TIMBER - FISH - WILDLIFE PROJECT

Level I and Level II
Cumulative Effects Analysis Methods

Overview and Status

Submitted to:

Washington Department of Natural Resources
and the
Timber/Fish/Wildlife
Cumulative Effects Steering Committee

Prepared by:

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DISCLAIMER

The opinions, findings, or recommendations expressed in this report are those of the authors and do not necessarily reflect the views of any participant in, or committee of, the Timber/Fish/Wildlife Agreement, the Washington Forest Practices Board, or the Washington Department of Natural Resources, nor does mention of trade names or commercial products constitute endorsement or recommendation of use.

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BACKGROUND

The term "cumulative effects", as used in this report, refers to the collective and long-term effects of multiple forest management activities on watershed resources. In August 1991, the Washington Forest Practices Board (FPB) adopted emergency rules (WAC 222-16-040) governing cumulative effects, and directed the state Department of Natural Resources (DNR) to develop prototype cumulative effects analysis methods. In the interim, DNR has collaborated with cooperators in the Timber/Fish/Wildlife (TFW) agreement to develop methods for the analysis of cumulative effects in the state. This effort under TFW is being coordinated by the Cumulative Effects Steering Committee (CESC). TFW has proposed a two-tiered analysis as follows:

- "Level I" Analysis. This methodology involves a rapid initial assessment of cumulative effects using primarily existing information and teams (4-5 individuals) of personnel with general training and experience in forested ecosystems. The target level of effort for Level I is 4-5 person-weeks.

- "Level II" Analysis. This detailed analysis is based primarily on field studies conducted by teams of experts (4-6 individuals) in the fields of hydrology, geomorphology, soil science, fisheries, forestry and related fields. Level II can be used both to verify results from, and resolve uncertainties related to, Level I studies. Level II studies are expected to require 16-24 person-weeks to complete.

Level I documents a basic understanding of hazards, processes and risks in the watershed using mostly remote sensing data (i.e., aerial photographs and maps). Level I also identifies specific processes that require further analysis using Level II methods. Level II involves detailed analysis of those processes determined to be a hazard in Level I, and focuses on dominant processes identified in Level I. It is expected that certain watersheds will not require a Level II analysis if cumulative effects (based on a relative ranking of hazard and resource value both locally and downstream) are determined to be low in the Level I analysis. In this sense, Level I is a screening analysis.

In December 1991, the Pacific Watershed Institute (PWI) published "Prototype Watershed Analysis" This document outlined a Level I methodology produced by PWI under a contract to the Northwest Indian Fisheries Commission and the Washington

Forest Protection Association. In the same month, EA Engineering, Science and Technology (EA) was contracted by DNR and TFW to develop a Level II methodology to complement the Level I methodology proposed by PWI.

EA, DNR and TFW agreed in January 1992 that the Level I methods proposed by PWI were not sufficiently developed to achieve the watershed analysis goals specified by the FPB. Accordingly, EA's contract with DNR/TFW was amended to allow EA to assist in the modification and refinement of PWI's Level I methodology.

This report summarizes status of the Level I and Level II methods being developed by EA as of 31 January 1992. At present, both Level I and Level II methods are in the early stages of development. EA and TFW will continue to work collaboratively on the development of these methods. Target dates of 28 February 1992 and 1 March 1992 have been set for completion of draft methods manuals for the Level I and Level II analyses, respectively.

Because the Level II methodology necessarily derives its structure from the Level I methods, EA has directed a large portion of its work effort to date to redeveloping and refining Level I methods. Consequently, this report focuses primarily on Level I methods. However, Level II methods are discussed in sufficient detail to provide the reader with a clear "picture" of this second tier effort. Discussions of both Level I and Level II methods focus on the specific steps that comprise these methodologies as outlined in a series of flow charts prepared by TFW. The overall structure and flow of the methodologies are similarly discussed.

1. INTRODUCTION

Although many individuals and organizations have assembled and utilized various methodologies to assess cumulative effects, at present there is no widely accepted approach to this work. Lack of universal acceptance of any methodology is related primarily to one of two factors. Many presently utilized methods do not consider all watershed processes of potential significance. Instead, they purposely focus on certain watershed processes (e.g., hydrology) to the exclusion of other processes (e.g., erosion). Alternately, some cumulative effects methodologies have been customized for certain physiographic conditions. Although this specificity often makes these methods quite accurate, it also limits the applicability of the techniques to other physiographic regimes. Individual techniques in existing cumulative effects methodologies may be applicable to Washington, but none really satisfy the DNR and TFW's desire for a generalized, broadly applicable, defensible and repeatable methodology suitable for forested ecosystems across the state. Therefore, new methodology must be developed to achieve these goals.

