystems. Water quality must remain within the range that maintains the biological, physical, and chemical integrity of the system and benefits survival, growth, reproduction, and migration of individuals composing aquatic and riparian communities.
5. Maintain and restore the sediment regime under which aquatic ecosystems evolved. Elements of the sediment regime include the timing, volume, rate, and character of sediment input, storage, and transport.
6. Maintain and restore in-stream flows sufficient to create and sustain riparian, aquatic, and wetland habitats and to retain patterns of sediment, nutrient, and wood routing. The timing, magnitude, duration, and spatial distribution of peak, high, and low flows must be protected.
7. Maintain and restore the timing, variability, and duration of flood-plain inundation and water table elevation in meadows and wetlands.
8. Maintain and restore the species composition and structural diversity of plant communities in riparian areas and wetlands to provide adequate summer and winter thermal regulation, nutrient filtering, appropriate rates of surface erosion, bank erosion, and channel migration and to supply amounts and distributions of coarse woody debris sufficient to sustain physical complexity and stability.
9. Maintain and restore habitat to support well-distributed populations of native plant, invertebrate, and vertebrate riparian-dependent species.

[1] From page B-11 of USDA and USDI 1994.

Appendix 2: Description of Physiographic Provinces[1]

Olympic Peninsula Province

The Olympic Peninsula in northwestern Washington is a mountainous region isolated on three sides by water and on the fourth side by a region of extensively harvested state and private lands. Streams flow outward from a central core of rugged mountains onto gently sloping lowlands. Landforms have been influenced by glaciation; main rivers flow in broad, U-shaped valleys, and peaks are surrounded by cirques. Steep slopes developed on resistant rocks are subject to narrow, shallow, rapid landslides (debris flows) originating from the heads of stream channels. Debris flows commonly scour steep tributary streams and deposit debris in fans on the valley floors. Unconsolidated glacial deposits are subject to accelerated streambank erosion and landslides.

Vegetation and climate on the peninsula include a mixture of coniferous rain forests on the western slopes of the Olympic Mountains and relatively dry Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) forests in the rain shadow on the eastern slopes.

The Olympic National Park occupies the interior of the Olympic Peninsula. It is surrounded by the Olympic National Forest, which is surrounded by extensive areas of private land, Indian reservations, and state-owned lands. Much of the Olympic National Park consists of high-elevation forests and subalpine areas, but lowland valleys in the park contain significant areas of late-successional and old-growth forest (older forest). A fragmented mixture of clearcuts, young plantations, and natural forests ranging from young stands to stands more than 500 years old characterizes the Olympic National Forest. The southern edge of the forest includes an extensive area referred to as the Shelton Sustained-Yield Unit, which was largely clearcut between 1960 and 1985. The forest includes several small wilderness areas on the east slope of the Olympic Range adjacent to the park. Most private, state, and Indian reservation lands on the peninsula have been clearcut in the last 80 years. Some of these areas are now being clearcut for the second time.

North Cascades Province

The North Cascades exhibit extremely high relief in comparison to other provinces. Glaciers have carved deep and steep-sided valleys into both resistant and weak rocks. Tributaries flow at high angles into broad U-shaped valleys such as that occupied by Lake Chelan. Steep slopes are subject to debris flows from the heads of stream channels. Unconsolidated glacial and volcanic deposits are subject to accelerated streambank erosion and landslides.

On the west side of the Cascade crest, lower and middle elevation forests consist primarily of Douglas-fir and western hemlock (*Tsuga heterophylla* (Raf.) Sorg.). The higher elevations support forests of silver fir (*Abies amabilis* Dougl. ex Forbes) and mountain hemlock (*T. mertensiana* (Bong.) Carr.). Although some national parks and wilderness areas in this region include significant areas of mid-elevation older forest, most are dominated by high-elevation areas of alpine or subalpine vegetation. The area on the east side of the Cascade crest is dominated by mixed-conifer forests and ponderosa pine (*Pinus ponderosa* Dougl. ex Laws.) forests at mid to lower elevations and by true fir forests at higher elevations.

Willamette/Puget Trough Province

The Willamette/Puget Trough province is typically divided into two subprovinces, the Western Washington Lowlands subprovince and the Willamette Valley subprovince. The Columbia River divides the two subprovinces. Land ownership in both subprovinces is predominantly private.

Puget Sound is a depressed, glaciated area that is now partially submerged. Unconsolidated deposits of alluvial and glacial materials are subject to accelerated streambank erosion and landslides. This area also includes extensive agricultural and metropolitan areas.

The Willamette Valley includes the lowland valley area, which lies in a broad structural depression between the Coast Range and Cascade Range in western Oregon. The Willamette River meanders northward along a very gentle valley slope. Unconsolidated deposits of alluvial

[1] Adapted from Appendix V-A in FEMAT (1993).

and glacial materials are subject to accelerated streambank erosion and landslides. This area, which was originally covered by a mosaic of lowland coniferous and deciduous forests and native prairie grasslands, was mostly cleared in the 1800s and early 1900s and converted to farmland, residential areas, and metropolitan areas. Land ownership is largely private.

West Cascades Province

The West Cascades province is distinguished from the High Cascades by older volcanic activity and longer glacial history. Steep, deeply dissected valleys separate ridge crests at similar elevations. Complex eruption materials juxtapose relatively stable lava flows and volcanic deposits that weather to thick soils and are subject to earth flows. Unconsolidated alluvial and glacial deposits are subject to streambank erosion and landslides. Tributary channels flow at large angles into wide, glaciated valleys.

This region is dominated by humid forests of Douglas-fir and western hemlock at lower to middle elevations. Forests in the southern section of the province are largely mixed-conifer forests consisting of Douglas-fir, grand fir, (*A. grandis* (Dougl. ex D. Don) Lindl.) and incense-cedar (*Libocedrus decurrens* Torr.).

Land ownerships include a mixture of private and state lands, and national forests. The Bureau of Land Management administers extensive areas in the province. Private and state lands in this area are mostly cutover, whereas federally administered lands still include significant areas (albeit highly fragmented) of older forest.

Washington/Oregon Coast Range Province

The southern part of the Washington/Oregon Coast Range province generally consists of steep slopes with narrow ridges developed on resistant sedimentary rocks. Westward flowing streams erode headward to mountain passes on the east side of the Coast Range. Many of the higher peaks are composed of resistant igneous rocks. Steep, highly dissected slopes are subject to debris flows. Tributary channels join at relatively low angles, which allows debris flows to travel for long distances. In the area drained by the Wilson and Trask Rivers in Oregon, weaker rocks form gentle slopes with thick soils that are subject to large, thick, slow-moving landslides (earth flows). Earth flows may constrict or deflect stream channels, creating local low-gradient stream reaches upstream.

The Washington portion of the province, which extends south from the Olympic Peninsula to the Columbia River, consists of a mixture of recent clearcuts and young stands on cutover areas. Forests on cutover areas are dominated by even-aged mixtures of Douglas-fir, western hemlock, and red alder (*Alnus rubra* Bong.). The Oregon portion of the province extends from the Columbia River south to the Middle Fork of the Coquille River. This area is dominated by forests of Douglas-fir, western hemlock, and western redcedar (*Thuja plicata* Donn ex D. Don).

The Washington portion of the province is largely in state and private ownership and has been almost entirely clearcut in the last 80 years. The Oregon portion includes a mixture of private, Forest Service, and Bureau of Land Management lands. The northern half is largely in private and state ownership. Heavy cutting and several extensive wildfires during the last century have eliminated most of the older forests in northern Oregon. Older forests in southern Oregon are highly fragmented, especially on Bureau of Land Management lands, which are typically intermixed with cutover private lands in a checkerboard pattern of alternating square-mile sections. Before the advent of fire suppression, the southern portion of the province was subject to frequent fires. As a result, many of the remaining natural forests consist of a mosaic of mature stands and remnant patches of older trees.

High Cascades Province

The High Cascades province consists of volcanic landforms with varying degrees of glaciation. Lava flows form relatively stable plateaus capped by the recent Cascade volcanoes. Drainages are generally not yet well developed or otherwise disperse into highly permeable volcanic deposits. Geologically recent volcanic deposits are subject to large debris flows when saturated by snowmelt.

Silver fir and mountain hemlock forests are found at high elevation in the Washington and Oregon portions of the province. Although some national parks and wilderness areas in this region include significant areas of mid-elevation older forest, most encompass high-elevation areas. Mixed-conifer and ponderosa pine forests are at mid to lower elevations. In California, mixed-conifer or ponderosa pine associations dominate forests.

Land ownership patterns include a mixture of Forest Service, private, state, Indian, National Park Service and Bureau of Land Management lands. Forests in this region are highly fragmented because of a variety of natural factors (e.g., poor soils, high fire frequencies, and high elevations) and human-induced factors (i.e., clearcutting and selective harvest). Before the advent of fire suppression in the early 1900s, wildfires played a major role in shaping the forests of this region. Intensive fire suppression efforts in the last 60 years have resulted in significant fuel accumulations in some areas and shifts in tree species composition from fire-resistant pine-dominated stands to mixed-conifer communities. These changes may have made forests more susceptible to large high-severity fires and to epidemic attacks of insects and diseases. Any plan to protect older forests in this area must include considerable attention to fire management and to the stability of forest stands.

Klamath/Siskiyou Province

The Klamath/Siskiyou province is in southwestern Oregon and northwestern California. The province is rugged and deeply dissected. Tributary streams generally follow the northeast-southwest orientation of rock structure created by accretion of rocks onto the continent. Variable materials juxtapose steep slopes subject to debris flows and gentle slopes subject to earth flows. Scattered granitic rocks are subject to debris flows and severe surface erosion. High rates of uplift have created steep streamside hillslopes known as inner gorges, especially near the coast.

Mixed-conifer and mixed-conifer/hardwood forests dominate this area. Land ownerships include a mixture of Forest Service, Bureau of Land Management, private, and state lands. Forests are highly fragmented by natural factors (e.g., poor soils, dry climate, and wildfires) and human-induced factors (such as harvest and roads). Much of the historical harvest in this area has been selective cutting rather than clearcutting. As a result, many stands logged in the early 1900s include a mixture of old trees left after harvest and younger trees that regenerated after harvest. Hillslope and channel disturbance from mining activities began in the 1850s and still continues. Much of the area in the province is characterized by high fire frequencies. Any plan to protect older forest in this province must include careful consideration of fire management.

Franciscan Province

The Franciscan province consists of the coastal strip that extends south from Coos Bay, Oregon, to Marin County, California. The province consists of accreted rocks, with structural discontinuities reflected in general stream orientations of northwest-southeast. Relatively rapid tectonic uplift has caused the dissected stream channels to become incised, creating inner gorges. Weak rocks are highly fractured along numerous faults and contacts and are weathered to deep soils subject to extensive earth flows. Sediment transport rates are among the highest in the world.

This area is dominated by redwood (*Sequoia sempervirens* (D. Don) Endl.) forests and mixed forests of Douglas-fir and hardwoods. Most of the area is privately owned, but Forest Service lands, Bureau of Land Management lands, and state and federal parks are also present. This area includes the coastal fog belt in which the last remaining stands of old-growth redwoods grow.

Appendix 3: The 250 Randomly Selected Watersheds[a]

Table 7—Watersheds and subwatersheds

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
171003030401	WA/OR Coast	Coos Bay BLM	Middle Umpqua River	Paradise Creek	55.5
171003030504	WA/OR Coast	Coos Bay BLM	Lake Creek	Upper Camp Creek	87.3
171003030701	WA/OR Coast	Coos Bay BLM	Lower Smith River	Upper Lower Smith River	54.7
171003050404	WA/OR Coast	Coos Bay BLM	East Fork Coquille	Brewster Canyon	49.6
171003050405	WA/OR Coast	Coos Bay BLM	East Fork Coquille	Elk Creek	46.5
171003050501	WA/OR Coast	Coos Bay BLM	North Fork Coquille	North Coquille	26.7
180102030101	High Cascades	Crater Lake NP	Wood River	East Fork Annie	100
170703010104	High Cascades	Deschutes NF	Deschutes River/ Charleton Creek	Snow Creek	100
170703010204	High Cascades	Deschutes NF	Deschutes River/ Browns Creek	Lower Odell Creek	100
170703010803	High Cascades	Deschutes NF	Squaw Creek	Upper Trout Creek	100
170703010907	High Cascades	Deschutes NF	Upper Metolius River	Canyon Creek	99.9
170703020203	High Cascades	Deschutes NF	Crescent Creek	Summit Creek	100
170703020204	High Cascades	Deschutes NF	Crescent Creek	Crescent Lake	100
170900020201	West Cascades	Eugene BLM	Mosby Creek	Table Mountain	38.7
170900020304	West Cascades	Eugene BLM	Upper Coast Fork Willamette	Middle Upper Coast Fork Willamette	27.6
171002060301	WA/OR Coast	Eugene BLM	Wildcat Creek	Upper Wildcat Creek	42.7
170701051002	West Cascades	Gifford Pinchot NF	Little White Salmon River	Big Lava Bed Frontal	97.8
170701051004	High Cascades	Gifford Pinchot NF	Little White Salmon River	Middle Little White Salmon River	60.3
170800020102	West Cascades	Gifford Pinchot NF	Upper Lewis River	Twin Falls Creek	100
170800020108	West Cascades	Gifford Pinchot NF	Upper Lewis River	Alec Creek	100
170800020202	West Cascades	Gifford Pinchot NF	Muddy River	Clearwater Creek	100
170800020203	West Cascades	Gifford Pinchot NF	Muddy River	Elk Creek	100
170800020401	West Cascades	Gifford Pinchot NF	Siouxon Creek	Upper Siouxon Creek	100
170800020404	West Cascades	Gifford Pinchot NF	Siouxon Creek	Cougar Creek	67.6
170800020503	West Cascades	Gifford Pinchot NF	East Fork Lewis River	Copper Creek	92.7
170800040205	West Cascades	Gifford Pinchot NF	Middle Upper Cowlitz River	Johnson Creek	99.8
170800040302	West Cascades	Gifford Pinchot NF	Lower Upper Cowlitz River	Willame Creek	99.9
170800040402	High Cascades	Gifford Pinchot NF	Upper Cispus River	Walupt Creek	99.8
170800040408	West Cascades	Gifford Pinchot NF	Upper Cispus River	Blue Lake-Cispus River	100
171100150110	West Cascades	Gifford Pinchot NF	Upper Nisqually River	Little Nisqually River	88.7
180102050102	High Cascades	Klamath NF	Mount Shasta Woods	Unnamed	68.7
180102050103	High Cascades	Klamath NF	Trapper Spring	Unnamed	77.3
180102060802	Klamath/Siskiyou	Klamath NF	Empire Creek	Humbug Creek	49.5
180102060803	Klamath/Siskiyou	Klamath NF	Empire Creek	Vesa Creek	62.5
180102060903	Klamath/Siskiyou	Klamath NF	West Fork Beaver Creek	Bear Creek	51
180102080101	Klamath/Siskiyou	Klamath NF	East Fork Scott River	Upper East Fork Scott River	33.4
180102080103	Klamath/Siskiyou	Klamath NF	East Fork Scott River	Noyes Valley	50.6
180102080203	Klamath/Siskiyou	Klamath NF	South Fork Scott River	Haynes Lake Creek	38.5
180102080402	Klamath/Siskiyou	Klamath NF	Moffett Creek	Indian Creek	52.7
180102080601	Klamath/Siskiyou	Klamath NF	Bridge Flat	Emigrant Creek	54.5
180102090203	Klamath/Siskiyou	Klamath NF	Indian Creek	East Fork Indian Creek	98.4
180102090302	Klamath/Siskiyou	Klamath NF	Elk Creek	Upper Elk Creek	100
180102090303	Klamath/Siskiyou	Klamath NF	Elk Creek	Lower Elk Creek	98.2
180102090402	Klamath/Siskiyou	Klamath NF	Clear Creek	Tenmile Creek	100
180102090501	Klamath/Siskiyou	Klamath NF	Ukonom Creek	Oak Flat Creek	96.4
180102100102	Klamath/Siskiyou	Klamath NF	South Fork Salmon River	Summerville	99.1
180102100106	Klamath/Siskiyou	Klamath NF	South Fork Salmon River	Crawford Creek	98.8

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
180102100401	Klamath/Siskiyou	Klamath NF	Lower Salmon River	Crapo Creek	98.7
180102111105	Klamath/Siskiyou	Klamath NF	Lower Trinity River	Big French Creek	99.6
171003020603	Klamath/Siskiyou	Medford BLM	Upper Cow Creek	Galesville	58.3
171003020801	WA/OR Coast	Medford BLM	West Fork Cow Creek	Upper West Fork Cow Creek	51.4
171003020803	WA/OR Coast	Medford BLM	West Fork Cow Creek	Elk Valley/Bobby	60.7
171003020901	Klamath/Siskiyou	Medford BLM	Lower Cow Creek	Lower West Fork Cow Creek	54.8
171003070504	West Cascades	Medford BLM	Elk Creek/Rogue River	Hawk Creek	40.9
171003070601	West Cascades	Medford BLM	Trail Creek	Upper Trail Creek	48.3
171003070701	Klamath/Siskiyou	Medford BLM	Rogue River/Reese Creek	Rogue Elk	61.1
171003070802	Klamath/Siskiyou	Medford BLM	Little Butte Creek	Lower North Fork Little Butte Creek	46.2
171003080304	Klamath/Siskiyou	Medford BLM	Evans Creek	Evans Creek	33.6
171003090203	Klamath/Siskiyou	Medford BLM	Upper Applegate River	Star Creek	87.1
171003090302	Klamath/Siskiyou	Medford BLM	Little Applegate River	Middle Little Applegate	82.8
171003090403	Klamath/Siskiyou	Medford BLM	Middle Applegate River	Humbug/Chapman	63.1
171003100403	Klamath/Siskiyou	Medford BLM	Rogue River/Kelsey Creek	Horseshoe Bend	99.8
171003100405	Klamath/Siskiyou	Medford BLM	Rogue River/Kelsey Creek	Kelsey Creek	92.3
171003110304	Klamath/Siskiyou	Medford BLM	Sucker Creek	Lower Sucker Creek	48.5
171003110503	Klamath/Siskiyou	Medford BLM	Deer Creek	Draper Creek	46.1
180102060405	High Cascades	Medford BLM	Jenny Creek	Keene Creek	53.9
180102060502	High Cascades	Medford BLM	Klamath-Iron Gate	Fall Creek	61.3
180102110603	Klamath/Siskiyou	Medford BLM	Weaver-Rush	Grass Valley Creek	60.4
180101030105	Klamath/Siskiyou	Mendocino NF	Lake Pillsbury	Anderson Creek	91.5
180101030202	Klamath/Siskiyou	Mendocino NF	Rice Fork	Lower Rice Fork	83.4
180101040103	Klamath/Siskiyou	Mendocino NF	Wilderness	Balm of Gilead Creek	100
180101040106	Klamath/Siskiyou	Mendocino NF	Wilderness	Howard Creek	88.7
180101040201	Klamath/Siskiyou	Mendocino NF	Black Butte River	Upper Black Butte River	76.2
180101040203	Klamath/Siskiyou	Mendocino NF	Black Butte River	Blue Slide Creek	94.9
180101040204	Klamath/Siskiyou	Mendocino NF	Black Butte River	Lower Black Butte River	66.3
180201160202	Franciscan	Mendocino NF	North Fork Cache Creek	Bartlett Creek	65
171100010201	North Cascades	Mt. Baker-Snoq. NF	Middle Chilliwack River	Silesia Creek	99.1
171100040104	North Cascades	Mt. Baker-Snoq. NF	Upper N. Fork Nooksack River	Glacier Creek	87.3
171100040301	North Cascades	Mt. Baker-Snoq. NF	South Fork Nooksack River	Upper South Fork Nooksack River	94
171100050603	North Cascades	Mt. Baker-Snoq. NF	Cascade River	Middle Cascade River	99.9
171100050702	North Cascades	Mt. Baker-Snoq. NF	Skagit River-Illabot Creek	Skagit River at Corkindale	64.7
171100050806	North Cascades	Mt. Baker-Snoq. NF	Baker River	Lake Shannon	51.5
171100060101	North Cascades	Mt. Baker-Snoq. NF	Upper Sauk River	Sloan Creek	100
171100060106	North Cascades	Mt. Baker-Snoq. NF	Upper Sauk River	Lower White Chuck River	100
171100060201	North Cascades	Mt. Baker-Snoq. NF	Upper Suiattle River	Suiattle River Headwaters	100
171100060203	North Cascades	Mt. Baker-Snoq. NF	Upper Suiattle River	Sulfur Creek	100
171100060303	North Cascades	Mt. Baker-Snoq. NF	Lower Suiattle River	Circle Creek	99.7
171100080102	North Cascades	Mt. Baker-Snoq. NF	North Fork Stillaguamish River	Squire Creek	37.9
171100090104	North Cascades	Mt. Baker-Snoq. NF	Tye and Beckler Rivers	Lower Tye River	74.1
171100090107	North Cascades	Mt. Baker-Snoq. NF	Tye and Beckler Rivers	Lower Beckler River	82.4
171100090201	North Cascades	Mt. Baker-Snoq. NF	Skykomish River Forks	Upper North Fork Skykomish River	100
171100090206	North Cascades	Mt. Baker-Snoq. NF	Skykomish River Forks	Lower South Fork Skykomish River	81.3
171100100102	North Cascades	Mt. Baker-Snoq. NF	North Fork Snoqualmie River	Sunday Creek	70.6
171100100303	North Cascades	Mt. Baker-Snoq. NF	Middle Fork Snoqualmie River	Taylor River	96.7
171100100402	North Cascades	Mt. Baker-Snoq. NF	Lower Snoqualmie River	South Fork Tolt River	30.7
171100130101	West Cascades	Mt. Baker-Snoq. NF	Upper Green River	Green River Headwaters	51.6
171100130102	West Cascades	Mt. Baker-Snoq. NF	Upper Green River	Twin Camp Creek	45.2

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
171100140104	West Cascades	Mt. Baker-Snoq. NF	Upper White River	Silver Creek	86.5
171100140105	High Cascades	Mt. Baker-Snoq. NF	Upper White River	Upper Greenwater River	100
171100140202	West Cascades	Mt. Baker-Snoq. NF	Lower White River	Clearwater River	46.1
170701050601	High Cascades	Mt. Hood NF	East Fork Hood River	Upper East Fork Hood River	100
170703060901	High Cascades	Mt. Hood NF	Tygh Creek	Upper Badger Creek	97
170800010102	West Cascades	Mt. Hood NF	Salmon River	Draw Creek	100
170800010201	West Cascades	Mt. Hood NF	Zigzag River	Still Creek	99.5
170800010501	West Cascades	Mt. Hood NF	Bull Run River	Blazed Alder Creek	98.6
170800010504	West Cascades	Mt. Hood NF	Bull Run River	Cedar Creek	98.5
170900110101	West Cascades	Mt. Hood NF	Collawash River	Upper Hot Springs Fork Collawash	100
170900110201	West Cascades	Mt. Hood NF	Upper Clackamas River	Cub Creek	100
170900110301	West Cascades	Mt. Hood NF	Oak Grove Fork Clackamas	Upper Oak Grove Fork Clackamas	32.3
170900110304	West Cascades	Mt. Hood NF	Oak Grove Fork Clackamas	High Rock Creek	100
171100150101	West Cascades	Mt. Rainer NP	Upper Nisqually River	Nisqually Headwaters	100
170200090110	North Cascades	North Cascades NP	Stehekin	Boulder Creek	100
171100050401	North Cascades	North Cascades NP	Skagit River-Gorge Lake	Fisher Creek	98
171100050502	North Cascades	North Cascades NP	Skagit River-Diobsud Creek	East Fork Bacon Creek	100
170200080102	North Cascades	Okanogan NF	Lost River	South Fork Lost River	100
170200080103	North Cascades	Okanogan NF	Lost River	Lower Lost River	99.7
170200080203	North Cascades	Okanogan NF	Upper Methow River	Rattlesnake Creek	92.1
170200080204	North Cascades	Okanogan NF	Upper Methow River	Cedar Creek	100
170200080502	North Cascades	Okanogan NF	Twisp River	South Creek	99.2
170200080703	North Cascades	Okanogan NF	Lower Methow River	Gold Creek	98
171100050104	North Cascades	Okanogan NF	Ross Lake	Devils Creek	99.2
171001010601	Olympic Peninsula	Olympic NF	Calawah River	North Fork Calawah River	63
171001020207	Olympic Peninsula	Olympic NF	Salmon River	Salmon River	30.3
171001040103	Olympic Peninsula	Olympic NF	Satsop River	Satsop River Middle Fork	34.4
171100180109	Olympic Peninsula	Olympic NF	Turner/Walkers Creek	Spencer/Marple Creek	62
171100180301	Olympic Peninsula	Olympic NF	Big Quilcene River	Upper Big Quilcene River	100
171100180701	Olympic Peninsula	Olympic NF	Hamma Hamma River	Hamma Hamma River	82.4
171100200302	Olympic Peninsula	Olympic NF	Gray Wolf River	Lower Gray Wolf River	100
171001010401	Olympic Peninsula	Olympic NP	Sol Duc River	North Sol Duc River	100
171001010402	Olympic Peninsula	Olympic NP	Sol Duc River	Head Sol Duc River	100
171001010702	Olympic Peninsula	Olympic NP	Bogachiel River	Upper Bogachiel River	98.7
171100200702	Olympic Peninsula	Olympic NP	Elwha River	Goldie River	100
180102110604	Klamath/Siskiyou	Redding BLM	Weaver-Rush	Indian Creek	31
171003070105	High Cascades	Rogue River NF	Upper Rogue River	Foster Creek	100
171003070112	High Cascades	Rogue River NF	Upper Rogue River	Lower Mill	88.4
171003070113	High Cascades	Rogue River NF	Upper Rogue River	Barr Creek	44.1
171003070203	High Cascades	Rogue River NF	South Fork Rogue River	Bessie Creek	99.3
171003070402	High Cascades	Rogue River NF	Big Butte Creek	Clarks Fork/Forbit	89
171003070403	High Cascades	Rogue River NF	Big Butte Creek	Willow Creek	64
171003070803	High Cascades	Rogue River NF	Little Butte Creek	Upper South Fork Little Butte Creek	100
171003080106	Klamath/Siskiyou	Rogue River NF	Bear Creek	Ashland Creek	88.8
171003090104	Klamath/Siskiyou	Rogue River NF	Upper Applegate River	Lower Elliott	82.9
171003090105	Klamath/Siskiyou	Rogue River NF	Upper Applegate River	Steve Fork Carberry Creek	96.6
171003090107	Klamath/Siskiyou	Rogue River NF	Upper Applegate River	Lower Carberry	82.3
171003020503	Klamath/Siskiyou	Roseburg BLM	South Umpqua River	Stouts Creek	54.4
171003020506	Klamath/Siskiyou	Roseburg BLM	South Umpqua River	Upper Shively Oshea	40.5
171003020902	Klamath/Siskiyou	Roseburg BLM	Lower Cow Creek	Middle Creek	41.4
171003030106	WA/OR Coast	Roseburg BLM	Upper Umpqua River	Yellow Creek	54.7

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
171003050201	Klamath/Siskiyou	Roseburg BLM	Middle Fork Coquille	Camas Valley	34.8
170900070201	WA/OR Coast	Salem BLM	Rickreall Creek	Upper Rickreall Creek	20.5
170900090503	West Cascades	Salem BLM	Upper Molalla River	Upper Molalla River	39.1
171002040402	WA/OR Coast	Salem BLM	Upper Siletz River	Lower North Fork of Siletz River	38.6
170900110601	West Cascades	Shasta-Trinity NF	Lower Clackamas River	Upper Clear Creek	32.9
180102070201	High Cascades	Shasta-Trinity NF	Grass Lake	Spring Creek	58.9
180102110102	Klamath/Siskiyou	Shasta-Trinity NF	Main Trinity River	Picayume Creek	59.1
180102110103	Klamath/Siskiyou	Shasta-Trinity NF	Main Trinity River	Little Trinity River	47.1
180102110404	Klamath/Siskiyou	Shasta-Trinity NF	Stuart Fork	Stoney Creek	71.5
180102110502	Klamath/Siskiyou	Shasta-Trinity NF	Trinity Reservoir	Lower Trinity Reservoir	61.1
180102110605	Klamath/Siskiyou	Shasta-Trinity NF	Weaver-Rush	Weaver Creek	56
180102111101	Klamath/Siskiyou	Shasta-Trinity NF	Lower Trinity River	Sailor Bar Creek	96.3
180102111104	Klamath/Siskiyou	Shasta-Trinity NF	Lower Trinity River	Little French Creek	96.9
180102120103	Klamath/Siskiyou	Shasta-Trinity NF	Upper South Fork Trinity River	Upper South Fork Trinity River	94.6
180102120204	Klamath/Siskiyou	Shasta-Trinity NF	Middle South Fork Trinity River	Indian Valley Creek	95.8
180102120302	Klamath/Siskiyou	Shasta-Trinity NF	Upper Hayfork Creek	North Fork Hayfork Creek	46.4
180102120402	Klamath/Siskiyou	Shasta-Trinity NF	Lower Hayfork Creek	Philpot Creek	81.6
180102120406	Klamath/Siskiyou	Shasta-Trinity NF	Lower Hayfork Creek	Grassy Flat Creek	94.9
180200031103	High Cascades	Shasta-Trinity NF	Squaw Creek	Lower Squaw Creek	82.1
180200031201	High Cascades	Shasta-Trinity NF	Pit Arm Shasta Lake	Potem Creek	56.7
180200040103	High Cascades	Shasta-Trinity NF	Ash Creek	Horse Creek	36.8
180200040106	High Cascades	Shasta-Trinity NF	Ash Creek	Lower Ash Creek	85.8
180200040401	High Cascades	Shasta-Trinity NF	Squaw Valley Creek	Panther Creek	39.5
180200040403	High Cascades	Shasta-Trinity NF	Squaw Valley Creek	Claireborne Creek	51.7
180200050103	High Cascades	Shasta-Trinity NF	Box Canyon	South Fork Sacramento River	68.7
180200050304	High Cascades	Shasta-Trinity NF	Lower Sacramento River	North Salt Creek	50.1
180200050401	High Cascades	Shasta-Trinity NF	Sacramento Arm Shasta Lake	Middle Salt Creek	41.5
171003050101	WA/OR Coast	Siskiyou NF	Lower South Fork Coquille	Headwaters South Fork Coquille	75.4
171003100602	Franciscan	Siskiyou NF	Rogue River	Shasta Costa Creek	99.9
171003100603	Franciscan	Siskiyou NF	Rogue River	Illahe Creek	93.3
171003110103	Klamath/Siskiyou	Siskiyou NF	East Fork Illinois River	Lower East Fork Illinois River	47.4
171003110303	Klamath/Siskiyou	Siskiyou NF	Sucker Creek	Grayback Creek	82.2
171003110603	Klamath/Siskiyou	Siskiyou NF	Illinois River/Josephine Creek	Sixmile Creek	98.4
171003110604	Klamath/Siskiyou	Siskiyou NF	Illinois River/Josephine Creek	Baker Creek	97.8
171003111101	Franciscan	Siskiyou NF	Lawson Creek	Lawson Creek	99
171003120104	Franciscan	Siskiyou NF	Upper Chetco River	Middle Upper Chetco River	100
171003120106	Franciscan	Siskiyou NF	Upper Chetco River	Boulder Creek	100
171003120501	Franciscan	Siskiyou NF	Hunter Creek	Upper Hunter	37.8
171002030204	WA/OR Coast	Siuslaw NF	Nestucca River	Niagara Creek	79.6
171002031002	WA/OR Coast	Siuslaw NF	Spring Creek/Sand Lake	Sand Creek	42.3
171002050201	WA/OR Coast	Siuslaw NF	Five Rivers/Lobster Creek	Upper Five Rivers	90.2
171002050302	WA/OR Coast	Siuslaw NF	Drift Creek	Middle Drift Creek	49.3
171002050403	WA/OR Coast	Siuslaw NF	Lower Alsea River	Middle Alsea River	78.5
171002050405	WA/OR Coast	Siuslaw NF	Lower Alsea River	Lower Alsea River	44.3
171002050704	WA/OR Coast	Siuslaw NF	Cummins Creek/Tenmile Creek	Mercer Lake	59.7
171002060501	WA/OR Coast	Siuslaw NF	Deadwood Creek	Upper Deadwood Creek	81.7
171002060602	WA/OR Coast	Siuslaw NF	Indian Creek	Lower Indian Creek	77.9
171003030704	WA/OR Coast	Siuslaw NF	Lower Smith River	Wassen Creek	80.4
171003030706	WA/OR Coast	Siuslaw NF	Lower Smith River	Lower North Fork Smith River	43.8
180101010204	Klamath/Siskiyou	Six Rivers NF	Middle Fork Smith River	Shelley Creek	89
180101010301	Klamath/Siskiyou	Six Rivers NF	South Fork Smith River	Prescott Fork	99.7
180101050201	Franciscan	Six Rivers NF	Upper North Fork Eel River	Headwaters North Fork Eel River	81.8
180102090801	Klamath/Siskiyou	Six Rivers NF	Bluff Creek	Cedar Creek	100

Table 7—Watersheds and subwatersheds (continued)

USGS HUC	Province	Admin. unit	Watershed name	Subwatershed name	FED
					Percent
180102091001	Klamath/Siskiyou	Six Rivers NF	Blue Creek	Upper Blue Creek	100
180102091004	Klamath/Siskiyou	Six Rivers NF	Blue Creek	Slide Creek	93.8
180102111203	Klamath/Siskiyou	Six Rivers NF	Trinity-South Fork Tish Tang	Horse Linto Creek	95
180102111204	Klamath/Siskiyou	Six Rivers NF	Trinity-South Fork Tish Tang	Tish Tang Creek	56.3
180102120505	Klamath/Siskiyou	Six Rivers NF	Grouse-Madden	Lower South Fork Trinity River	87.4
180201160503	Franciscan	Ukiah BLM	Lakeport	Lower Scotts Creek	39
170900020101	West Cascades	Umpqua NF	Row River	Layne Creek	88
171003010103	High Cascades	Umpqua NF	Diamond Lake	Diamond Lake East	100
171003010204	High Cascades	Umpqua NF	Lemolo Lake	Thirsty Creek	100
171003010301	West Cascades	Umpqua NF	Upper North Umpqua	Warm Springs	100
171003010402	High Cascades	Umpqua NF	Clearwater	Bear Creek	100
171003010501	West Cascades	Umpqua NF	Fish Creek	Clear Creek	100
171003010801	West Cascades	Umpqua NF	Steamboat Creek	City Creek	96.8
171003011101	West Cascades	Umpqua NF	Little River	Little River Canyon	99.3
171003011104	West Cascades	Umpqua NF	Little River	Emile	84.4
171003011106	West Cascades	Umpqua NF	Little River	Upper Cavitt Creek	97.5
171003020203	West Cascades	Umpqua NF	Jackson Creek	Squaw	100
171003020302	West Cascades	Umpqua NF	Middle South Umpqua	Dumont	99.5
171003020403	West Cascades	Umpqua NF	Elk Creek/South Umpqua	Drew Creek	83.6
170200090202	North Cascades	Wenatchee NF	Upper Chelan	Fish Creek	98.8
170200090204	North Cascades	Wenatchee NF	Upper Chelan	Emerald Park Creek	98.2
170200110202	North Cascades	Wenatchee NF	Chiawa River	Middle Chiawa River	100
170200110203	North Cascades	Wenatchee NF	Chiawa River	Lower Chiawa River	92
170200110303	North Cascades	Wenatchee NF	Nason-Tumwater	Chiwaukum Creek	91.3
170200110403	North Cascades	Wenatchee NF	Icicle-Chumstick	Chumstick Creek	58.2
170300010301	North Cascades	Wenatchee NF	Middle Upper Yakima River	Swauk Creek	75.3
170300020302	High Cascades	Wenatchee NF	Tieton River	North Fork Tieton River	100
170900010106	West Cascades	Willamette NF	Upper Middle Fork Willamette	Echo Creek	73.7
170900010201	West Cascades	Willamette NF	Hills Creek	Upper Hills Creek	100
170900010303	West Cascades	Willamette NF	Salt Creek/Willamette River	Lower Salt Creek	99.5
170900010504	West Cascades	Willamette NF	Hills Creek Reservoir	Larison Creek	85.8
170900010603	West Cascades	Willamette NF	North Fork of Middle Fork Willamette	Fisher Creek	100
170900010701	West Cascades	Willamette NF	Lost Creek	Lookout Point Reservoir	72.7
170900010902	West Cascades	Willamette NF	Fall Creek	Hehe Creek	97.6
170900040102	West Cascades	Willamette NF	Upper McKenzie River	Fish Lake Creek	97.2
170900040107	West Cascades	Willamette NF	Upper McKenzie River	Upper White Branch	100
170900040201	West Cascades	Willamette NF	Horse Creek	Upper Separation Creek	100
170900040307	West Cascades	Willamette NF	South Fork McKenzie River	Walker Creek	87.1
170900040501	West Cascades	Willamette NF	McKenzie River	Quartz Creek	45.9
170900050107	West Cascades	Willamette NF	Upper North Santiam River	Boulder Creek	74.4
170900050202	West Cascades	Willamette NF	North Fork Breitenbush River	North Fork Breitenbush River	95.8
170900050203	West Cascades	Willamette NF	North Fork Breitenbush River	Humbug Creek	100
170900050301	West Cascades	Willamette NF	Blow Out Divide Creek	Upper Blowout Creek	100
170900050503	West Cascades	Willamette NF	Little North Santiam River	Gold Creek	99.9
170900060401	West Cascades	Willamette NF	Quartzville Creek	Upper Quartzville Creek	100
170900060503	West Cascades	Willamette NF	Middle Santiam River	Sixes Creek	86.2
170900060604	West Cascades	Willamette NF	South Santiam River	Falls Creek	94.3
170900060607	West Cascades	Willamette NF	South Santiam River	Owl Creek	37.1
180102030202	High Cascades	Winema NF	Klamath Lake	Threemile Creek	97.9

[a] Includes the U.S. Geological Survey hydrologic unit code (USGS HUC), the aquatic province, the national forest (NF), Bureau of Land Management (BLM) unit, or national park (NP) that manages the land, the fifth-field watershed name, the sixth-field subwatershed name, and the percentage of the total watershed area that is federally owned (FED).

Appendix 4: Model Structure and Evaluation Criteria for Each of the Provincial Decision-Support Models

Model Structures

A decision-support model was developed for each aquatic province by a team of local experts. Each provincial model includes an evaluation of watershed-scale and reach-scale attributes. These models hierarchically aggregate a number of attributes into broader indices of reach and watershed condition. The reach condition score also serves as one component of the broader watershed condition score. In this case, the reach condition score used in the watershed model is the average condition score of all the reaches in the watershed. A graphical depiction of the model structures for each province is contained in this appendix (figs. 55 through 66). Some model sections were "turned off" in this iteration because the corresponding data were not available. These unused portions of the models are indicated by gray text.

Attribute Aggregation

After each attribute datum is evaluated, the model begins to aggregate these scores together in a hierarchical fashion. The combined score is passed up to the next level in the model hierarchy, where it is combined again with results from other parts of the model. The modeling software enables a number of different aggregation functions, but we limited choice to the three simplest:

- MIN: take the minimum score from those being aggregated.
- AVE: take the average of the aggregated scores.
- MAX: take the maximum score from those being aggregated.

These functions determine whether the situation is of a "limiting factor" type, where the worst condition score determines the combined score, a "partially compensatory" situation, where scores are all counted equally, or a "fully compensatory" situation, where the best score determines the combined score.

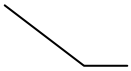
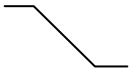
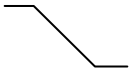
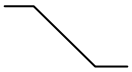
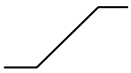
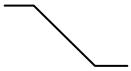
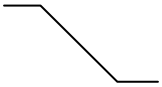
In addition to operators, each node in the model can also be assigned a weight. These weights are listed on the model structure diagrams. For example, the Franciscan/Klamath models (fig. 57) weighted riparian vegetation at 0.7 and upland vegetation at 0.3, so the overall vegetation score comes 70 percent from riparian value and 30 percent from the upland value. These weights are only relevant under the AVE operator.

Attribute Scores

A model begins by reading in a set of data observations, which we call "attributes," for a watershed. These attributes are the rightmost nodes in the model structure diagrams. For example, attributes for the Olympic Peninsula (fig. 63) include average total nitrogen and the area of watershed in urban/agricultural land uses. When the provincial experts constructed the model structure, they also developed evaluation criteria for each attribute (shown in this appendix in the tables that follow each provincial model figure). These evaluation curves determine how any particular data value is scored on a common scale from +1 to -1 according to its contribution toward overall watershed condition. As the attribute data for each watershed are read into the model, they are each compared to their respective evaluation criteria to produce an evaluation score for each between +1 and -1. For the Olympic Province, if there are no riparian roads (density = 0), then the evaluated score would be +1; if road density was 0.3 mi/mi^2 of riparian area or greater, the score would be -1; and if the density falls between 0 and 0.3 mi/mi^2, the attribute receives a score that is a linear interpolation between +1 and -1 (e.g., 0.15 mi/mi^2 would evaluate to 0). Note that there is an important difference between a data value of "zero" and "no data." Data values of zero (e.g., riparian roads example above) are compared to their evaluation curve the same as all other data values. However, if data for a particular attribute are lacking in a particular watershed, then that attribute is given an **evaluated score** of zero, representing a neutral value that does not indicate either good or poor condition.