The approach utilized first by PWI and now by EA is to develop an orderly framework for creation of a cumulative effects analysis methodology. The first step in this process is to outline the goals of such a methodology. A cumulative effects analysis must:

- describe existing conditions within the watershed of interest and their association with forest practices;

- evaluate all hydrologic and geomorphic processes that potentially contributed to the formation of current conditions, and identify those processes that are principally responsible;

- identify vulnerable resources that are present within and downstream of the watershed;

- discuss (qualitatively or quantitatively) how forest practices contributed to the occurrence of hazards and resulting risks to resources, and what actions are predicted to mitigate risks. Hazard is defined in this document as changes in the production of sediment, runoff or riparian function. Risk is defined as impact to watershed resources, especially fish habitat and water quality;

- identify uncertainties in the analysis and validity of conclusions; and

- present results of the cumulative effects analysis in a format viable by forest managers for developing forest practice prescriptions or other planning activities.

The second step involves determining the scope of the Level I and Level II methodologies. Scoping involves four components: deciding the size of the basins to be considered; selecting a level of effort (time, staff hours, etc.) to be allocated to these analyses; determining, *a priori*, what watershed processes are, or potentially are, of consequence; and, deciding what public resources are potentially impacted by the cumulative effects of forest practices. The second component, level of effort, was discussed above. For the remaining components, EA reviewed PWI's report and conducted discussions with DNR and TFW. The following outline for the scope of Level I and Level II methods resulted from this effort.

- Watershed area: Areas on the order of 30,000 to 60,000 acres (50-100 square miles); thus, several watersheds would fit into the DNR-defined sub-WRIA (Water Resource Inventory Area) units.

- Geomorphic and hydrologic processes to be evaluated:

    - erosion: mass wasting (shallow-rapid landslides, debris flows, dambreak floods and deep-seated landslides) and surface erosion;

    - hydrology: peak flows from rain-on-snow, increased water yield spring melt timing, and alteration of baseflow discharge; and

    - riparian function: temperature, large organic debris (LOD), channel condition and fish habitat.

- Public and natural resources that are vulnerable to cumulative effects:

    - anadromous and resident fish populations and habitat;
    - domestic and hatchery water supplies;
    - public infrastructure (roads, bridges, etc.); and

- site-specific concerns, including historical and other locally important resources.

The third step in determining an orderly framework for a cumulative effects methodology involves specifying the assumptions and uncertainties associated with the method. The complexity of natural processes, current level of knowledge on what controls these processes and amount of available site data let to the following simplifying assumptions which presently limit the scope and detail of a cumulative effects analysis:

- Existing cumulative effects that are observable in watersheds are the result of the current state of forest management (to the extent that historical trends can be identified and associated with changes in management practices and standards); therefore, current conditions must be used to quantify watershed hazard levels and reduction in hazards will lead to reductions in risk.

- The linkage between hillslope or channel processes and the biology of the stream is a fundamental weak link in our understanding of cause and effect relationships; therefore, many conclusions on resource risks may not be supported by direct evidence or process linkages.

- Many geomorphic cause and effect relationships can only be addressed qualitatively or with very rough quantitative results (i.e., sediment budgets); therefore, the evaluation of existing conditions may end up being largely qualitative with many unanswered questions on specific sources and rates of sediment and water inputs within a watershed.

As the methods are developed further, additional assumptions, weaknesses or uncertainties in the methods will become apparent and will be identified.

The remainder of this document discusses the details of the Level I and Level II methodologies as currently developed. The basic structure of the methodologies is summarized by reviewing flow charts prepared by TFW. In addition, specific work items to be conducted at each step of these flow charts are reviewed. These work items are discussed separately by subject (e.g, hydrology, erosion, etc.) where appropriate.

2. OVERALL STRUCTURE OF LEVEL I AND LEVEL II ANALYSES

Figures 1-8 outline the structure of the analyses that comprise the Level I and Level II methodologies. Figure 1 is an overview of the entire process, whereas Figures 2-8 detail the steps related to each of the major tasks outlined in Figure 1. These figures were developed by the Cumulative Effects Steering Committee of TFW and, except as noted below, have not been modified by EA.

Figure 1 shows the overall approach to be used for the analysis of cumulative effects. Eight major tasks are numbered and identified in this diagram. Each requires a series of actions to complete. Hazard assessment (#1 on diagram) involves determining the significance of hydrology, erosion and riparian function related processes in the watershed being analyzed. The public resource assessment (#2) determines the public resources present within a watershed, and the relative value of these resources. The resource vulnerability assessment (#3) identifies the portion of the stream network that may respond to hazards, and identifies channel condition and fish habitat in these areas. Deliverability assessment (#4) determines the extent to which identified hazards actually import materials (sediment, water, etc.) to streams within the basin. Sensitivity assessment (#5) combines the vulnerability of the stream resources with expected delivery of materials from upslope hazards to estimate impacts to the stream system. The hazard, deliverability and sensitivity assessments each consider the classes of watershed processes (i.e., erosion, hydrology, riparian function) separately. The channel integration assessment (#6) considers all three types of processes collectively to assess the total impact of hazards on stream resources. The risk assessment process (#7) reviews the previous tasks to identify both uncertainties in the analyses or conclusions and the decisions (decision criteria) used in the analysis. Finally, the watershed assessment product (#8) summarizes the previous work efforts and presents them in a format amenable to review by managers and other interested parties.