Attributes for each province are shown in tables 8 through 13. The "attribute and measure" column contains the attribute name, units of measure, and qualifiers if any, (e.g., temperature is evaluated differently in watersheds depending on whether bull trout (*Salvelinus confluentus*) are present). "Data value" and "Evaluation score" columns show how the raw data values correspond to evaluated scores, and the "Curve shape" column gives a graphical depiction of this relationship with data values represented on the x-axis and corresponding evaluation scores on the y-axis. The "Source" column gives the basis on which the curve was constructed, most often the professional judgment of workshop participants but also including data sets and published reports or standards.

Table 8—Evaluation criteria used in decision-support model for Washington/Oregon Coast province

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Riparian road density—164-ft buffer (mi road/mi stream)	0 0.1	1 -1		Professional judgment AREMP[a] workshop 06/23/04
Road crossing frequency (number of crossings/mi stream)	0.25 1	1 -1		Professional judgment Bob Metzger (OLY) 07/22/04
Urban/agriculture (percentage of watershed)	20 40	1 -1		Professional judgment AREMP workshop 04/01/03
Riparian vegetation, large-conifer cover—164-ft buffer (percentage of area with conifers >20 in d.b.h.)	25 50 75 85	-1 1 1 -1		Kelly Burnett dissertation AREMP workshop 04/01/03
Water temperature (maximum 7-day average, °C)				
Bull trout present	4 6 9 13	-1 1 1 -1		Oregon Department of Environmental Quality standard AREMP workshop 06/23/04
No bull trout	16 23	1 -1		Oregon Department of Environmental Quality standard AREMP workshop 06/23/04
Dissolved oxygen (mg/L)	4 10	-1 1		North Cascades workshop AREMP workshop 06/23/04
Reach model attributes				
Morphology	Rosgen-type F or G All others	-1 1		AREMP workshop 04/01/03
Pool frequency (number of bankfull widths per pool)	8 20	1 -1		ODFW benchmarks AREMP workshop 06/23/04
Pool quality (average residual pool depth in inches)	14 30	-1 1		ODFW benchmarks AREMP workshop 06/23/04
Wood frequency (number of pieces per 100 m) 0.3 × 3 m minimum	10 20	-1 1		ODFW Benchmarks AREMP workshop 06/23/04
Substrate pool-tail fines (percent)	17 11	-1 1		North Cascades workshop AREMP workshop 06/23/04

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.

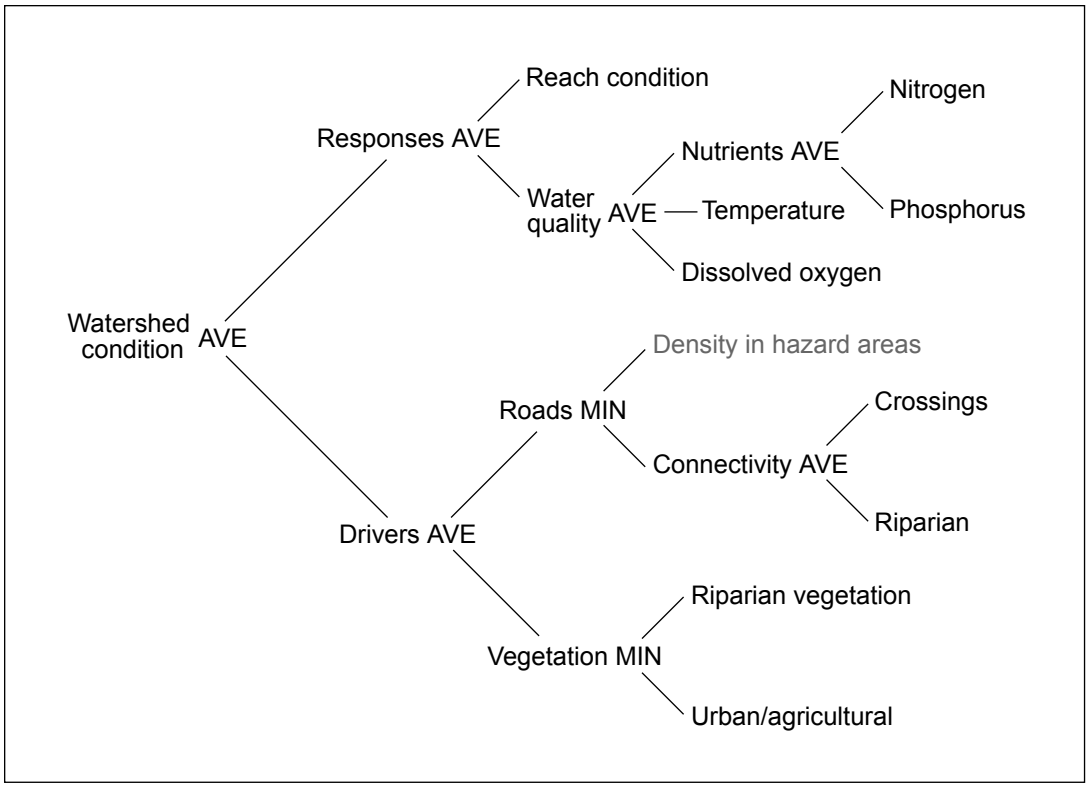


Figure 55—Watershed condition decision-support model used in the Washington/Oregon Coast province. Guidance on interpreting the figures is provided in appendix 4 text.

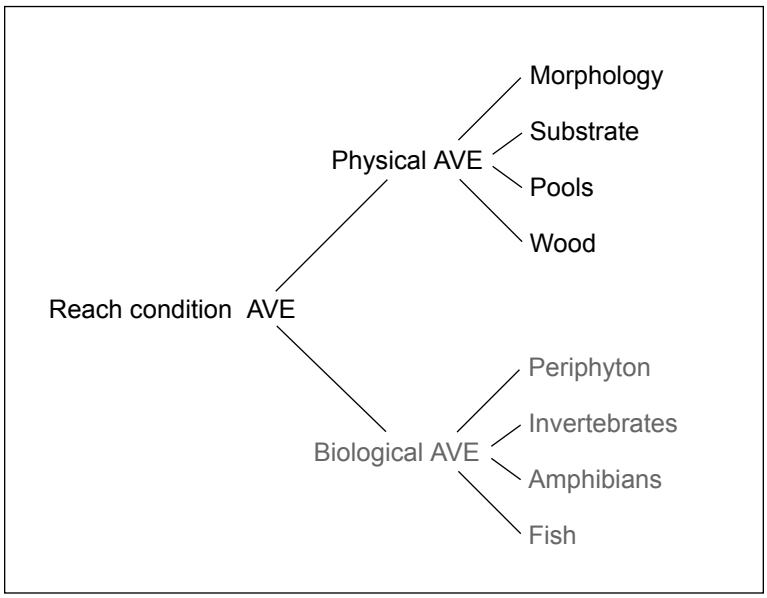


Figure 56—Reach condition decision-support model used in the Washington/Oregon Coast province. Guidance on interpreting the figures is provided in appendix 4 text.

Table 10—Evaluation criteria used in decision-support model for Klamath/Siskiyou and Franciscan provinces

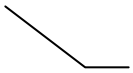
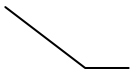
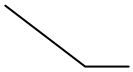
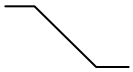
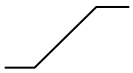
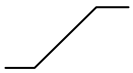
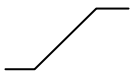
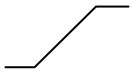
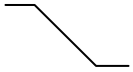
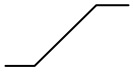
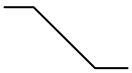
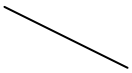
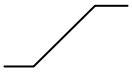
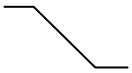
Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Road density in hazard areas—slope >65 percent and geology sensitive to mass failure (mi road/mi^2 hazard area)	0.5 1.5	1 -1		Randy Frick[a] data
Road density in lower one-third of slope (mi road/mi^2 lower slope)	1 1.7	1 -1		Klamath NF data
Riparian road density—164-ft buffer (mi road/mi^2 riparian area)	0.5 1.5	1 -1		Klamath NF data
Road crossing frequency (number of crossings/mi stream)	1 3	1 -1		Randy Frick data
Upslope vegetation (average percentage of canopy cover)				
Coniferous forest	50 70 85	-1 0 1		Professional judgment
Oak woodland	10 40	-1 1		Professional judgment
Upslope vegetation—small conifer cover (percentage of area with conifers ≤5 in d.b.h.) Wet = precipitation >40 in; dry = precipitation <40 in	25 5	-1 1		Professional judgment
Riparian vegetation—164-ft buffer (average percentage of canopy cover)	50 70 85	-1 0 1		Professional judgment
Riparian vegetation—large-conifer cover, 164-ft buffer (percentage of area with conifers ≥20 in d.b.h.)	40 75	-1 1		Professional judgment
Water temperature (maximum 7-day average, °C)	64 68 70 75	1 0.8 0 -1		Professional judgment
Dissolved oxygen (mg/L)	4 7	-1 1		Professional judgment
Reach model attributes				
Entrenchment ratio Slope <4 percent	<2.2 >2.2	0 1		Professional judgment
Sinuosity Slope <2 percent, entrenchment >1.4	<1.5 >1.5	0 -1		Professional judgment

Table 10—Evaluation criteria used in decision-support model for Klamath/Siskiyou and Franciscan provinces (continued)

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Bankfull width:depth—slope <4 percent	15 35	1 -1		Randy Frick data
Pool frequency (number of wetted widths per pool)	10 14	1 -1		Randy Frick data
Wood frequency (number of pieces per 100 meters) 12 in small end × 25-ft minimum	1 3	-1 1		Randy Frick data
Substrate D_{50} (mm)	2 45 362 4,096	-1 1 1 -1		Professional judgment
Substrate pool-tail fines (percent)	10 30	1 -1		Professional judgment

[a] Randy Frick is a Fisheries Program Manager on the Rogue River National Forest.

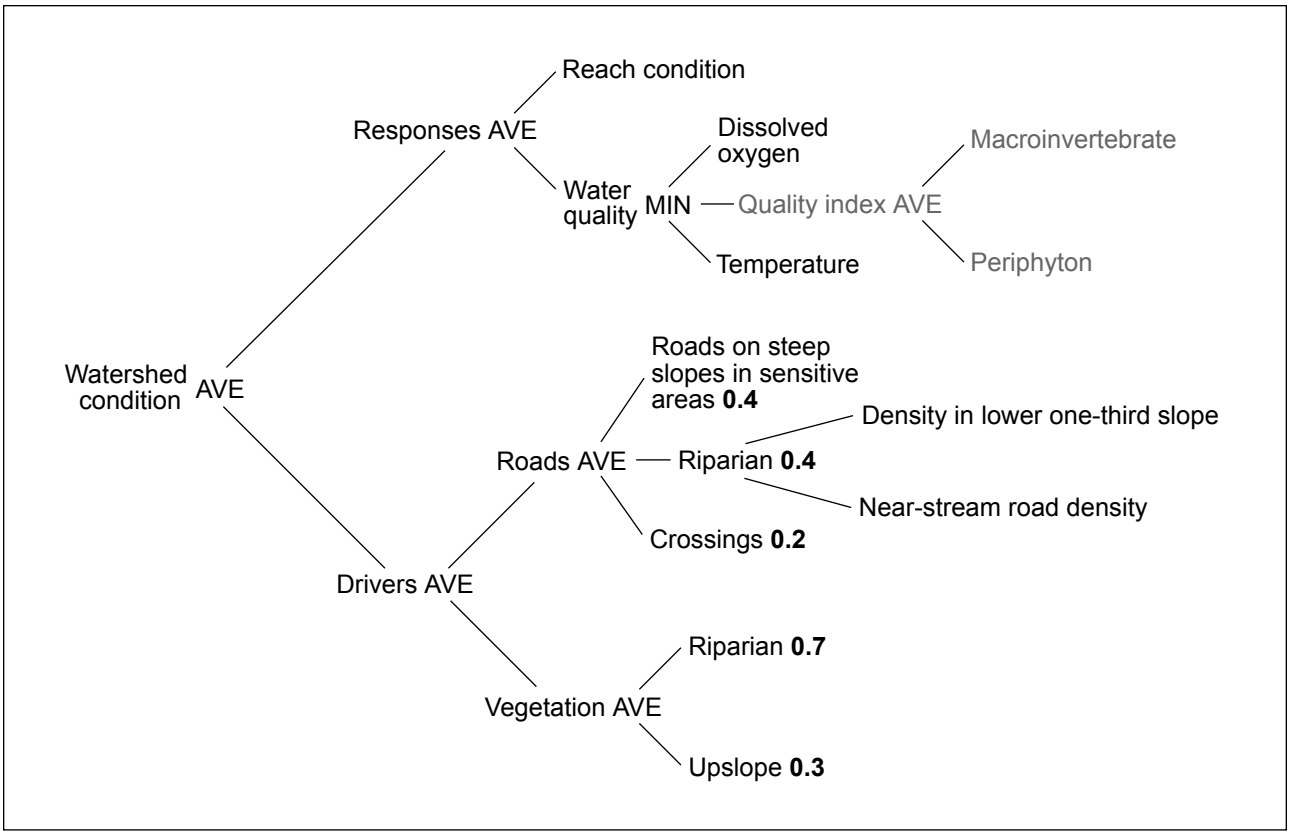


Figure 57—Watershed condition decision-support model used in the Klamath/Siskiyou and Franciscan provinces. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

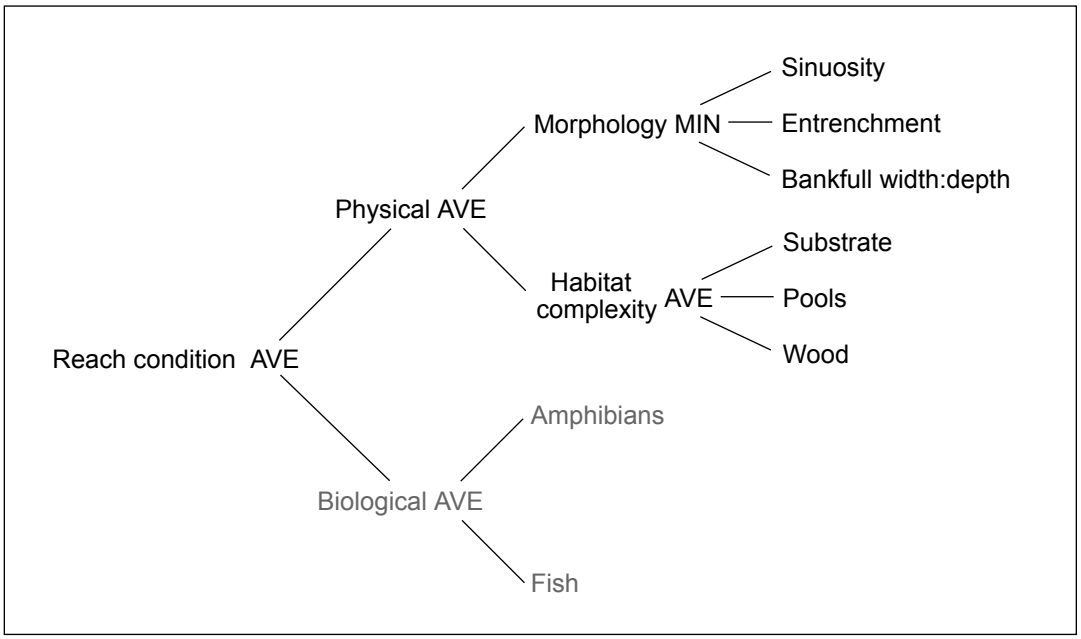


Figure 58—Reach condition decision-support model used in the Klamath/Siskiyou and Franciscan provinces. Guidance on interpreting the figures is provided in appendix 4 text.

Table 9—Evaluation criteria used in decision-support model for High Cascades province

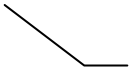
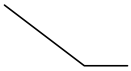
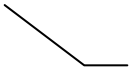
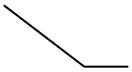
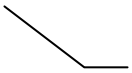
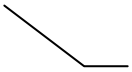
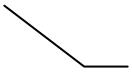
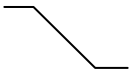
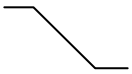
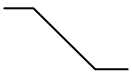
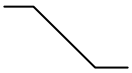
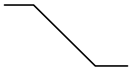
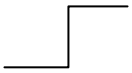
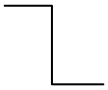
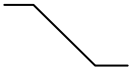
Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
High-slope road density—slope >50 percent (mi road/mi^2 watershed)				
North subprovince	0 0.5	1 -1		AREMP[a] workshop 05/22/03
Central and south subprovinces	0 1	1 -1		AREMP workshop 05/22/03
Upslope road density (mi road/mi^2 watershed)				
North subprovince only	0 4	1 -1		Dose and Roper 1994 AREMP workshop 05/22/03
Riparian road density—164-ft buffer (mi road/mi stream)				
North and south subprovinces	0 0.1	1 -1		AREMP workshop 05/22/03
Central subprovince	0 0.25	1 -1		AREMP workshop 07/07/04
Road crossing frequency (number of crossings/mi stream)				
North and south subprovinces	0 0.5	1 -1		AREMP workshop 05/22/03
Central subprovince	0 1.5	1 -1		AREMP workshop 07/07/04
Upslope vegetation—small-conifer cover (percentage of area with conifers <10 in d.b.h.)				
North and south subprovinces	10 50	1 -1		AREMP workshop 05/22/03
Central subprovince	30 70	1 -1		AREMP workshop 07/07/04
Riparian vegetation—large-conifer cover, 98-ft buffer (percentage of area with conifers ≥10 in d.b.h.)				
North and south subprovinces	30 60 80	1 0 -1		AREMP workshop 05/22/03
Central subprovince	20 60	1 -1		AREMP workshop 07/07/04
Water temperature (maximum 7-day average, °C)				
Bull trout present	3 6 9 13	0 1 1 -1		AREMP workshop 05/22/03
No bull trout	16 18 23	1 0 -1		AREMP workshop 05/22/03

Table 9—Evaluation criteria used in decision-support model for High Cascades province (continued)

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Dissolved oxygen (mg/l)	≤ 4 > 4	-1 1		
Reach model attributes				
Morphology				
Slope Entrenchment ratio Sinuosity Bankfull width:depth	Use to determine Rosgen stream type If D, F, G channel then -1, otherwise +1			Professional judgment AREMP workshop 05/22/03
Pool frequency (number of bankfull widths per pool)				
≤3 percent slope	≤15 >15	1 -1		Professional judgment AREMP workshop 05/22/03
>3 percent slope	≤12 >12	1 -1		
Wood frequency (number of pieces per 100 m)				
South of Broken Top—18 in × 50 ft North of Broken Top—12 in × 50 ft	1.5 4	-1 1		
Substrate pool-tail fines (percent)				
South of White River	20 35	1 -1		Professional judgment AREMP workshop 05/22/03
North (uses original West Cascades curve)(percent)	10 25	1 -1		Professional judgment AREMP workshop 05/22/03

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.