Figure 2 outlines the hazard assessment process. Hazard assessment is conducted separately for erosion, hydrology and riparian function. The data collection and assumption identification steps (steps 1.1. and 1.2, respectively) are self-explanatory. Interpretive steps (step 1.3) involve identifying and using methods to analyze the data collected in step 1.1. Decision criteria (step 1.4) are the standards used to decide if a given process constitutes a cumulative effects hazard, whereas identification of hazard areas (step 1.5) is the actual process of making these decisions. Potential contributing activities (step 1.6) involves determining the extent to which current (or future) forest

Figure 1

Overview of Watershed Resource Assessment Process

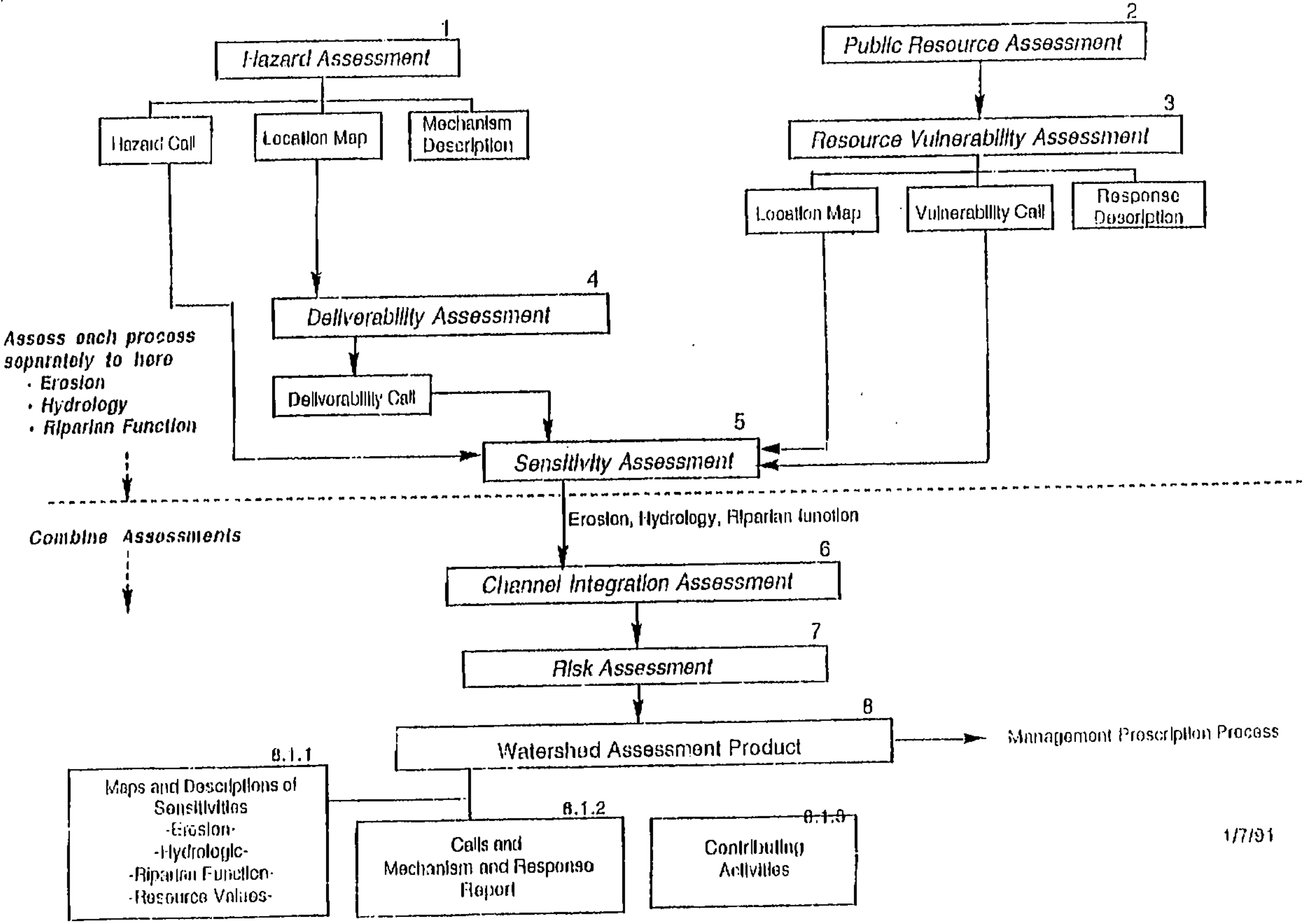

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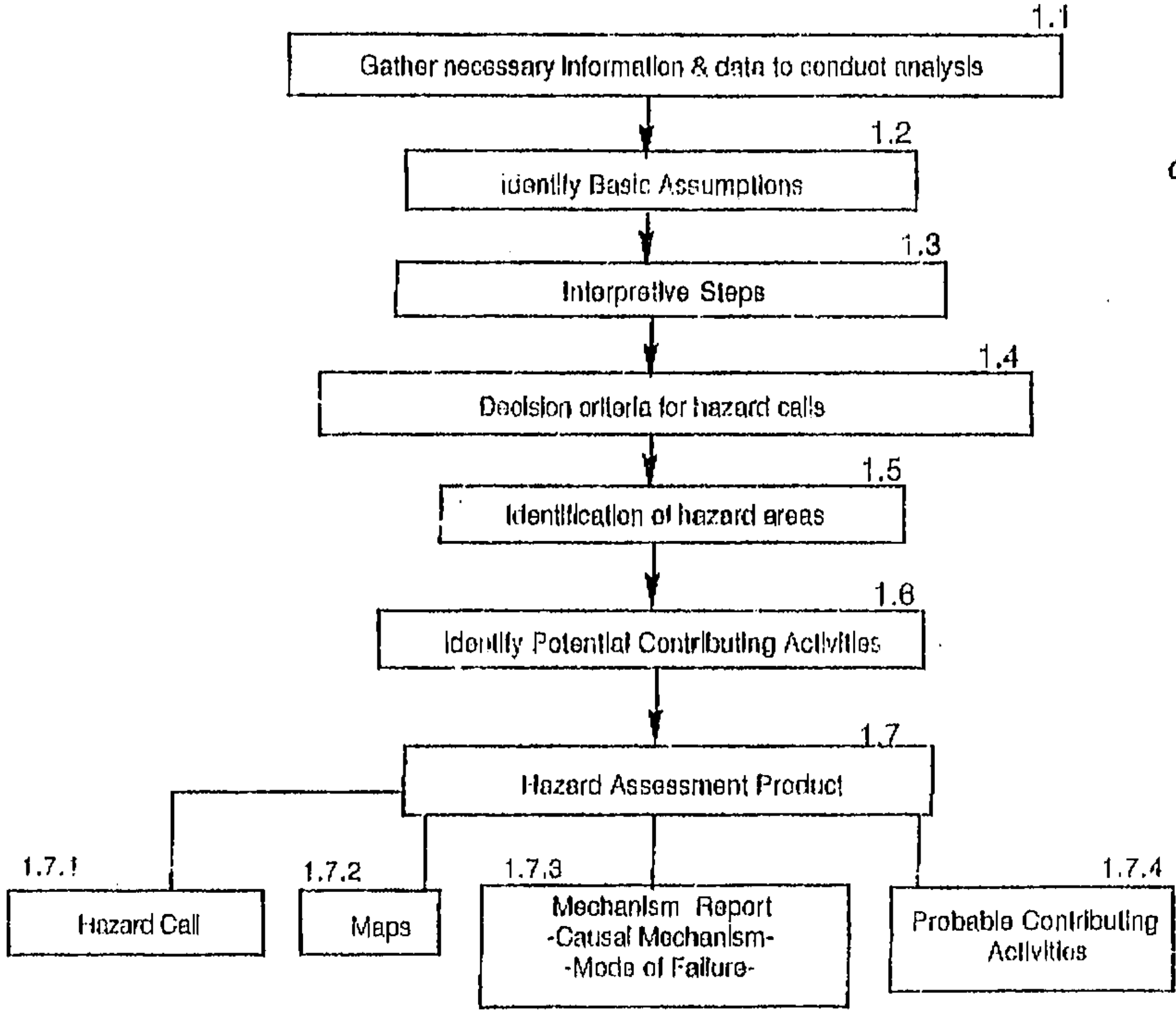
Figure 2

Hazard Assessment Process



Construct separate methods for
- *Erosion*
- *Hydrology*
- *Riparian Function*

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practices actions are (could be) responsible for the identified hazards. Finally, the hazard assessment product summarizes the work efforts and conclusions of the hazard assessment process. Final products from the hazard assessment include: maps identifying the locations of hazards within the basin; descriptions of the hazards and the decisions used to identify them; an assessment of the degree to which forest practices activities have contributed to hazard; and, a discussion of the cause-effect relationships between watershed processes and hazards.

Figure 3 outlines the public resource assessment process. This process in straightforward. Information on significant public and natural resources in the basin is collected (step 2.1), reviewed to determine the type and value of resources present (step 2.2) and summarized to provide input to the resource vulnerability assessment (step 2.3).

Figure 4 details the resource vulnerability assessment process. As with the previous assessments, the first step is to gather information necessary to conduct the assessment (step 3.1). Using information from the initial assessment of watershed hazards, certain areas ("potential response segments") with potential to be impacted by hazard are identified (step 3.2). The presence and value of resources in the response segments are then determined (step 3.3) using information on resource distribution from step 3.1 and on resource value from the public resource assessment. A number of risk indicator areas are then chosen for further study from areas within the potential response segments where valuable public resources are present (step 3.4). Channel condition, the types/quality of fish habitat, and the values for resource condition indicators are then assessed within these risk indicator areas (steps 3.5, 3.6 and 3.7, respectively). Resource condition indicators (also called threshold parameters) are variables selected by TFW to indicate the overall suitability of stream habitats for different species of anadromous salmonids. The resource vulnerability assessment product [replaces TFW's step 3.8, "assess recoverability"] summarizes the results of the vulnerability assessment. Final products from the vulnerability assessment (step 3.8) include: maps identifying the locations of response areas, channel condition and fish habitat within the basin; descriptions of the resource vulnerabilities and the decisions used to identify them; an assessment of the degree to which hazard has affected resource condition; and, a rating of habitat quality using observed values for the resource condition indicators.