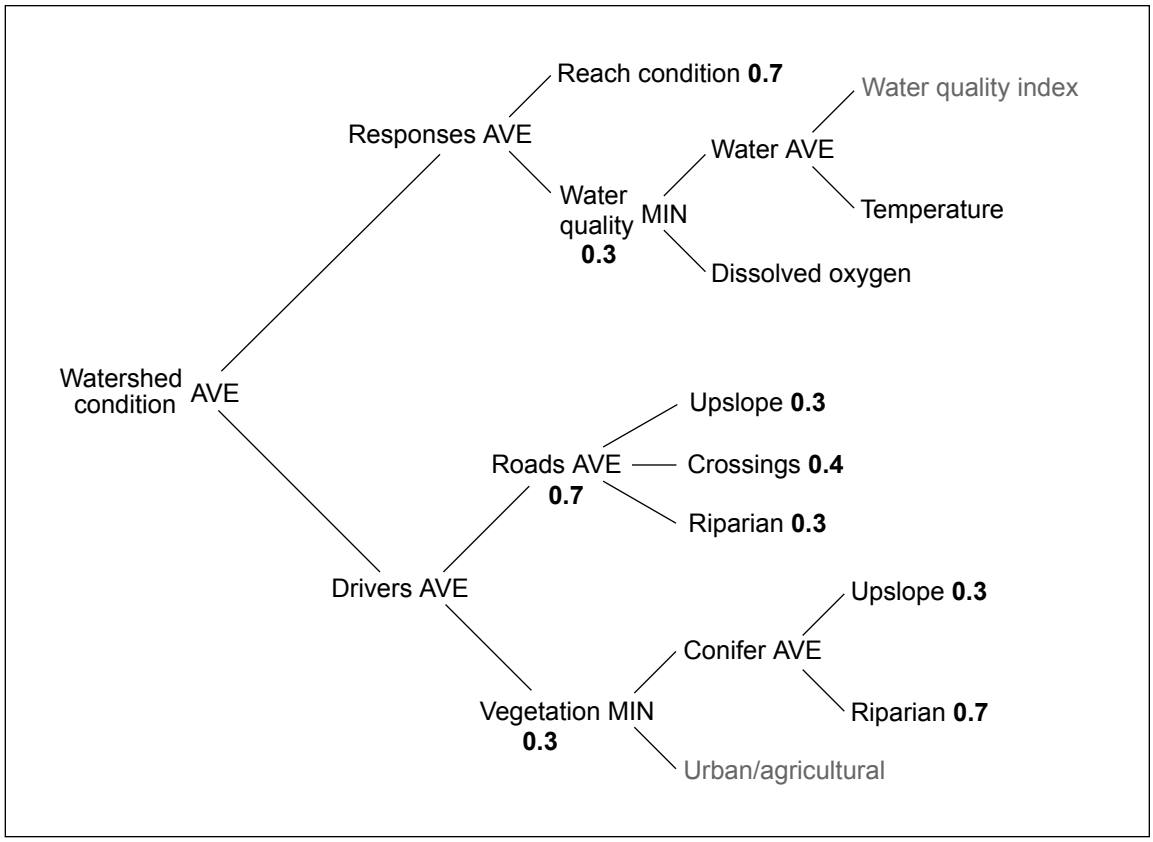


Figure 59—Watershed condition decision-support model used in the High Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

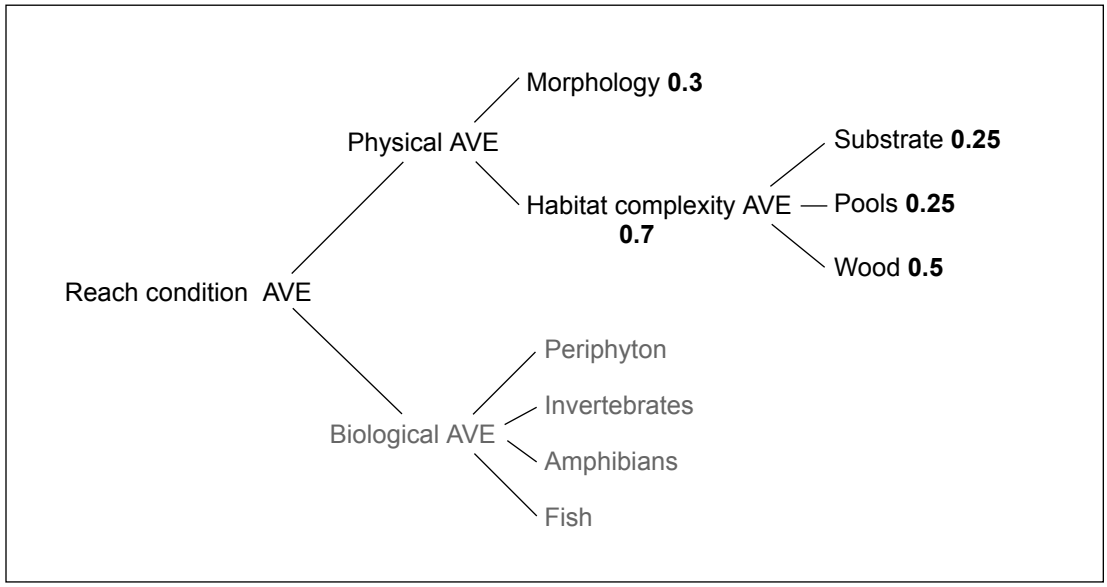


Figure 60—Reach condition decision-support model used in the High Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

Table 11—Evaluation criteria used in decision-support model for North Cascades province

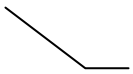
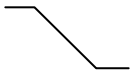
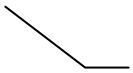
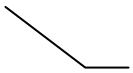
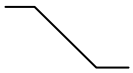
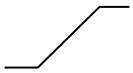
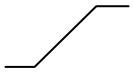
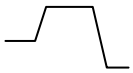
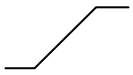
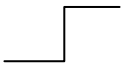
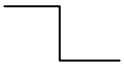
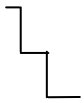
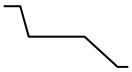
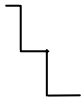
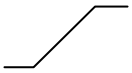
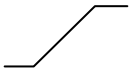
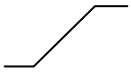
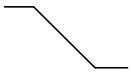
Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Upslope road density (mi road/mi^2 watershed)	0.7 2.4	1 -1		Cederholm and Reid 1987 AREMP[a] workshop 04/28/03
Riparian road density (percentage of stream mi with road within 66 ft)	5 20	1 -1		Professional judgment AREMP workshop 07/01/04
Road crossing frequency—hazard areas (number of crossings/mi^2 watershed)	0 4	1 -1		Professional judgment AREMP workshop 04/28/03
Road crossing frequency—nonhazard areas (number of crossings/mi^2 watershed)	0 20	1 -1		AREMP workshop 04/28/03
Upslope vegetation—east side of Cascades (area-weighted average of fire condition class in mi$^{2)}$	1 3	1 -1		Professional judgment AREMP workshop 07/01/04
Upslope vegetation—west side of Cascades (percentage of area with canopy cover >70 percent)	65 88	-1 1		Workshop follow-up Gary Ketcheson[b] AREMP workshop 04/28/03
Riparian vegetation—large-conifer cover (percentage of area with conifers ≥20 in d.b.h.)	65 88	-1 1		AREMP workshop 04/28/03
164-ft buffer—west side of Cascades				
98-ft buffer—east side of Cascades				
Water temperature (maximum 7-day average, °C)	4 6 15 18	0 1 1 -1		AREMP workshop 07/01/04 Ken MacDonald[c] data
Dissolved oxygen (mg/L)	5 10	-1 1		
Reach model attributes				
Entrenchment ratio				
East side of Cascades	≤1.4 >1.4	-1 1		Professional judgment AREMP workshop 04/28/03
West side of Cascades	≤1.2 >1.2	-1 1		North Cascades NP data
Bankfull width:depth ratio				
East side of Cascades	≤40 >40	1 -1		AREMP workshop 04/28/03
West side of Cascades	≤55 >55	1 -1		North Cascades NP data

Table 11—Evaluation criteria used in decision-support model for North Cascades province (continued)

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Pool frequency (number of bankfull widths per pool)				
Eastside gradient >2 percent	<1 1 4 >4	1 0 0 -1		Montgomery and Buffington (1993)
Eastside gradient ≤2 percent	< 5 5 7 >7	1 0 0 -1		Montgomery and Buffington (1993)
Westside—all gradients	≤4 5 14 18	1 0 0 -1		North Cascades NP data
Wood frequency (number of pieces per 100 m)				Okanogan-Wenatchee NF data
Eastside (western subsections)—12 in × 50 ft minimum	1.6 3.1 4.5	-1 0 1		
Eastside (eastern subsections)	0.9 1.9 2.8	-1 0 1		Okanogan-Wenatchee NF data
Westside <3 percent slope—12 in × 25 ft minimum	0.5 2.5 7.5	-1 0 1		North Cascades NP data
Substrate D_{50} (mm)	20 30 100 500	-1 1 1 -1		Professional judgment AREMP workshop 04/28/03
Substrate pool tail fines (percent)	11 17	1 -1		Professional judgment AREMP workshop 04/28/03

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.
[b] Gary Ketchison is a hydrologist on the Mount Baker-Snoqualmie National Forest.
[c] Ken MacDonald is a Fisheries Program Manager on the Okanogan National Forest.

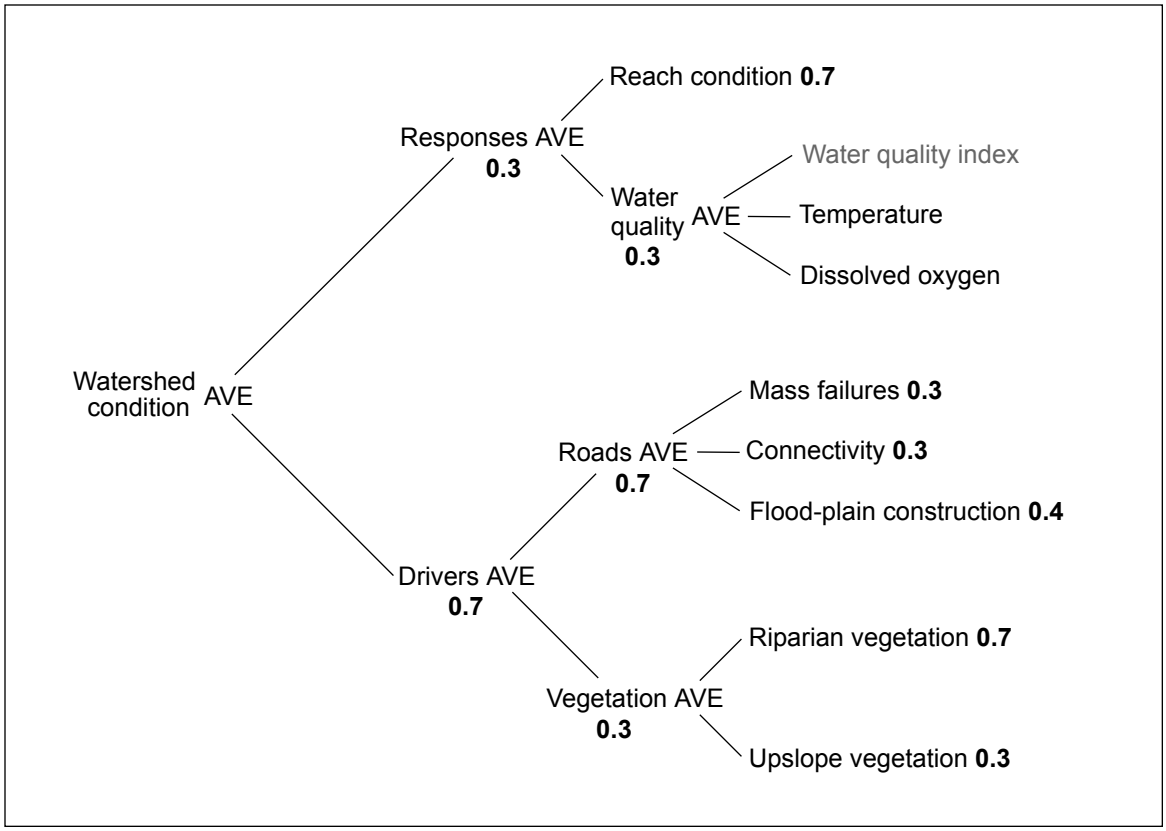


Figure 61—Watershed condition decision-support model used in the North Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

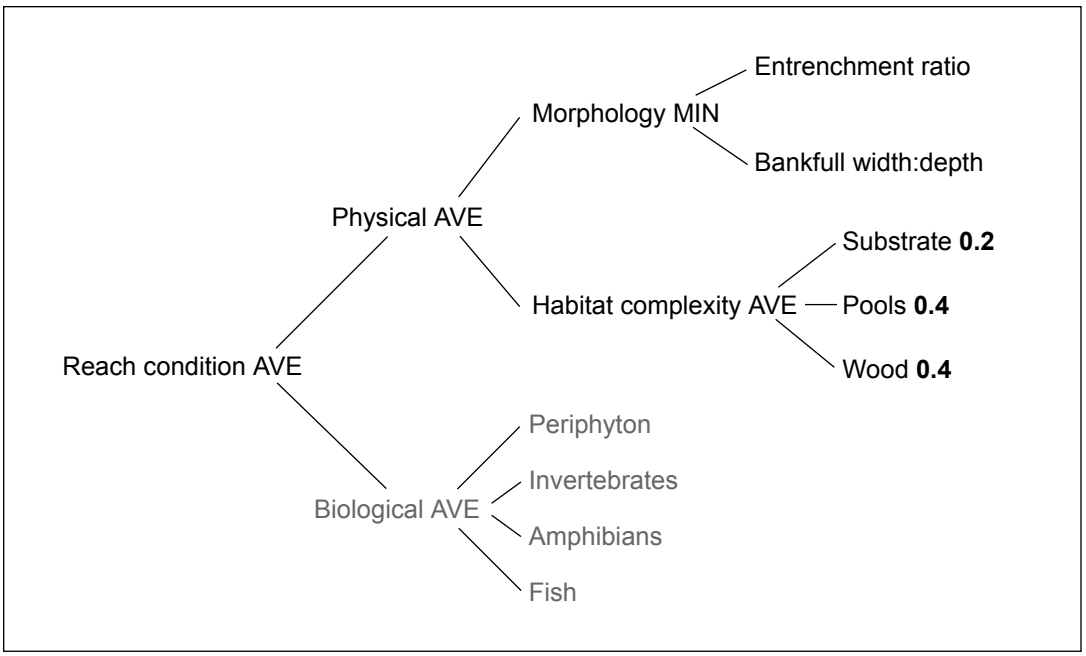


Figure 62—Reach condition decision-support model used in the North Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

Table 12—Evaluation criteria used in decision-support model for Olympic province

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
Hazard road density (mi road/mi^2 watershed)	0 0.5	1 -1		Professional judgment West/High Cascades workshop
Riparian road density (mi road/mi stream)—164-ft buffer	0 0.3	1 -1		Professional judgment Olympic/Coast workshop 1
Road crossing frequency (number of crossings/mi stream)	0 4	1 -1		Professional judgment Olympic/Coast workshop 1
Urban/agriculture (percentage of watershed)	20 40	1 -1		Professional judgment Olympic/Coast workshop 1
Riparian vegetation, large-conifer cover—164-ft buffer (percentage of area with conifers ≥20 in d.b.h.)	25 50	-1 1		Kelly Burnett[a] dissertation Olympic workshop 07/15/04
Water temperature (maximum 7-day average, °C) Bull trout present	4 6 9 13	-1 1 1 -1		Oregon Department of Environmental Quality standard
No bull trout	16 23	1 -1		Oregon Department of Environmental Quality standard
Dissolved oxygen (mg/L)	4 10	-1 1		Professional judgment
Reach model attributes				
Morphology	Rosgen type F or G All others	-1 1		Professional judgment Olympic/Coast workshop 1
Pool frequency (number of bankfull widths per pool)	8 20	1 -1		Oregon Department of Fish and Wildlife (ODFW) benchmarks
Pool quality (average residual pool depth in inches)	14 30	-1 1		ODFW benchmarks (averaged)
Wood frequency—12 in × 10 ft minimum (number of pieces per 100 m)	10 20	-1 1		ODFW Benchmarks

[a] Kelly Burnett is a fisheries biologist with the Corvallis Forestry Sciences Laboratory.

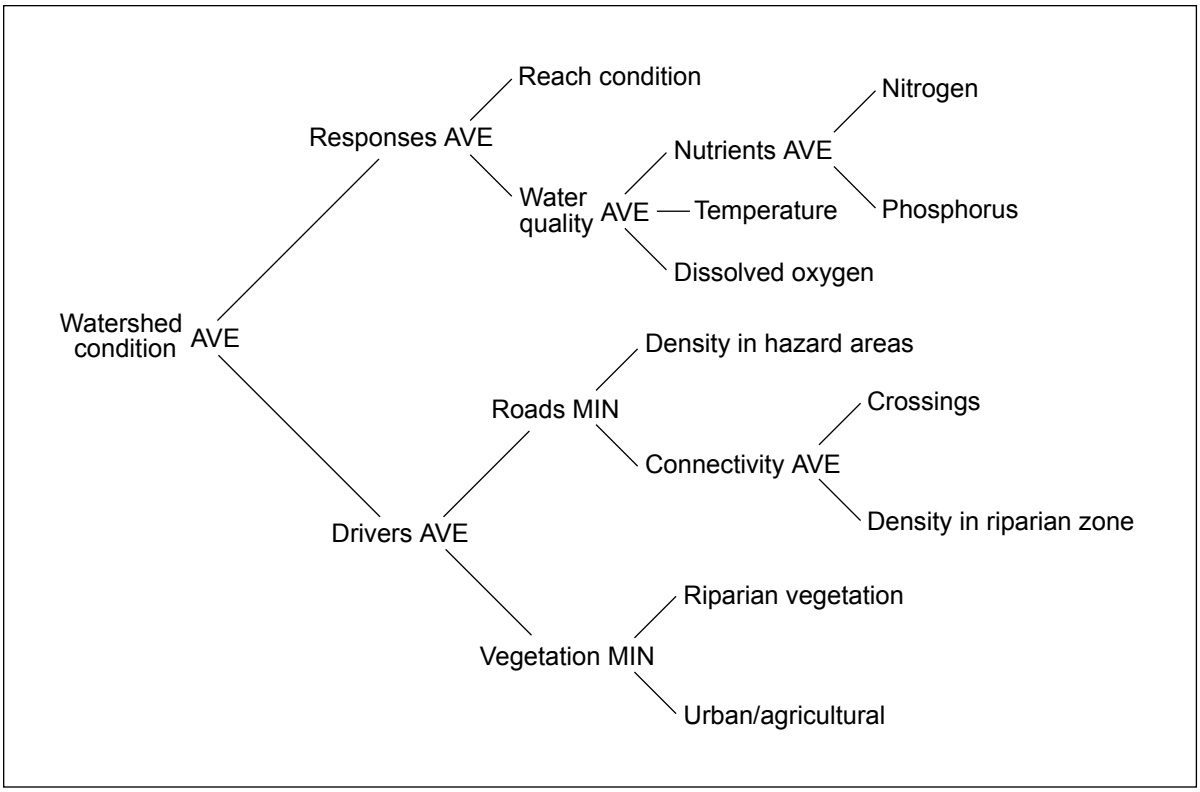


Figure 63—Watershed condition decision-support model used in the Olympic Peninsula province. Guidance on interpreting the figures is provided in appendix 4 text.

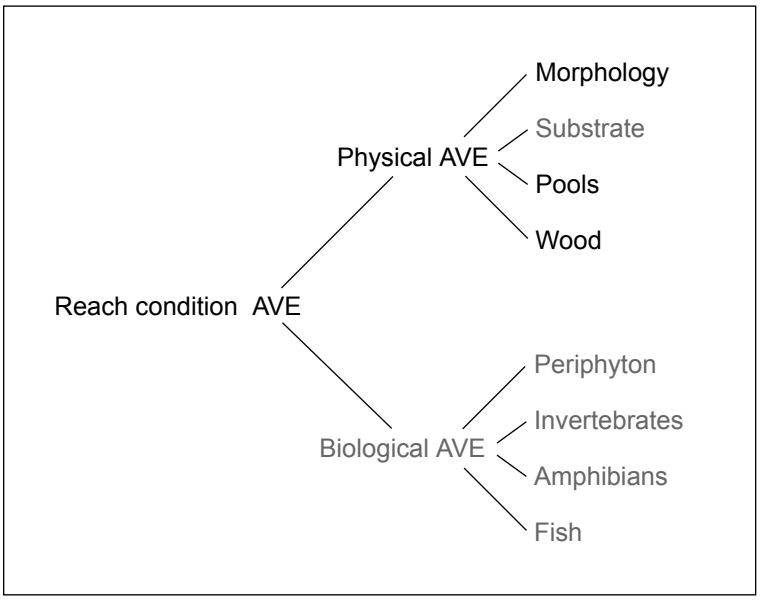
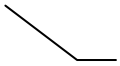
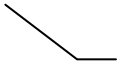
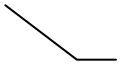
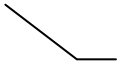
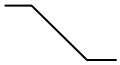
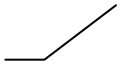
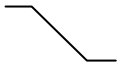
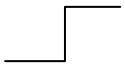
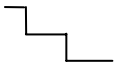
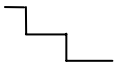
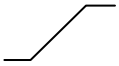


Figure 64—Reach condition decision-support model used in the Olympic Peninsula province. Guidance on interpreting the figures is provided in appendix 4 text.