Figure 5 outlines the deliverability assessment process. [EA has made one change in TFW's assessment for this process; step 4.1, "combine hazard and resource vulnerability assessment", has been eliminated and the remaining steps re-numbered. Hazard and

Figure 3

Public Resource Assessment Process

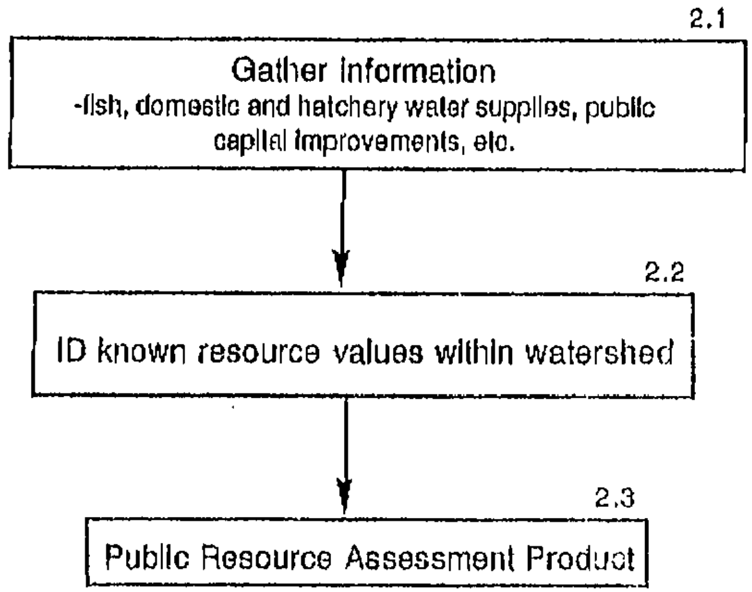

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Figure 4

Resource Vulnerability Assessment Process

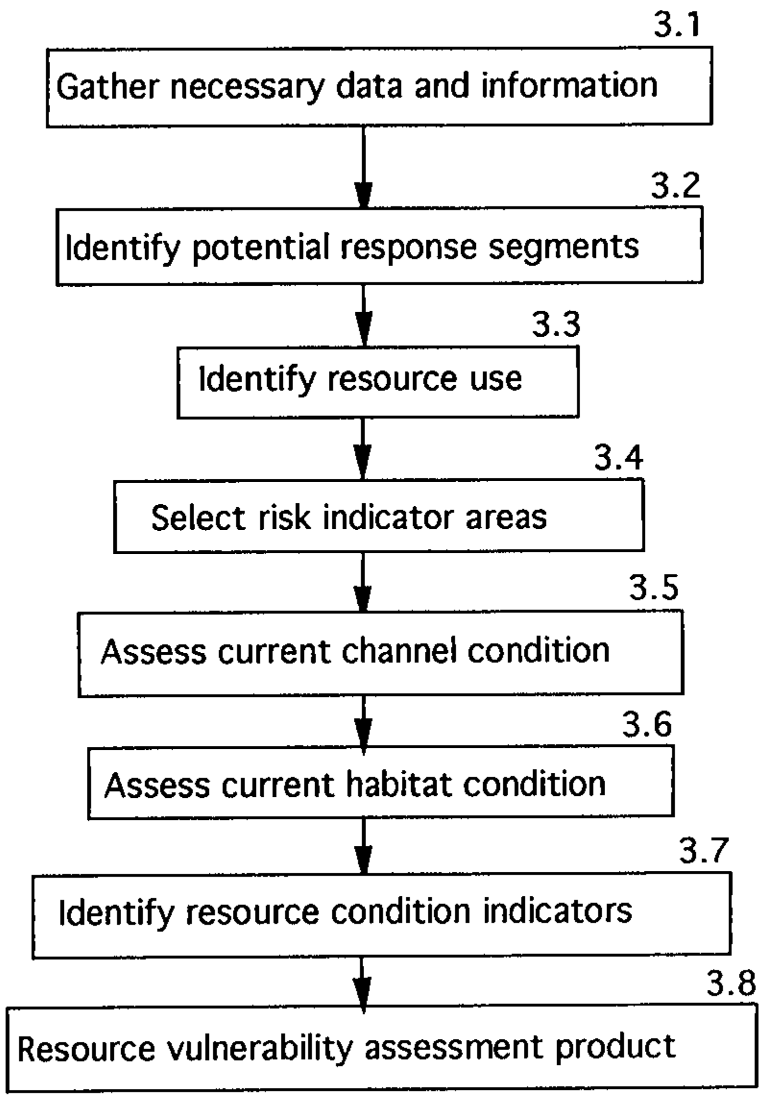
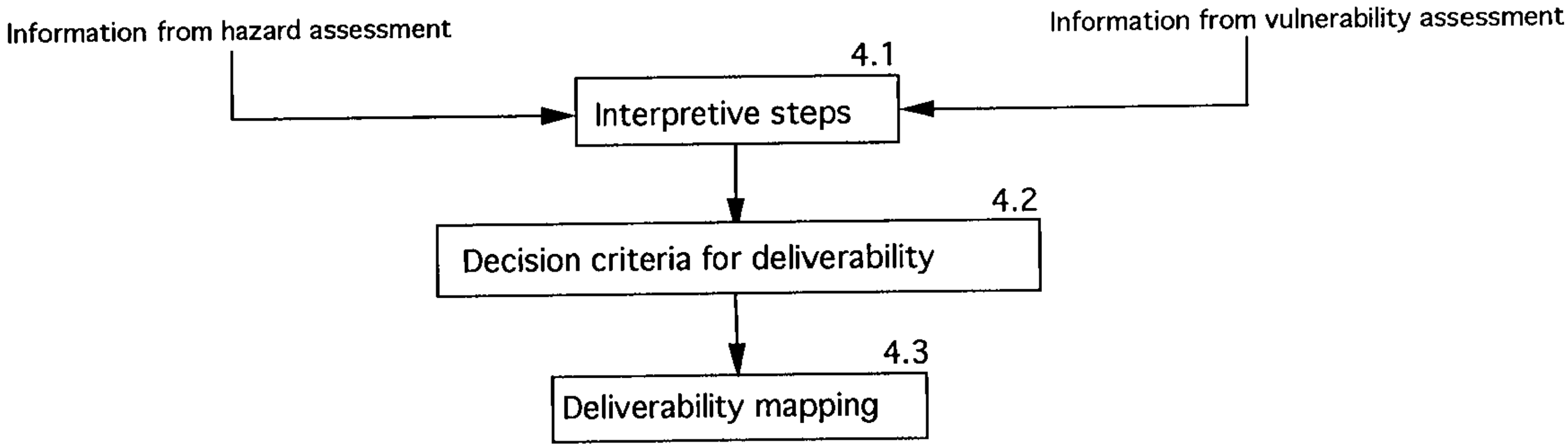