Table 13—Evaluation criteria used in decision-support model for West Cascades province

Attribute and measure	Data value and node x-value	Evaluation score and node y-value	Curve shape	Source of criteria
Watershed model attributes				
High-slope road density (mi road/mi^2 watershed)	0 0.5	1 -1		AREMP[a] workshop 05/22/03
Upslope road density (mi road/mi^2 watershed)	0 4	1 -1		Dose and Roper 1994 AREMP workshop 05/22/03
Riparian road density (mi road/mi stream)—164-ft buffer	0 0.1	1 -1		AREMP workshop 07/01/04
Road crossing frequency (number of crossings/mi stream)	0 1.75	1 -1		AREMP workshop 07/01/04 Willamette NF data
Upslope vegetation—small-conifer cover (percentage of area with conifers <10 in d.b.h.)	10 40	1 -1		AREMP workshop 05/22/03
Riparian vegetation, large-conifer cover—197-ft buffer (percentage of area with conifers ≥20 in d.b.h.)	60 100	-1 1		AREMP workshop 07/01/04 d.b.h. from wildlife handbook Dose and Roper 1994 harvest roads vs. condition >30 percent of watershed impacted
Water temperature (maximum 7-day average, °C)	16 18	1 0		
Bull trout present	23	-1		AREMP workshop 05/22/03
Dissolved oxygen				
Percentage of saturation	<50 ≥50	-1 1		AREMP workshop 05/22/03
Mg/L	<4 ≥4	-1 1		
Reach model attributes				
Morphology				
Slope	Use to determine Rosgen stream type			Professional judgment
Entrenchment ratio	If D, F, G channel then -1, otherwise +1			
Sinuosity				
Bankfull width:depth				
Pool frequency (number of bankfull widths per pool)				
≤3 percent slope	≤5 5 7 >7	1 0 0 -1		Montgomery and Buffington (1997)
>3 percent slope	<1 1 >4	1 0 -1		
Wood frequency (number of pieces per 100 m)	1 4	-1 1		Professional judgment
Substrate D_{50} (mm)				AREMP workshop 05/22/03
≤5 percent slope	40 60 140 200	-1 1 -1 1		
>5 percent slope	40 60 200 500	-1 1 1 -1		Professional judgment

[a] AREMP = Aquatic and Effectivenesss Monitoring Program.

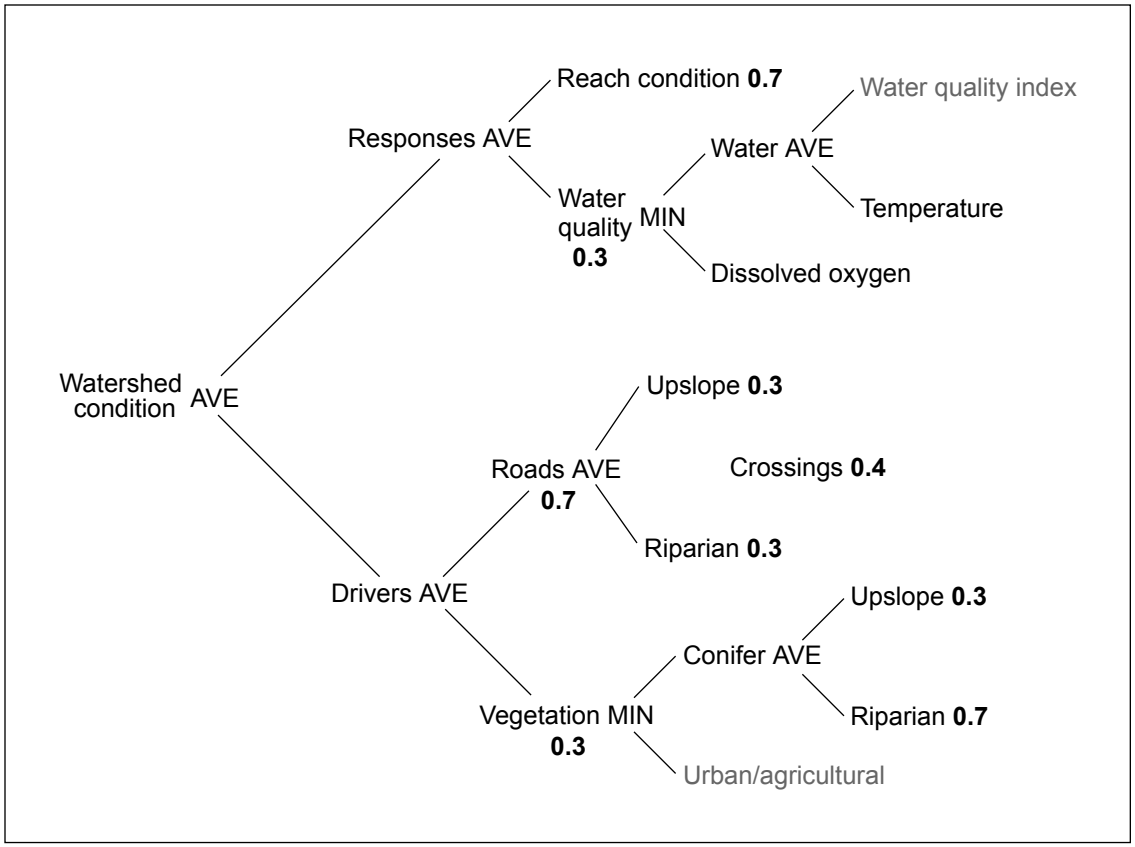


Figure 65—Watershed condition decision-support model used in the West Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

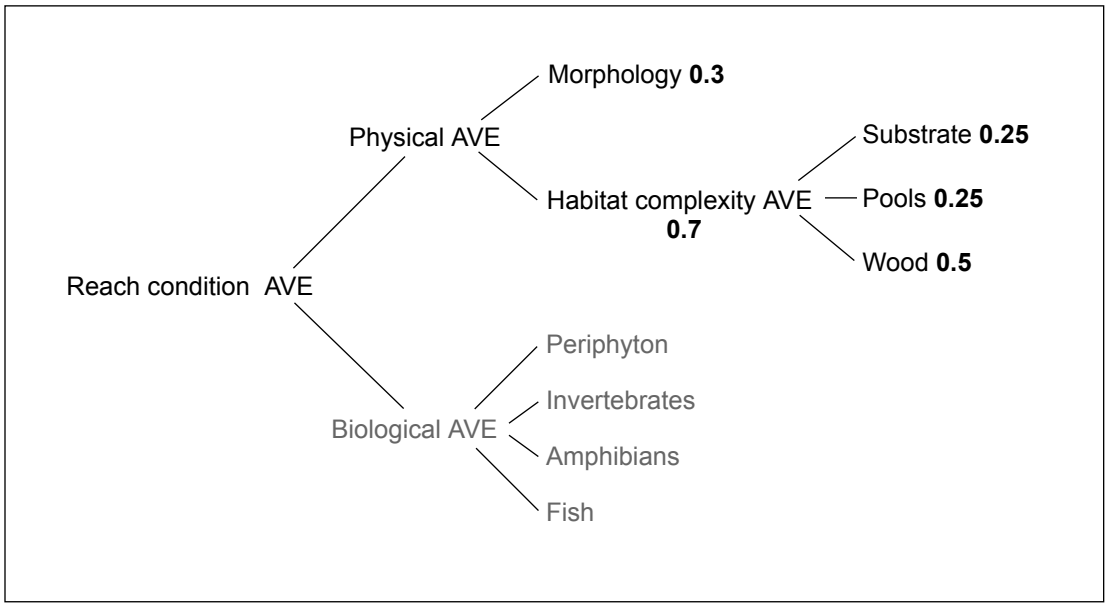


Figure 66—Reach condition decision-support model used in the West Cascades province. Guidance on interpreting the figures is provided in appendix 4 text. Numbers in boldface are attribute weights.

Appendix 5: Sensitivity Analysis of the Decision-Support Models

Each of the provincial models was analyzed to determine how sensitive it was to changes in individual watershed attributes. This evaluation differed from typical sensitivity analyses that vary the model parameters to determine how the results are affected by their values. Here we make a first attempt at developing relationships between management activities (road building and decommissioning and vegetation harvest) and watershed condition score. For each attribute, we selected the value that would produce an evaluation score of 0 as a starting point (selected for ease of interpretation) and then changed the value of that attribute by 5, 25, 50, and 100 percent in a direction intended to improve watershed condition scores (e.g., roads attributes were decreased and vegetation attributes were increased). We ran each model on the data set generated for the analysis and examined the effect of changing each attribute on the watershed condition score (figs. 67 through 73).

To examine the sensitivity of each model to change, we looked at the effect that changing individual attributes has on the overall watershed condition score. Two main factors influence the sensitivity of the models: the evaluation criteria used and the weights given to individual attributes. Curves generally have one of two shapes, linear or asymptotic. Asymptotes occur at the point that the attribute data evaluated meet or exceed the +1 (or -1) evaluation curve value. Linear curves describe attribute data that have yet to approach the asymptote. The magnitude of change that can occur before reaching the asymptote is related to the distance (in terms of the units of the attribute data evaluated) between the -1 and +1 evaluation criteria values. For example, in the Olympic Peninsula model, riparian vegetation can increase by 50 percent before the asymptote is achieved (fig. 72). Once the asymptote is achieved, then additional increase in the attribute will not contribute positively to the watershed condition score. In contrast, the density of hazard roads can be reduced by 100 percent without reaching the asymptote. The asymptote that corresponds to the -1 evaluation criterion indicates the attribute level that must be reached before the condition score increases. As an example, in the Washington/Oregon Coast province, most of the watersheds received a -1 evaluation score for riparian roads. Most watersheds have riparian road densities more than twice the -1 evaluation criterion (fig. 74). In this case, riparian road densities in these watersheds must be reduced to 0.1 mi of road per mile of stream before any improvement in watershed condition will be realized.

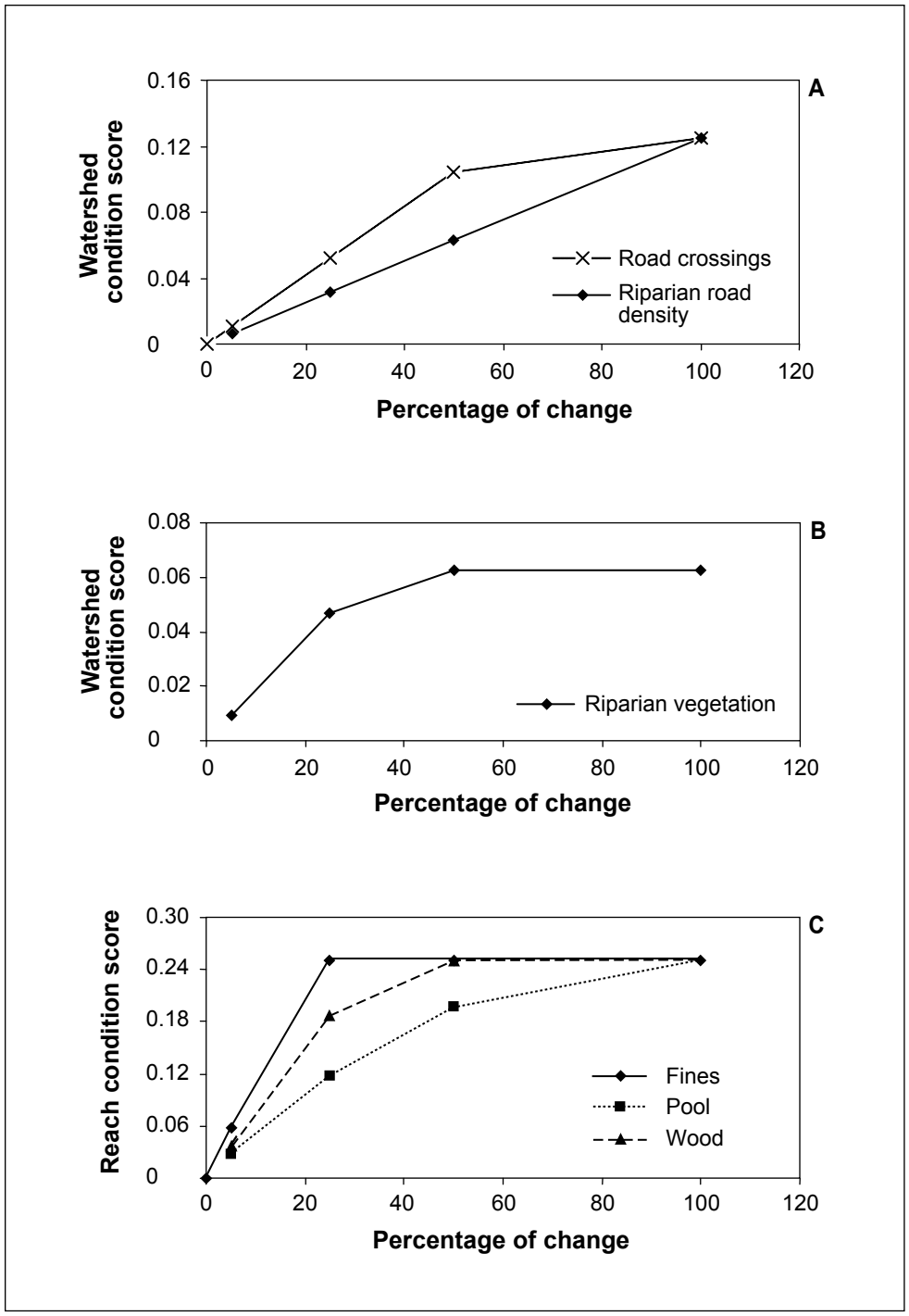


Figure 67—Sensitivity analysis results from the Washington/Oregon Coast province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

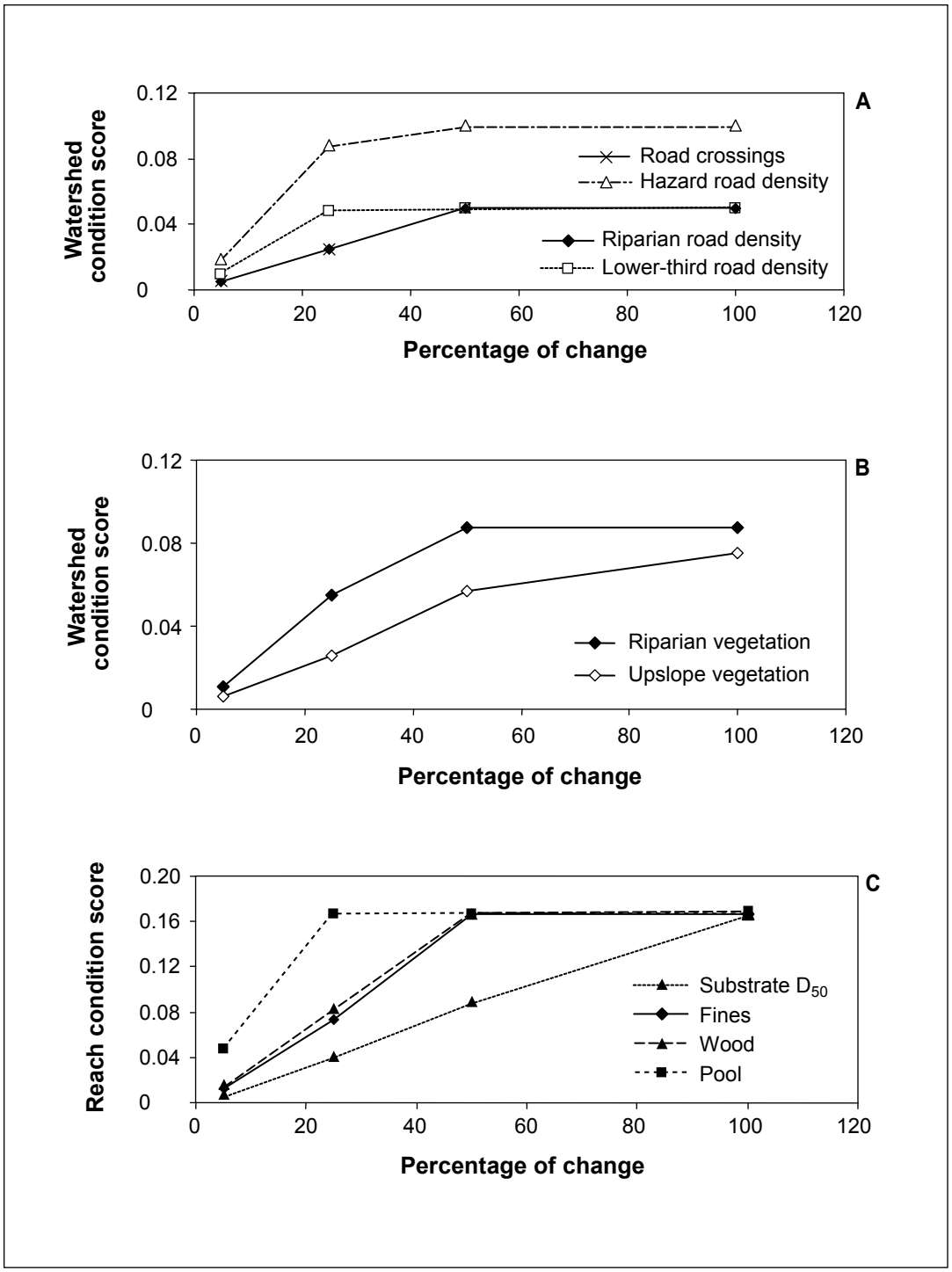


Figure 68—Sensitivity analysis results from the Franciscan province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

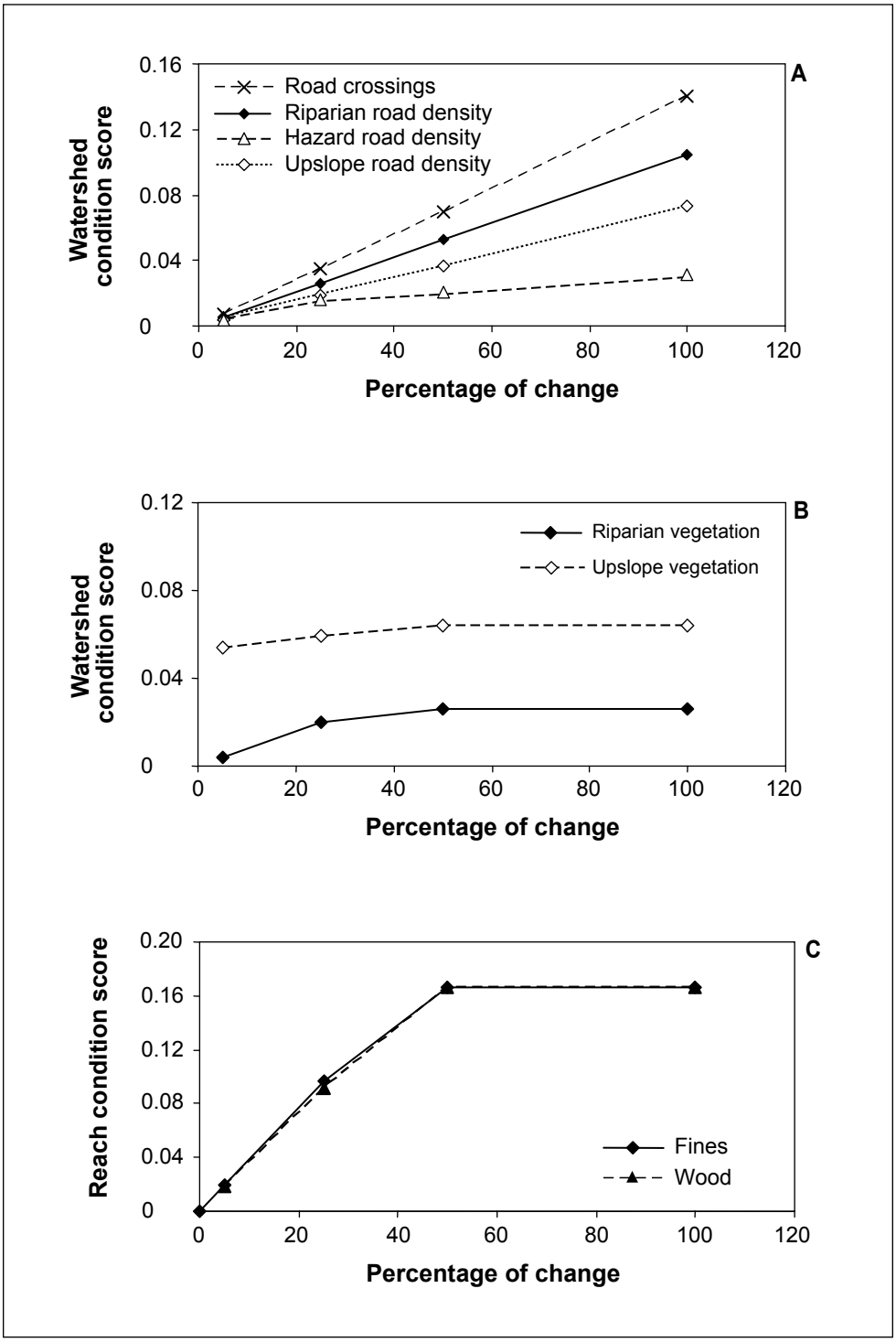


Figure 69—Sensitivity analysis results from the High Cascades province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

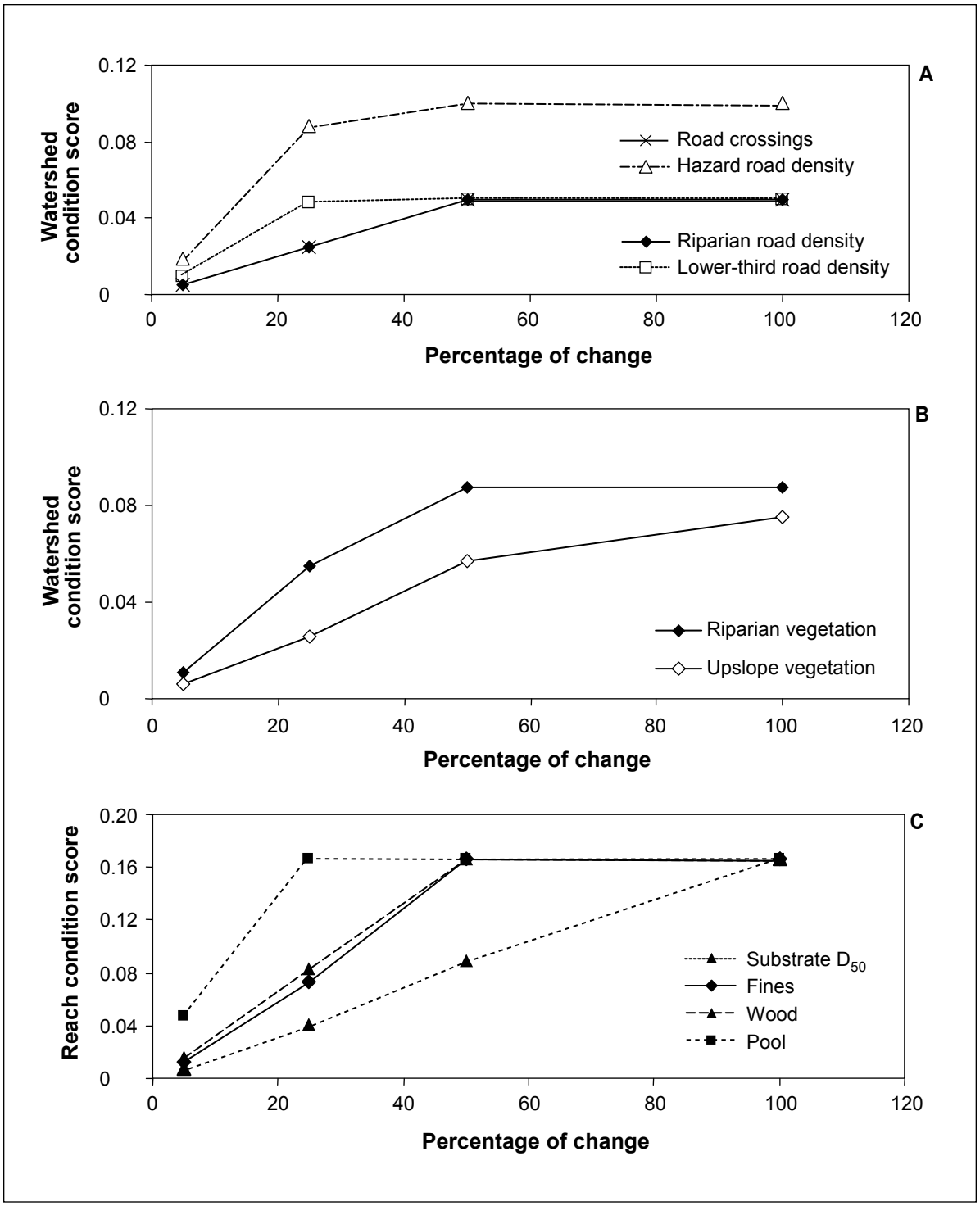


Figure 70—Sensitivity analysis results from the Klamath/Siskiyou province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

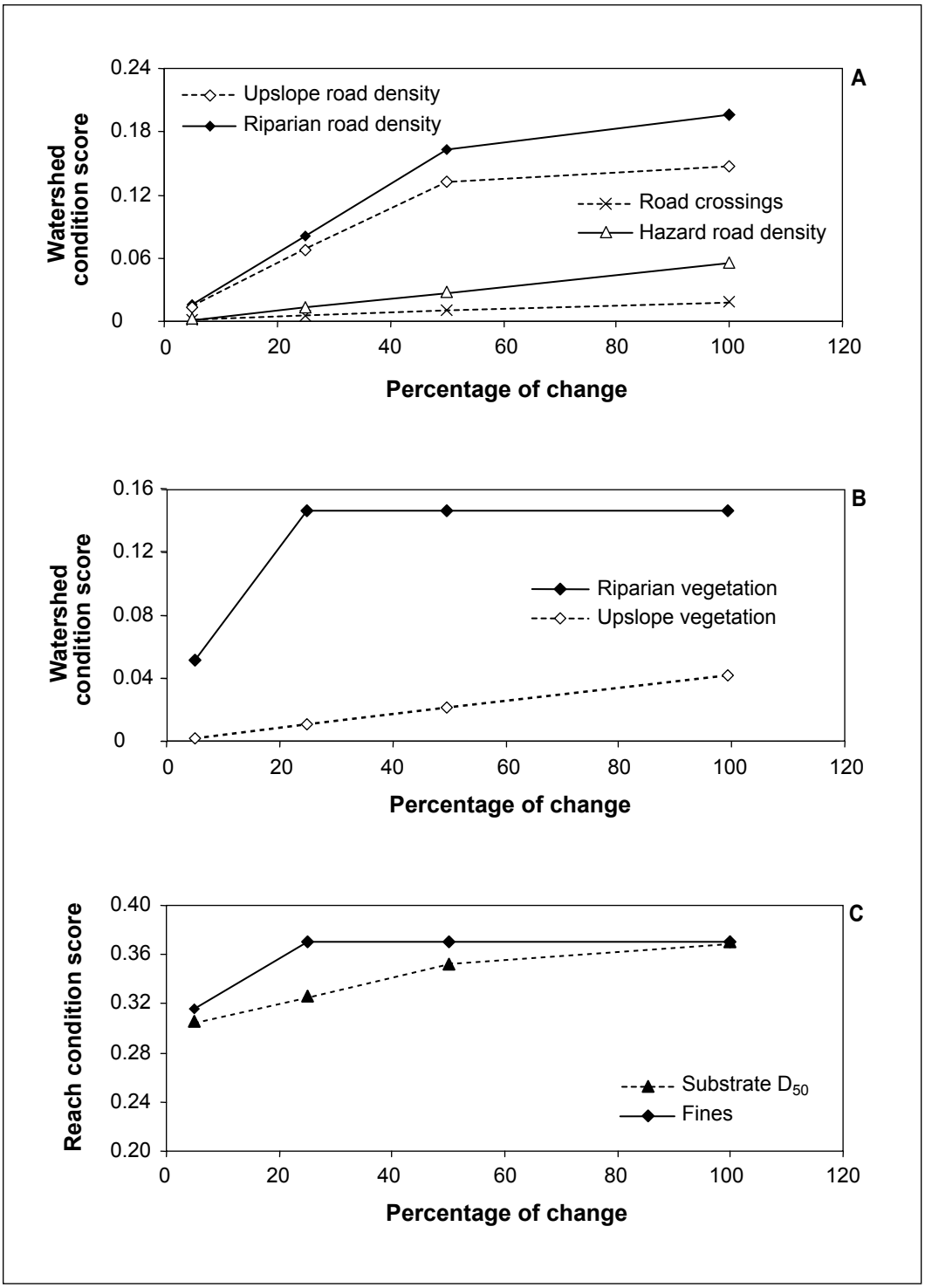


Figure 71—Sensitivity analysis results from the North Cascades province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

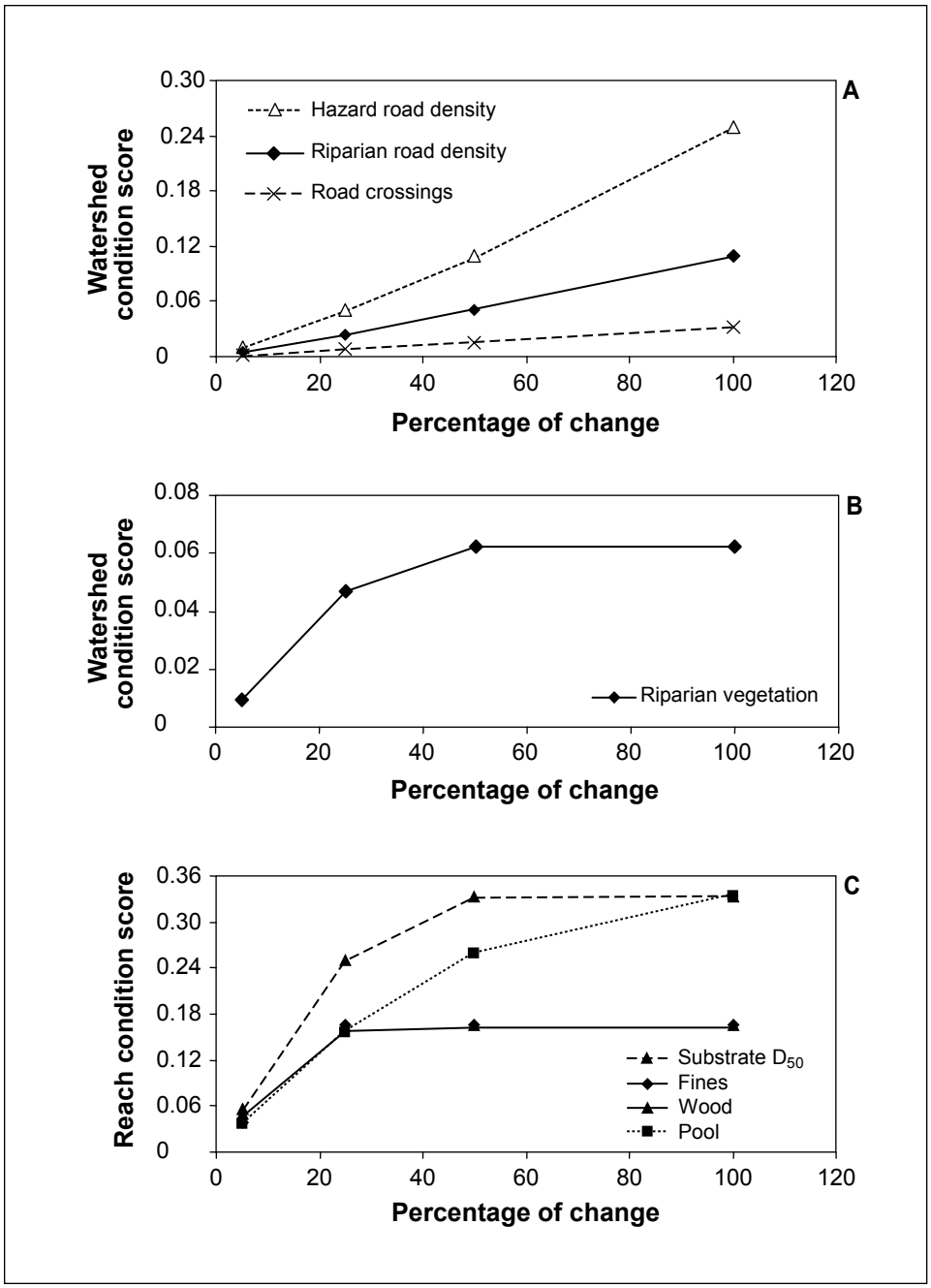


Figure 72—Sensitivity analysis results from the Olympic Peninsula province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

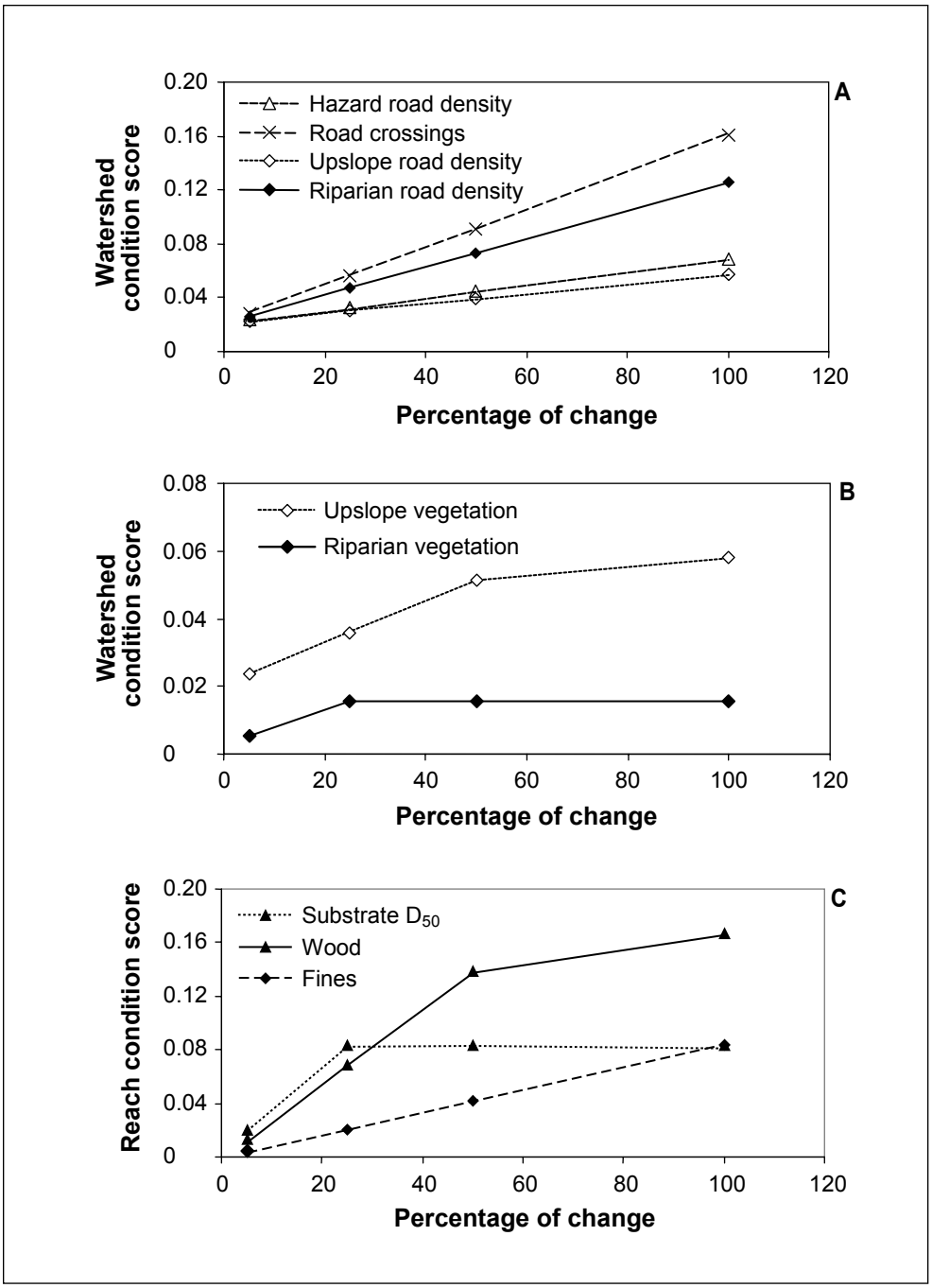


Figure 73—Sensitivity analysis results from the West Cascades province. Shown is (A) the relation between watershed condition score and the percentage of change in the roads attributes, (B) vegetation attributes, and (C) the relation between reach condition scores and percentage of change in inchannel attribute scores.

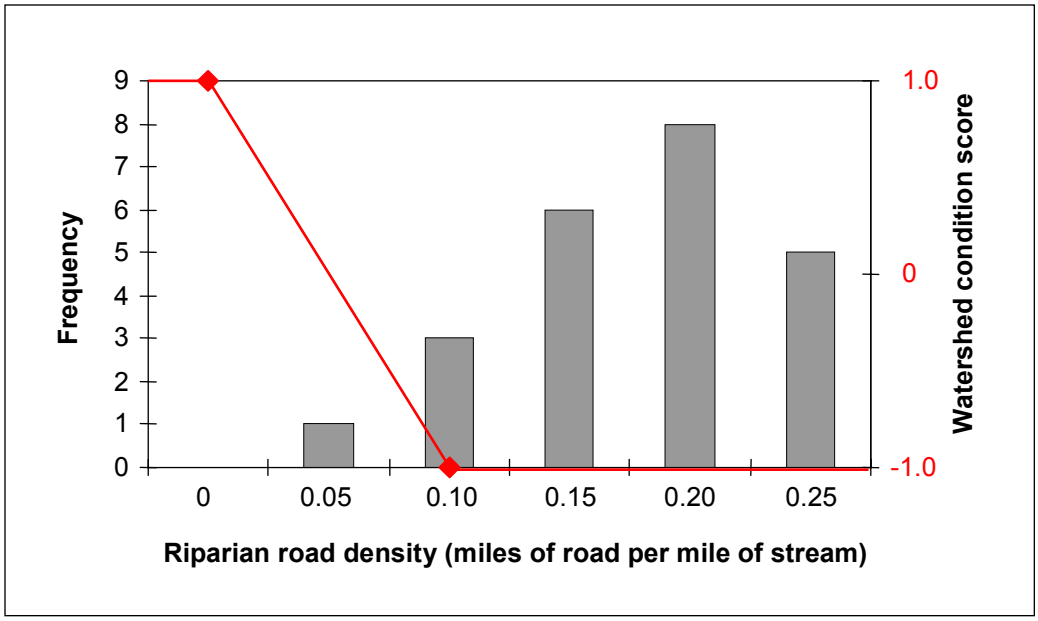


Figure 74—Riparian road density distribution in the Washington/Oregon Coast province. The evaluation criteria used to evaluate riparian road density in this province is shown in red. Watersheds that have riparian road density higher than 0.10 mi of road per mile of stream will have an evaluation score of -1 for riparian roads.

Appendix 6: Road and Vegetation Analyses Conducted by Province

Common Geographic Information System (GIS) Coverages Used for All Provinces

- **Roads**. Road layers used in Oregon and Washington were a combination of USDA Forest Service (FS) road coverages with the USDI Bureau of Land Management (BLM) ground transportation coverage. The FS coverages were obtained from each of the national forests in the Northwest Forest Plan (the Plan) area. The FS coverages included attributes from the infrastructure application (INFRA) core table attached to the road segments, and the coverage was clipped to the administrative boundary of the forest. The FS administrative areas were removed from the BLM coverage and the FS coverages were pasted in by using a "cookie cutter" process. No edge matching was done. The FS coverages were dated 2002, and the BLM data are a collection of data from various sources and years. The final Oregon and Washington road coverage has decommissioning and year-built attributes. The BLM roads have both decommissioning and year-built attributes, whereas the FS only has decommissioning, which is tracked in the INFRA attributes. The decommissioning and year-built attributes were used to determine the change in the road system since 1994. The FS Pacific Southwest Region (Region 5) remote sensing laboratory constructed the California coverage.
- **Streams and lakes**. The Oregon and Washington streams were the result of the FS Pacific Northwest Region hydrography framework project, which pieced together the best available stream data from various sources. The project has not been completed; thus some of the data used in the analysis were preliminary. The coverage data varied in density depending on the source. The California coverage was pieced together by the FS Region 5 remote-sensing laboratory by using a combination of FS, BLM, and cartographic feature file data. The resulting coverage also had varying stream density depending on the source. Stream data were at the 1:24,000 scale except for some areas in California where only 1:100,000 scale data were available.
- **Digital elevation models (DEM)**. 30-m (98.4-ft) DEMs were obtained in 2001 from the National Elevation Dataset (NED) compiled by U.S. Geological Survey (USGS).
- **Watershed boundaries**. The boundaries used were from the first draft of the sixth-field hydrologic unit code boundaries developed by the Regional Ecosystem Office dated 2002. The first draft was used because it was all that was available when we selected the 250 watersheds.
- **Stream buffers**. Stream buffer widths differed by province, and different buffer widths were sometimes used for road-stream interactions and vegetation. The first step was to buffer the stream lines by the prescribed width. Streams wide enough to be represented by a double line were buffered separately and the resulting buffer added to the single-line stream buffers. Lakes were removed from the final buffered coverage.
- **Vegetation**. Interagency vegetation mapping project (IVMP) was used for Oregon and Washington. CALVEG 1998 data was used for California. The IVMP versions used are as follows:

  Eastern Cascades, OR—1.1
  Western Cascades, OR—2.2
  Klamath, OR—1.0
  Coast, OR—3.0
  Eastern Cascades, WA—1.0
  West Cascades, WA—2.0
  Olympics, WA—2.1
  Western Lowlands, WA—1.0

Franciscan Province

Roads

Analyses include:

- Road density in steep areas (>65-percent slope) expressed as miles of road per square mile of steep area. For this analysis, DEMs were used to generate >65-percent-slope polygons. The road coverage was then laid over these areas, and the miles of road in the steep areas were summed.
- Number of road crossings expressed as number of crossings per mile stream. For this analysis, road and stream coverages were clipped to watershed boundaries and the number of road-stream intersections counted.
- Riparian road density expressed as miles of road per square mile of riparian area. The road and stream layer was clipped to watershed boundaries. A 50-m (164-ft) buffer was created on the streams to represent the riparian area. The road coverage was laid over the delineated riparian area and the total miles of road summed.
- Road density on the lowest one-third slope expressed as miles of road per square mile of lowest slope. The lowest one-third of the slope was determined by running a slope position Arc Macro Language (AML) script that uses DEMs and creates a grid with the slope numbered from 1 to 100, with 1 being the bottom and 100 the top. The numbers 1 to 33 were used to define the lower one-third of the slope. The lower one-third area was turned into a polygon layer and intersected with the roads.