Figure 5

Deliverability Assessment Process



resource integration is now considered as part of task 5, sensitivity assessment.] The deliverability assessment examines the results from the hazard analysis and determines the present and future potential inputs of sediment, water and large organic debris to the risk indicator areas. Interpretive steps (step 4.1) involve identifying and using methods to determine actual/potential deliverability of materials from hazard areas. Results from the vulnerability assessment (e.g., channel condition measurements) can be used to help assess current deliverability. Decision criteria (step 4.2) are the standards used to decide if a given level/type of deliverability could significantly impact vulnerable resources. Deliverability mapping (step 4.3) involves mapping hazards with significant deliverability. This mapping must identify the risk indicator areas affected.

Figure 6 summarizes the steps to conduct the sensitivity assessment process. This process is repeated for each of the hazard classes. Criteria (decision rules) for determining the significance of resource-hazard combinations are specified (step 5.1). The deliverability and vulnerability assessments are then combined and evaluated using the decision rules to identify sensitive situations (step 5.2). Each of the identified sensitivities is then mapped (step 5.3). For each mapped unit, a written summary is prepared including a description of the sensitivity, the hazard-vulnerability combination causing the sensitivity, and the possible changes in resource condition resulting from the sensitivity (step 5.4).

Figure 7 outlines the channel integration assessment process. The individual sensitivity assessments are combined (step 6.1) and the collective impact determined (step 6.2). The effects of these impacts are then extrapolated to predict future resource conditions (step 6.3).

Figure 8 details the risk assessment process. This process contains only two steps. First, the entire analysis is examined to determine the types and magnitude of any uncertainties (step 7.1). Second, given the uncertainties, decisions are made concerning the conclusions included into the final work product (step 7.2).

The watershed assessment product (#8 of Figure 1), the last component of the Level I and Level II cumulative effects analysis, is a summary report that addresses all aspects of the methods used. The product includes: all maps or map overlays; all written descriptions of the individual units mapped; a listing of the criteria used to make decisions and any uncertainty; discussion of the hazard-response mechanisms operating in the basin; and, a discussion of the actual or potential impact of forest practices on these mechanisms.

Figure 6

Sensitivity Assessment Process

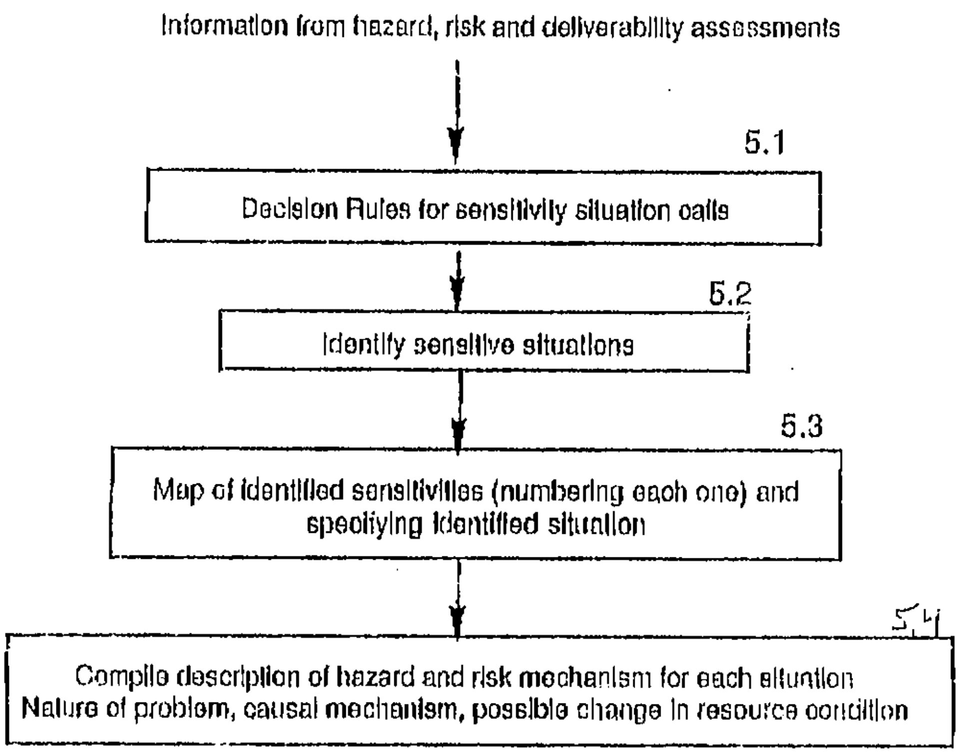


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Figure 7

Channel Integration Assessment Process

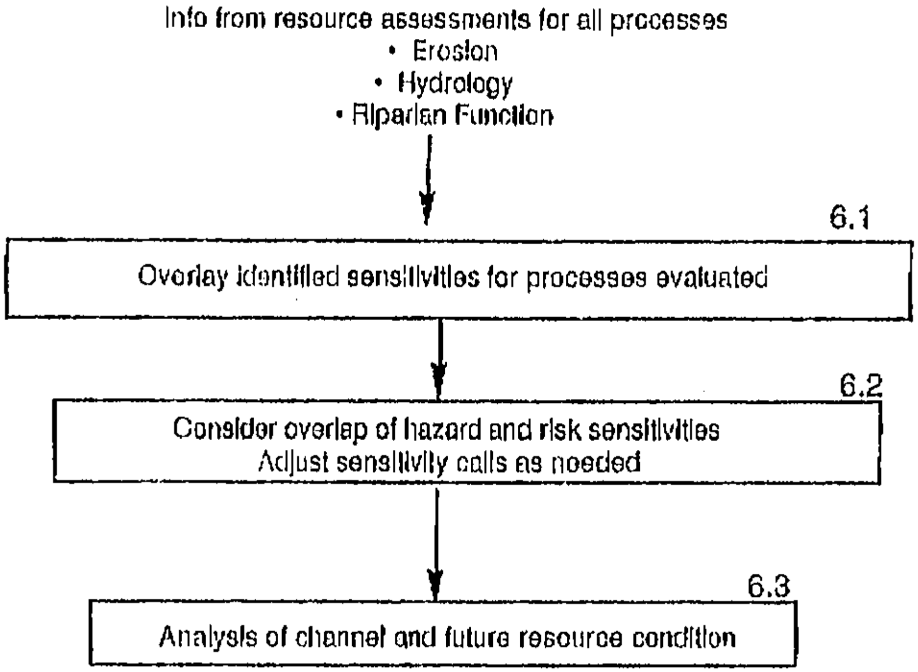
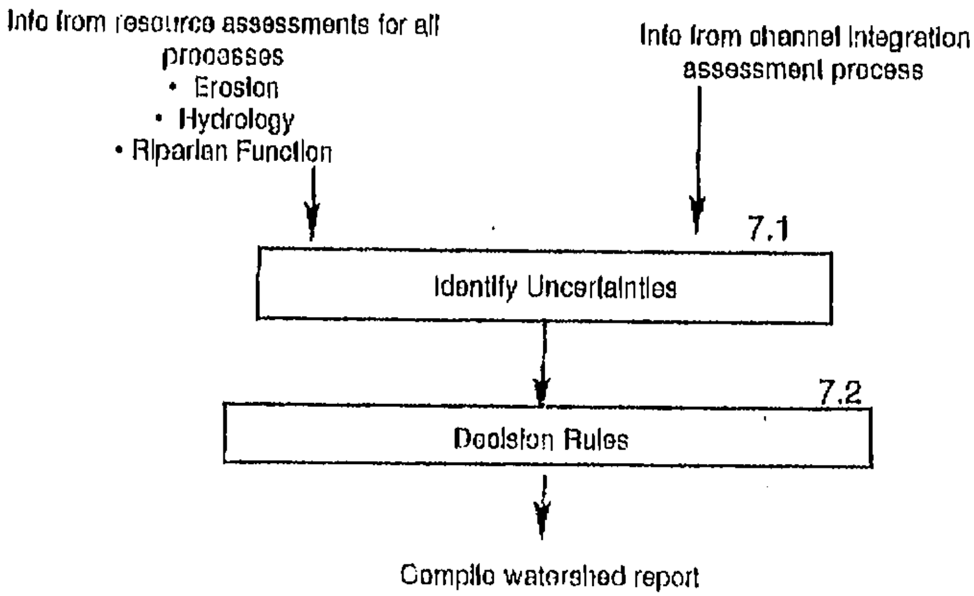


Figure 8

Risk Assessment Process



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3. HAZARD AND VULNERABILITY ASSESSMENTS

The following sections discuss the proposed approach to conducting hazard and vulnerability assessments. Hazard assessments will be performed following the generalized task sequence shown in Figure 2 for the following process groups:

- erosion, including mass wasting and surface erosion;
- hydrology; and
- Riparian Function including temperature and Large Organic Debris (LOD).