Vegetation

Additional GIS coverages used in the analyses include:

- Average annual precipitation from 1961 to 1990, created by Oregon State University in 2000.

Analyses include:

- Percentage of cover of riparian forest (conifer and broadleaf). Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of riparian area covered in conifers >20 in diameter at breast height (d.b.h.). Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of cover of upslope forest, when percentage of conifers is greater than 10 percent. Upslope is defined as the area outside the riparian buffer. In California, oak woodland was separated from other forest types and evaluated for percentage of cover separately.
- Percentage of upslope area covered in conifers <5 in d.b.h. Upslope is defined as the area outside the riparian buffer.

High Cascades Province

Roads

Analyses include:

- Road density in areas that have slope >50 percent. Expressed as miles of road per square mile of watershed. Digital elevation models were used to locate areas within watersheds that had gradient >50 percent. The road layer was laid over the stream areas and the miles of road within the steep areas summed.
- Upslope road density expressed as mile of road per square miles of watershed (North of White River only).
- Riparian road density expressed as miles of road per mile of stream. Riparian buffer is defined as 60 m (197 ft) on both sides of the stream.
- Frequency of road crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of conifers in riparian zone that are >10 in d.b.h. Riparian buffer is defined as 30 m (98 ft) on both sides of the stream.
- Percentage of conifers in upslope areas that are <10 in d.b.h. Upslope is all areas outside the riparian buffer.

Klamath/Siskiyou

Roads

Analyses include:

- Road density in steep areas (>65-percent slope) expressed as miles of road per square mile of steep area. For this analysis, DEMs were used to generate >65-percent-slope polygons. The road coverage was then laid over these areas, and the miles of road in the steep areas were summed.
- Number of road crossings expressed as number of crossings per mile of stream. For this analysis, road and stream coverages were clipped to watershed boundaries and the number of road-stream intersections counted.
- Riparian road density expressed as miles of road per square mile of riparian area. The road and stream layer was clipped to watershed boundaries. A 50-m (164-ft) buffer was created on the streams to represent the riparian area. The road coverage was laid over the delineated riparian area and the number of miles of road counted.
- Road density on the lowest one-third of the slope expressed as miles of road per square mile of lowest slope. The lowest one-third of the slope was determined by running a slope position AML that uses DEMs and creates a grid with the slope numbered from 1 to 100, with 1 being the bottom and 100 the top. The numbers 1 to 33 were used to define the lowest one-third of the slope. The lowest one-third area was turned into a polygon layer and intersected with the roads.

Vegetation

Additional GIS coverages used in the analyses include:

- Coverage of average annual precipitation from 1961 to 1990, created by Oregon State University in 2000.

Analyses include:

- Percentage of cover of riparian forest (conifer and broadleaf). Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of riparian area covered in conifers >20 in d.b.h. Riparian is defined as a 50-m (164-ft) buffer around the 1:24,000 stream layer.
- Percentage of cover of upslope forest, when percentage of conifers is greater than 10 percent. Upslope is defined as the area outside the riparian buffer. In California, oak woodland was separated from other forest types and evaluated for percentage of cover separately.
- Percentage of upslope area covered in conifers <5 in d.b.h. Upslope is defined as the area outside the riparian buffer.

North Cascades

Additional GIS coverages used in the analyses include:

- Hazard areas, based on land type associations on the east side of the Cascades. The land type associations were obtained from Wenatchee and Okanogan National Forests in 2003. The shallow rapid hazard areas were Fa2, Fb7, Fb8, Fb9, Ff9, Ka2, Ka5, Ka7, K68, K69, Kc6, Kf5, Kf7, Kj2, Kj8, Kk7, Qu2, and Qu8. Deep-seated hazard areas were Bu6, Tu3, Tu5, Tu7, Tu8, Uu7, and Uu8. On the west side of the Cascades, we used the grid produced by the Washington Department of Natural Resources with the Shalstab model in 2000. We used the areas coded as high hazard for shallow landslides. Information for deep-seated landslides was not available on the west side.

Roads

Analyses include:

- Upslope road density expressed as miles of road per square mile of upslope area. Upslope area was defined as all land outside riparian buffer. Riparian buffer defined as 50 m (164 ft) on the west side of the Cascades and 30 m (98 ft) on the east side.
- Riparian road density expressed as percentage of stream with road within a 20-m (66-ft) buffer. Applies only to streams that have gradient >3 percent.

- Number of road-stream crossings in nonhazard areas, expressed as number of crossings per square mile of watershed.
- Number of road-stream crossings in hazard areas expressed as number of crossings per square mile of watershed.

Vegetation

Additional GIS coverages used in the analyses include:

- Plant association groups (PAG) that have been modeled by the Forest Service in Oregon and Washington, by using the PAG model in 2003.
- Fire regimes developed from land type association layer, fuel condition class derived from vegetation, crown closure, and slopes. Developed by the Wenatchee and Okanogan National Forests.
- Subalpine areas derived from the plant association groups above.

Analyses include:

West side of Cascades—

- Percentage of forested upslope area with conifer cover ≥70 percent. Upslope area defined as the area outside a 50-m (164-ft) stream buffer. To determine forested area, subtract the area naturally nonforested (such as lakes, glaciers, subalpine, etc.) from the total upslope area.
- Percentage of cover of conifers >20 in d.b.h. in riparian areas. Riparian buffer defined as 50-m (164-ft) buffer on either side of the stream.

East side of Cascades—

- Mesic/wet areas—Percentage of upslope area with conifers less than 5 in d.b.h. Total cover (conifer + broadleaf) had to be greater than or equal to 50 percent to be included in the analysis. Wet/mesic and dry was determined by using a plant-association layer, the following plant categories are dry:
    - All ponderosa pine and Douglas-fir PAGs or zones
    - Grand fir-pinegrass
    - Grand fir-pinegrass-lupine
    - Grand fir-pinemat manzanita
    - Grand fir-oceanspray-pinegrass
    - Grand fir-mountain snowberry
    - Grand fir-spirea-bracken fern
    - Grand fir-snowberry-pinegrass
    - Shrub-steppe
- Dry areas—Percentage of cover of trees >20 in d.b.h. in upslope areas that are not subalpine areas.
- Average fire condition class—Weighted based on area of watershed in each class.
- All of east side—Percentage of conifers >20 in d.b.h. in riparian area that are not subalpine areas. Riparian area defined as the area within a 30-m (98-ft) buffer of the stream.

Olympic Peninsula

Roads

Additional GIS coverages used in the analyses include:

- Road hazard layer developed by the Olympic National Forest, which identified high-hazard roads based on a variety of factors including geology, fish presence, and road-stream crossings.

Analyses include:

- Road density in hazard areas expressed as miles of road per watershed area.
- Riparian road density expressed as miles of road per mile of stream (based on 1:24,000 high-density layer).
- Number of road-stream crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of cover of conifers (mixed or pure stands) in the riparian zone >20 in d.b.h. Riparian zone is defined as a 50-m (164-ft) buffer along both sides of the stream.
- Percentage of watershed covered by urban and agricultural land.

Washington/ Oregon Coast

Roads

Analyses include:

- Riparian road density expressed as miles of road per mile of stream.
- Number of road-stream crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of cover of conifers (mixed or pure stands) in the riparian zone >20 in d.b.h. Riparian zone defined as a 50-m (164-ft) buffer along both sides of the stream.
- Percentage of watershed covered by urban and agricultural land.

West Cascades

Roads

Analyses include:

- Upslope road density expressed as miles of road per square mile of watershed.
- Road density in areas that have slope >50 percent. Expressed as miles of road per square mile of watershed.
- Riparian road density expressed as miles of road per mile of stream. Riparian buffer is 60 m (197 ft) on both sides of the stream.
- Frequency of road crossings expressed as number of crossings per mile of stream.

Vegetation

Analyses include:

- Percentage of conifers (mixed or pure stands) in the riparian zone >20 in d.b.h. Riparian buffer is 60 m (164 ft) on both sides of the stream.
- Percentage of conifers (mixed or pure stands) in the upslope area <10 in d.b.h. Upslope is defined as all areas outside the riparian zone.

Appendix 7: Synopsis of Field Protocols Used by the Monitoring Program

Introduction

Field data collected provide information on physical habitat, chemical properties, and the biota. Physical habitat indicators include bankfull width-to-depth ratio, entrenchment ratio, pool frequency, sinuosity, gradient, wood frequency, percentage of fine substrate, and substrate D_{50}. Discharge and water chemistry data were also collected. Biological indicators include periphyton, benthic macroinvertebrates, aquatic and terrestrial amphibians, and fish.

The stream data will be combined with upslope and riparian information (primarily vegetation and road density) to provide an estimate of watershed condition. Condition will be determined by using a decision-support model that aggregates all indicators. The stream data collected in the field represent about two-thirds of the data included in the decision-support model.

Site Selection

Eighty potential sampling sites were randomly chosen along the stream network in the sixth-field subwatershed. In the field, sites were considered for sampling beginning with number 1 and continuing through the list, omitting sites that could not be sampled. The only reasons sites cannot be sampled include:

- The site is on private land or cannot be accessed without crossing private land.
- The site is not safely accessible; i.e., the site cannot be reached without putting the crew in danger. Long hikes down into steep canyons do not qualify.
- The stream is too small or physically cannot be sampled. The minimum stream size is about 3 ft wide (wetted width) and 4 in deep in riffle habitats.
- The stream is too large to physically sample (i.e., not wadeable) and is a safety concern for crews.
- The site is in a lake or pond.

The goal was to sample eight sites in a subwatershed. The length of the site was 20 times the bankfull width, with minimum 150 m (164 yd) and maximum 500 m (547 yd) reach lengths.

Physical Habitat Mapping

Cross-Sectional Profiles

Channel cross-sectional and longitudinal profiles were mapped by using a laser rangefinder. Cross-sectional profile information was used to calculate bankfull width-to-depth ratios and entrenchment ratios. In nonconstrained reaches, 11 cross-sectional profiles were mapped, equally spaced along the length of the sample reach. At each cross section, 11 shots were taken on increments in the bankfull prism, with measurements taken at both wetted edges and the thalweg (fig. 75). Of the 11 cross sections, two randomly selected profiles extended beyond flood-prone area to determine flood-prone width. Only one point was taken outside bankfull in the remaining cross sections. In the constrained reaches, six profiles were mapped as described for nonconstrained reaches.

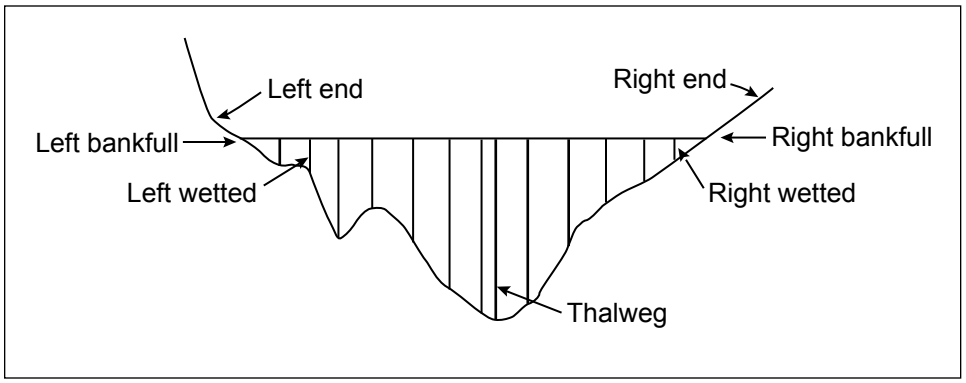


Figure 75—Cross-sectional profile with point labeling (looking downstream).

Longitudinal Profiles

Longitudinal profiles were used to calculate sinuosity, gradient, and pool frequency by shooting points with the laser rangefinder. Shots were taken on an increment that was about 1/100 of the sample site length. Additional measurements were taken at each pool tail crest, maximum pool depth, and pool head. The same protocol was used in all sample reaches.

Substrate

The protocol for measuring substrate is similar to that used by the Environmental Protection Agency's Environmental Monitoring and Assessment Program (Peck et al. 1999). In nonconstrained reaches, 11 substrate measurements were taken at each of the 11 transects. Substrate measurements were taken on evenly spaced increments in the bankfull channel. In constrained reaches, measurements were taken at each of the six transects, and at five intermediate transects as well. The intermediate transects were set up midway between the primary transects (Peck et al. 1999). Percentage of fine sediment was measured in the tails of scour pools as described by the USDA Forest Service Pacific Southwest Region stream condition inventory protocol (1998). Three measurements were taken by using a Klamath grid in each pool tail in the reach (maximum of 12 pools).

Large Wood

The large wood protocol was adapted from that used in the Oregon Department of Fish and Wildlife's Stream Habitat Surveys (Moore et al. 1999). In each reach, pieces of large wood were counted if they had a minimum length of 10 ft and were at least 12 in diameter at breast height (d.b.h.). Length and d.b.h. were estimated for each piece. Measurements of length and d.b.h. were taken on the first 10 pieces in the reach and every fifth piece thereafter. In addition, notes covered location in the channel, whether the piece was natural or artificial (i.e., had a cut end or was part of an artificial structure), and whether the piece was single or part of an accumulation. Large wood in jams (defined as five or more pieces) was not measured, but the presence of the jam and its approximate size was documented.

Other Chemical and Physical Parameters

Discharge was taken at one location in the sample site by using a flow meter. Water samples for nutrient analyses (total Kjeldahl nitrogen and total phosphorus) were taken at one location in the subwatershed, at the lowest point in the subwatershed on federal land. Additional information on temperature, dissolved oxygen, pH, and conductivity was collected at each sample site. All of these physical and chemical data were used as support data for the biological sampling. An overview of the sampling is shown in figure 76.

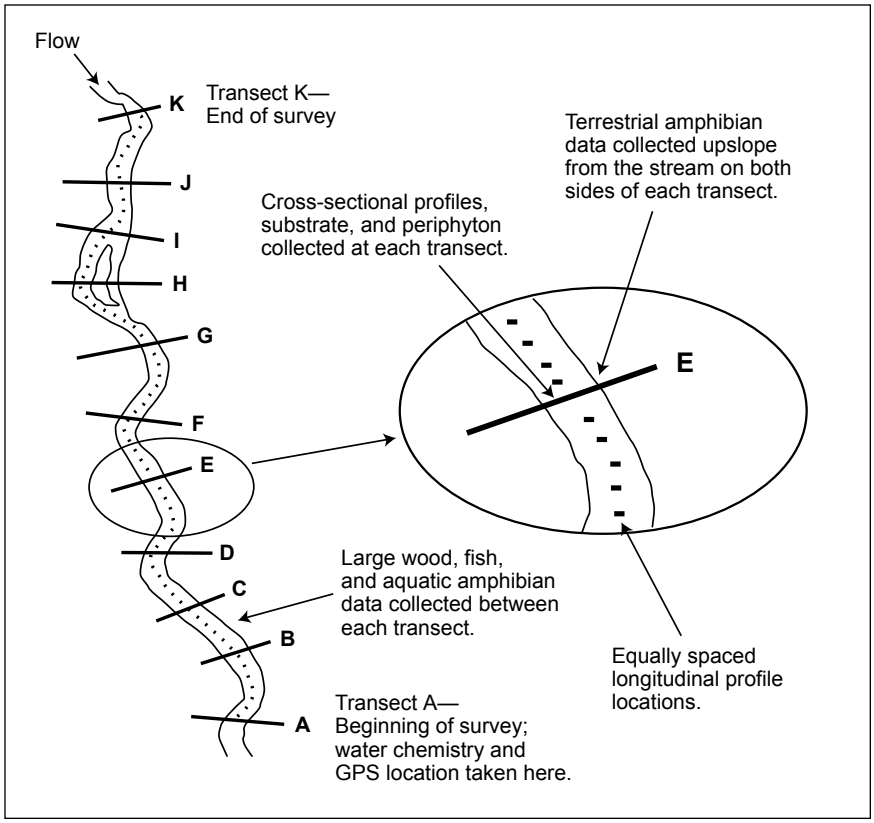


Figure 76—Overview of site layout including sampling strategy for nonconstrained sample sites. GPS = global positioning system.

Appendix 8: Quality Assurance Assessment of Geographic Information System and Inchannel Data

We conducted a quality assurance/quality control assessment on the geographic information system (GIS) layers used for the roads and vegetation analyses and on the inchannel data collected in the field. Details on how we conducted these analyses and the results are presented.

Roads

Methods

Road coverages from multiple sources were collected for use in the analysis. The quality and density of the coverages differed, depending on their source and land ownership. Mapping on private lands was often less intensive than on federal land. To assess the accuracy of the road coverages, we used digital orthquads (DOQ) from two periods (1990 or 1994 and 1998 or 2000) to develop a road layer to compare with the agency (i.e., Forest Service or Bureau of Land Management [BLM]) coverages in 38 of the 250 randomly selected watersheds. Individual watersheds were selected based on availability of DOQs, and the number of watersheds was based on the available budget. Roads were drawn along linear clearings on the DOQs. Obvious nonroads, such as skid trails, were not included on the DOQ-based layer because we did not expect these features to be included on the agency layer. If these features had been included on the DOQ layer, we would have confounded our comparison with the agency layer. In each watershed, the agency road network was laid over the DOQs from the two periods. Each segment of road on the DOQ layer that did not match the agency coverage was placed into one of the following classes:

Moved — The road segment was more than 200 ft from where it appeared on the agency coverage and was moved to match the DOQ image.

Added — The road segment appears on both the 1994 and recent DOQ but not on the agency coverage.

Deleted — The road segment does not appear on either the 1994 or the recent DOQ but is on the agency coverage.

Built — The road appears on the recent DOQ but not the 1994 DOQ; it was assumed to have been built since 1994.

We calculated riparian road density and frequency of road crossings in 38 watersheds by using the agency road coverages and on the layer developed from the DOQs, as described for the roads analysis above.

To examine the differences between the agency road layers and the layer drawn from DOQs for the road quality-assurance assessment, we used a paired, two-tailed t-test to determine whether the results derived from the two layers were significantly different.

Results

Examination of the road layers suggests that a significant number of roads on agency GIS layers appear to be missing (table 14). About 17 percent more road miles were found on the digital orthoquads (DOQ) than on the agency roads layers. Differences between the two layers were due primarily to the number of roads on nonfederal lands, which were not well represented on the agency layers (fig. 77, right panel). About 37 percent of the roads on nonfederal lands were missing on the agency layer, compared to 10 percent on BLM lands and 15 percent on Forest Service lands.

The roads missing on federal lands include spur roads, temporary roads, and others not maintained as part of official road networks. Without field verification, we could not determine whether these roads are passable by wheeled vehicles. We did remove what appeared to be skid trails from the analysis. Although some of these roads may not be passable, their effects on watershed processes are assumed to be similar to those of unimproved roads.

The increased number of roads found on the DOQ layer compared to the agency layer suggests that we underestimated the number of roads in this analysis (fig. 78). Average frequency of road crossing was 1.6 crossings per mile of road (SD 1.1) on the DOQs, and 1.2 (SD 0.7) on the agency layer, an increase of 33 percent. Average riparian road density across the 37 watersheds was 2.8 mi of road per square

Table 14—Results from the roads layer quality assessment[a]

USGS HUC	Watershed name	Agency	Agency	Built	Deleted	Percent difference[b]
		- - - - - - - - - - - - -	*Miles*	- - - - - - - - - - - - -		
180101030105	Anderson Creek	61.13	26.31	0	6.03	33.2
171003080106	Ashland Creek	66.46	7.86	.28	1.54	9.9
171003070113	Barr Creek	120.49	23.49	8.89	5	22.7
170703010403	Benham Falls	131.18	27.86	.13	3.07	19.0
170200090110	Boulder Creek	16.81	.39	.44	18.35	-104.2
170703010907	Canyon Creek	104.73	6.42	.78	3.26	3.8
171003110503	Deer-Draper	130.15	78.73	21.1	1.42	75.6
170800010102	Draw Creek	5.6	3.19	0	0	57.0
171003020302	Dumont	124.32	8.58	.22	.36	6.8
180102030101	East Fork Annie	43.6	8.39	2.88	1.03	23.5
170200080703	Gold Creek	53.52	3.52	2.91	2.7	7.0
171100180701	Hamma Hamma River	65.97	12.07	.48	.66	18.0
180101050201	Headwaters North Fork Eel River	159.17	35.82	2.91	3.22	22.3
171003050101	Headwaters South Fork Coquille River	242.54	21.77	12.35	.38	13.9
171003111101	Lawson Creek	71.47	23.16	1.42	.21	34.1
171003011101	Little River Canyon	149.57	4.73	0	0	3.2
171003110103	Lower East Fork Illinois River	235.33	50.68	12.35	1.42	26.2
170900010504	Middle Fork Willamette River/ Larison Creek	69.81	7.2	.26	2.01	7.8
170200110504	Mission Creek	150.78	42.76	7.6	2.47	31.8
170900010603	North Fork Middle Fork Willamette/ Fisher Creek	46.36	4.85	.99	1.16	10.1
170900040501	Quartz Creek	137.84	22.11	2.98	2.07	16.7
170200080203	Rattlesnake Creek	49.73	6.65	1.72	1.39	14.0
171003100403	Rogue-Horseshoe Bend	57.48	18.16	1.52	.85	32.8
180101010204	Shelley Creek	90.86	25.01	.85	2.56	25.6
170900060503	Sixes Creek	51.08	4.53	.09	0	9.0
171003110603	Sixmile Creek	34.48	10.72	.12	.97	28.6
170703010104	Snow Creek	72.45	14.04	37.37	4.99	64.1
170800010201	Still Creek	27.25	4.64	.26	1.1	13.9
180102100102	Summerville	68.56	3.04	.21	15.65	-18.1
170703020203	Summit Creek	5.6	3.19	0	0	57.0
170300010301	Swauk Creek	313.1	58.9	10.68	23.25	14.8
180102030202	Threemile	31.61	1.65	0	.31	4.2
180101040201	Upper Black Butte River	202.46	73.62	10.03	21.51	30.7
171003030504	Upper Camp Creek	61.14	.81	1.45	.57	2.8
171002050201	Upper Five Rivers	61.2	4.95	3.59	1.1	12.2
171003030701	Upper Lower Smith River	109.19	31.69	18.27	.51	45.3
170900010106	Upper Middle Fork Willamette River/ Echo Creek	140.74	6.39	3.54	1.13	6.3
170900060401	Upper Quartzville Creek	76.49	17.87	.09	.09	23.4
171003020801	Upper West Fork Cow Creek	78.93	4.29	0	0	5.4
171003030704	Wassen Creek	32.43	17.91	5.69	.39	71.6

[a] Included is the USGS hydrologic unit code (HUC), the name of the watershed, the miles of road in the watershed identified on the agency layer, miles of roads added according to the digital orthoquad (DOQ) layer, miles of roads built based on the DOQ layers, miles of road deleted according to the DOQ layer. Percentage difference (the net difference in road miles between the agency and DOQ road layers) was calculated as added + built – deleted/agency × 100.

[b] Percent difference is derived by added + built - deleted ÷ agency × 100.

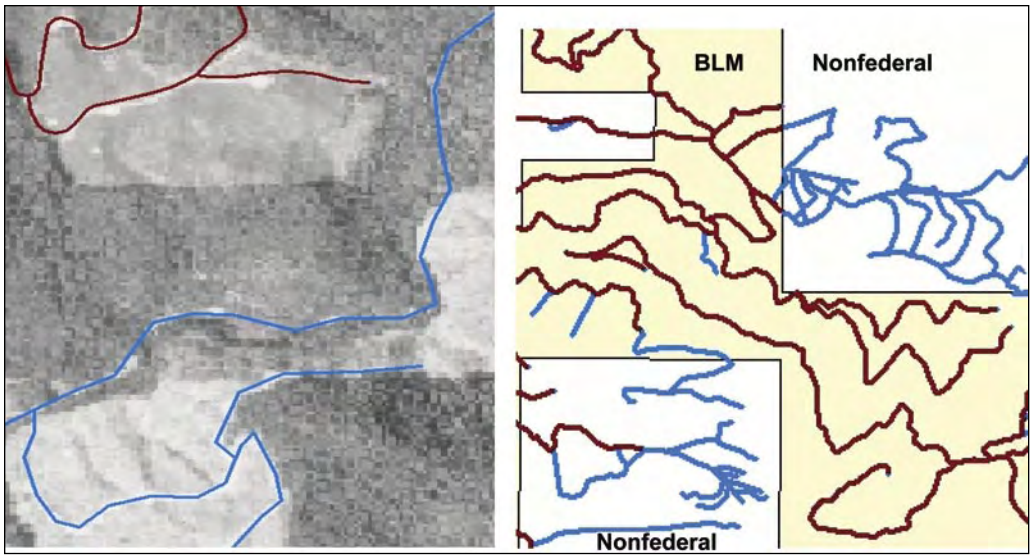


Figure 77—Comparison of agency and digital orthoquad (DOQ)-derived road layers in two watersheds. In both watershed panels, roads marked in red represent those included on the agency road layer, and those in blue represent roads present on the layer based on DOQs but not found on the agency layers. Left panel: roads were drawn in linear clearings visible on DOQs. Right panel: nonfederal land is shown in white, and Bureau of Land Management (BLM) land is shown in yellow. Roads on nonfederal lands are underrepresented on agency road layers.

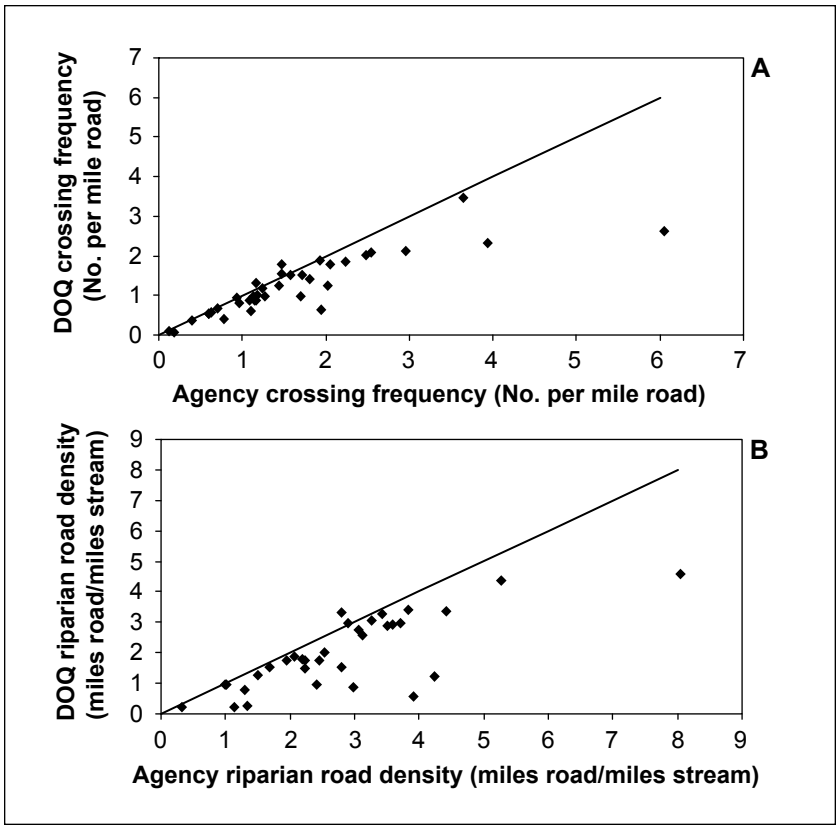


Figure 78—(A) Frequency of road crossings and (B) riparian road density based on agency roads data and on a layer developed from digital orthoquads (DOQ).

mile of riparian area (SD 1.5) on the DOQs and 2.0 (SD 1.2) on the agency layer, an increase of 40 percent.

The differences between the two road layers were less important when condition scores were compared, particularly when attribute condition scores have been aggregated. Drivers condition scores based on the two layers were highly correlated, and the slope between the two was equal to 1 (fig. 79a). The slope between the two layers was also equal to 1 for riparian road density, but was 0.88 for road crossings, suggesting that scores derived from the agency layer for this attribute are 12 percent less than those derived from the DOQ layer (fig. 79c and d).

Vegetation

Methods

The vegetation layers created by Interagency Vegetation Mapping Project (IVMP) and CalVeg were intended for landscape- or provincial-scale analysis, not for project-scale analysis. We were unsure whether the 25-m (82-ft) pixels used to build the layers would provide fine enough resolution for use at the sixth-field hydrologic unit scale, particularly for analysis of riparian vegetation. We conducted an exercise with aerial photographs to assess the accuracy of the monitoring program's use of the vegetation layers.

We analyzed 14 of the 250 randomly selected watersheds distributed throughout Northwest Forest Plan (the Plan) area. These watersheds were among those sampled in 2002 and were included in this analysis because we had some local knowledge of the watershed. The number of watersheds included in the analysis was based on available budget. In each watershed, a 100-m (328-ft) buffer was laid on either side of the stream channel to separate riparian and upslope areas. Riparian area was defined as being in the buffer, and upslope was the area outside the buffer. A 10 × 10 grid was laid over both the riparian and upslope areas. Grid points were placed on aerial photographs, and vegetation-class data were collected in a 75- by 75-m (246- by 246-ft) area (the equivalent of nine pixels on the IVMP layer) at the grid intersections (n = 100 data points in both riparian and upslope). Data from the air photos

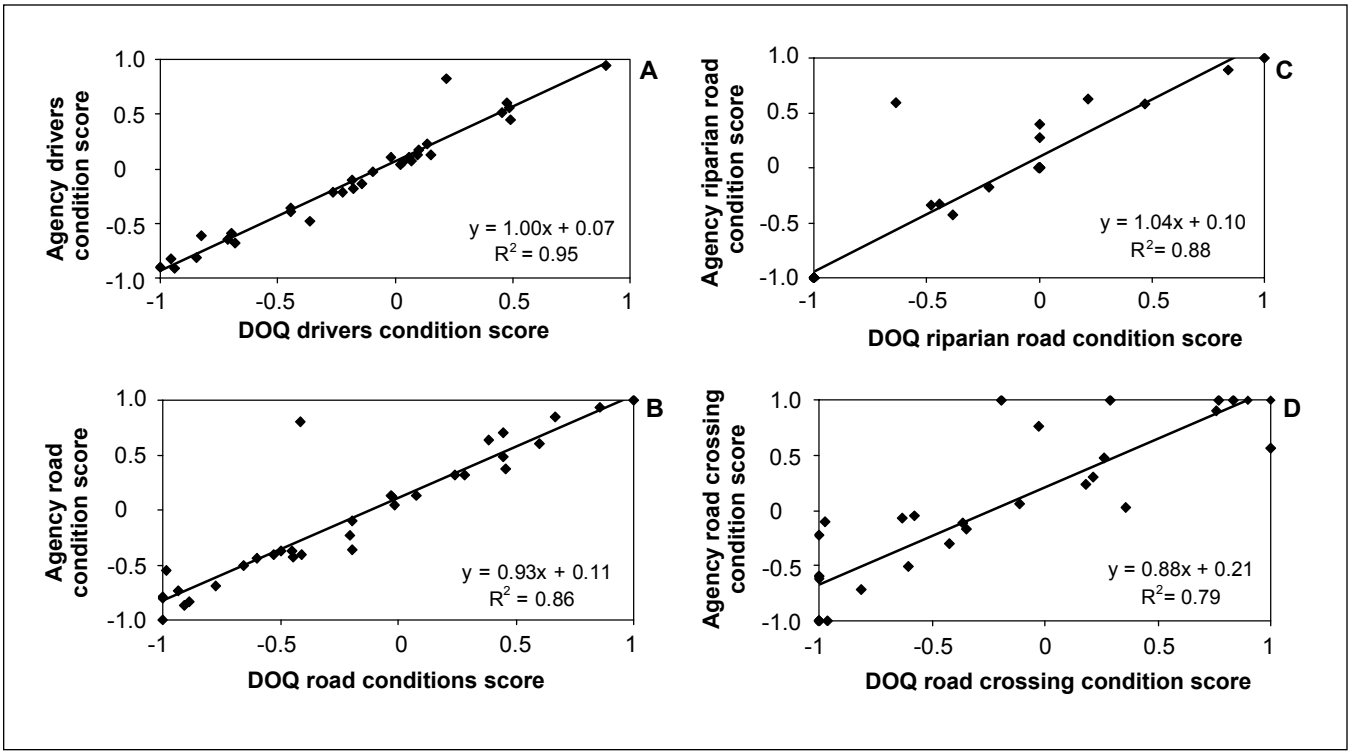


Figure 79—Relation between (A) drivers, (B) roads, (C) riparian roads, and (D) road crossing condition scores determined from the digital orthoquad (DOQ)-derived road layer and the agency road layer.

were compared with data from IVMP and CalVeg layers to determine the accuracy of the monitoring program's use of these layers. The vegetation classes analyzed for the accuracy assessment were based on the classes evaluated for the monitoring program's assessment of watershed condition. We did not conduct field verification of the aerial photograph interpretation; thus we are unable to describe the accuracy of the interpreted data.

Results

In general, accuracy assessments derived from the aerial photography exercise were consistent with the accuracy assessments derived by the IVMP and CalVeg. The accuracy of the maps differed widely between watersheds, however. Across all watersheds, overall accuracy of the vegetation layers averaged 65 percent in the riparian area (range = 49 to 97 percent; table 15); and 72 percent in the upslope area (range = 57 to 86 percent; table 16). We did not field verify the air photo data (i.e., the reference data), so we are unable to describe its accuracy. We are not able to determine whether differences in map accuracy across watersheds can be attributed to the map or to the reference data. The maps did not consistently overestimate or underestimate the size of trees relative to the reference data; therefore, we are unable to evaluate how the accuracy of the maps affected the outcome of this analysis.

Inchannel Attributes

Methods

A quality system management plan (quality plan) was developed for all the effectiveness monitoring programs under the Plan (Palmer 2002). Its goal was to ensure that all data collected were scientifically sound and of known quality. The monitoring program implemented a data-quality-assurance program in 2001 and has continued to develop the program since then as described by the quality plan. The quality-assurance program had multiple components, including formalized field training, remeasurement of a subset of sample sites by an independent field crew, field audits, and crew exit-surveys.

Analysis of the remeasured subset of sample sites (generally referred to as the paired set of initial-survey and secondary-survey data) was conducted to determine the repeatability of the sample data. These paired survey results were examined to distinguish between environmental and measurement effects. Environmental effects are the differences that occur naturally between watersheds and between sites in watersheds; these effects are considered uncontrollable. Measurement effects include differences in measurements between crews and unexplained error; these effects are considered controllable through training, refinements in field protocols (to reduce subjectivity), and improvement in equipment. A forthcoming report (Moyer and Chambers, n.d.) will detail the methods and results of the quality-assessment program with particular emphasis on the field data.

Results

The results of the remeasurements differed considerably depending on the attribute in question. For example, 75 to 95 percent of the total variability in average bankfull width from the sites measured in each year from 2001 to 2003 was explained by the natural variation that exists in the environment (i.e., streams vary in width naturally within and across watersheds), and the balance was due primarily to unexplained (residual) variation. In spite of a wide range of unexplained variation across years, the signal:noise ratio (S:N; calculated as described by Kaufmann et al. 1999) was ≥ 4, indicating the data were useful in detecting a change if a change actually occurred on the landscape. The result further indicates that the current methods were performing satisfactorily and do not need improvement. In contrast, the total number of pools counted in each site did not perform to these same standards. Only 30 to 50 percent of the total variability was attributed to the environment, indicating that field crews had a difficult time identifying the same number of pools between the two surveys. The S:N values for all 3 years were <1; therefore, a change in the data could not be attributable to an actual change on the landscape. These results indicated that a change in field technique was warranted. The results for the remainder of the attributes are described in Moyer and Chambers (n.d.).

Table 15—Accuracy assessment of the vegetation layers in the riparian zone[a]

		Photointerpretation			
		<20 in	≥20 in	Sum	Accuracy
		- - - No. of plots - - -			Percent
North Fork Eel					
CalVeg	<20 in	40	4	44	
	≥20 in	25	8	33	
	Sum	65	12	77	62.3
Summerville					
CalVeg	<20 in	16	27	43	
	≥20 in	6	37	43	
	Sum	22	64	86	61.6
Upper Black Butte					
CalVeg	<20 in	25	19	44	
	≥20 in	10	28	38	
	Sum	35	47	82	64.6
North Coquille					
IVMP	<20 in	38	6	44	
	≥20 in	15	9	24	
	Sum	53	15	68	69.1
Still Creek					
IVMP	<20 in	7	40	47	
	≥20 in	0	34	34	
	Sum	7	74	81	50.6
Big Lava Bed					
IVMP	<20 in	33	7	40	
	≥20 in	33	17	50	
	Sum	66	24	90	55.6
Fisher Creek					
IVMP	<20 in	19	7	26	
	≥20 in	15	11	26	
	Sum	34	18	52	57.7
Swauk Creek					
IVMP	<20 in	35	0	35	
	≥20 in	37	1	38	
	Sum	72	1	73	49.3
Willame Creek					
IVMP	<20 in	30	14	44	
	≥20 in	16	22	38	
	Sum	46	36	82	63.4
Upper West Fork Cow					
IVMP	<20 in	37	15	52	
	≥20 in	3	26	29	
	Sum	40	41	81	77.8
Snow Creek					
IVMP	<20 in	71	2	73	
	≥20 in	0	2	2	
	Sum	71	4	75	97.3
Steve Fork Carberry					
IVMP	<20 in	22	9	31	
	≥20 in	15	21	36	
	Sum	37	30	67	64.2
Headwaters South Fork Coquille					
IVMP	<20 in	41	8	49	
	≥20 in	14	16	30	
	Sum	55	24	79	72.2
Hamma Hamma					
IVMP	<20 in	31	15	46	
	≥20 in	19	16	35	
	Sum	50	31	81	58.0

[a] Number of plots was chosen based on average conifer size in the photointerpreted plots and by the Interagency Vegetation Mapping Project (IVMP) or CalVeg method. Accuracy assessments are the total number of plots that were mapped the same by using the two methods divided by the total number of plots, times 100.

Table 16—Accuracy assessment of the vegetation layers in the upslope area[a]

		Photointerpretation			
		<10 in	≥10 in	Sum	Accuracy
		- - - *No. of plots* - - -			*Percent*
North Fork Eel					
CalVeg	<10 in	7	8	15	
	≥10 in	14	49	63	
	Sum	21	57	78	71.8
Summerville					
CalVeg	<10 in	8	38	46	
	≥10 in	3	46	49	
	Sum	11	84	95	56.8
Upper Black Butte					
CalVeg	<10 in	17	26	43	
	≥10 in	4	34	38	
	Sum	21	60	81	63.0
North Coquille					
IVMP	<10 in	6	5	11	
	≥10 in	9	51	60	
	Sum	15	56	71	80.3
Still Creek					
IVMP	<10 in	3	13	16	
	≥10 in	3	64	67	
	Sum	6	77	83	80.7
Big Lava Bed					
IVMP	<10 in	3	26	29	
	≥10 in	4	39	43	
	Sum	7	65	72	58.3
Fisher Creek					
IVMP	<10 in	9	3	12	
	≥10 in	3	10	13	
	Sum	12	13	25	76.0
Swauk Creek					
IVMP	<10 in	10	9	19	
	≥10 in	10	44	54	
	Sum	20	53	73	74.0
Willame Creek					
IVMP	<10 in	15	13	28	
	≥10 in	6	48	54	
	Sum	21	61	82	76.8
Upper West Fork Cow					
IVMP	<10 in	13	8	21	
	≥10 in	20	27	47	
	Sum	33	35	68	58.8
Snow Creek					
IVMP	<10 in	11	13	24	
	≥10 in	0	46	46	
	Sum	11	59	70	81.4
Steve Fork Carberry					
IVMP	<10 in	12	5	17	
	≥10 in	5	51	56	
	Sum	17	56	73	86.3
Headwaters South Fork Coquille					
IVMP	<10 in	11	7	18	
	≥10 in	13	46	59	
	Sum	24	53	77	74.0
Hamma Hamma					
IVMP	<10 in	8	6	14	
	≥10 in	13	32	45	
	Sum	21	38	59	67.8

[a] Number of plots was based on average conifer size in the photointerpreted plots and by the Interagency Vegetation Mapping Project (IVMP) or CalVeg method. Accuracy assessments are the total number of plots that were mapped the same number of plots by using the two methods divided by the total number of plots.

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