The resource vulnerability assessment follows the sequence shown in Figure 4. Initial annotated outlines for each of these assessments are contained in Appendix A. General discussions of hazard and vulnerability assessments are provided below for both Level I and Level II analyses. Each discussion includes an overview of the methods to be used and an initial estimate of the effort required to conduct each analysis. Decision criteria are also reviewed when available.

At this time, several proposed Level I and Level II methods are only at the conceptual or experimental stage of development, have not been tested in a cumulative effects-type application, or have not been fully evaluated in terms of level of effort required to produce usable results. Initially, it is expected that interim methods will be presented and refinement of these methods will occur over time as new methods are proven to be implementable in a watershed analysis framework. Alternately, analysis of certain processes might have to be deferred until adequate methods are available.

3.1 Erosion Hazard Assessment

3.1.1 Level I

The Level I erosion hazard assessment evaluates the two primary erosion processes, mass wasting and surface erosion, to determine baseline conditions, dominating processes and relative hazard. These two erosion processes will be evaluated independently in Level I.

Mass Wasting. Mass wasting includes shallow-rapid landslides, debris flows, dam break floods, and deep seated landslides (slump-earthflows). Differentiating these processes is necessary to aid in delineation of hazard areas. Evaluation of cause and effect relationships will not only consider geomorphic processes, but also how changes in forest practice standards over the last two decades have altered the rate and occurrence of mass wasting features. Objectives of the mass wasting component of the erosion assessment are to:

- produce an erosion hazard map by delineating existing and potential erosion areas (mapping units) based on current slope conditions and landform extrapolation;
- describe each erosional mapping unit in terms of sediment source areas and forest practice contributing to the condition (i.e., roads and harvest areas), and whether obsolete management activities are responsible;
- in a brief report, qualitatively discuss dominating processes, whether sediment is delivered to streams, and probable downstream effects; and
- identify processes and/or watershed areas that require further analysis in Level II.

Surface Erosion. Evaluation of surface erosion consists of a screening-level analysis of basin-wide soil erosion potential. This analysis results in an overall index of erosion potential that is compared to threshold index values that define low, medium, and high basin erosion hazard ratings.

An initial field reconnaissance will be conducted at the onset of the Level I analysis. This visit will identify existing surface erosion problems within the watershed, and describe the dominant cause and effect relationships controlling surface erosion. This information will aid in the interpretation of the office based analysis method.

The method, currently under development and therefore undocumented, combines the following three independent terms to derive the erosion potential:

- Rainfall Erosivity: An index of the erosive power of rainfall. This term is identical to the EI index in the Universal Soil Loss Equation (USLE), and is equal to the product of rainfall energy and the maximum 30 minute intensity of rainfall. The EI index is converted to an average annual R value using one of several available methods (e.g., as a function of the 2-year, 6-hour precipitation).

- Soil Erodibility: An index that reflects a soil's susceptibility to erosion in terms of resistance to detachment by rainfall and flowing water and its ability to take up water (infiltration capacity). This term is identical to the K factor in the USLE. This value can be obtained from soil surveys.

- Drought Susceptibility: An index of revegetation potential of a soil. This index combines growing season precipitation and solar radiation (i.e., slope, aspect). Revegetation potential is important because a location that has high rainfall erosivity and soil erodibility, as predicted by USLE, may have a high revegetation rate that substantially reduces the long-term erosion potential.

Indices for each of the three parameters are then combined for a basin-wide index. The basin index is compared to a hazard scale that is developed either from regionally verified information on known erosion rates or effects, or by simple comparison to the range of indices developed for the region or state. A low hazard rating would mean that a Level II analysis would not be required.

This method is particularly suited as a Geographic Information System (GIS) application. Most information is currently contained in the DNR's GIS and therefore can be manipulated relatively easily on a watershed scale. Furthermore, simultaneous evaluation of all watersheds in the state would result in an immediate comparison of a particular watershed to state or regional variability.

3.1.2 Level II

The Level II analysis for erosion is designed to develop quantitative estimates of sediment loading and transport in watersheds where Level I analyses indicated the presence of high erosion hazard. A sediment budget is the central feature of the Level

II analysis. The following discussion outlines the potential methods available for a Level II analysis.

Sediment Budget. A sediment budget quantifies the mass of sediment that various processes contribute to a stream system. This allows identification of specific hazard areas within a watershed. Processes in a sediment budget include mass wasting, road surface erosion, channel bank erosion and surface wash (non-road areas), and possibly others that are identified in the Level I analysis. Existing procedures are generally available for conducting sediment budgets.

For mass wasting, landslide loading to streams can be based on volume of slides over time. This requires temporal interpretation of aerial photographs to derive rates, supplemented with field work to gather dimensional information, locate landslides hidden by forest canopy and assess delivery. Evaluation of bank erosion is also based on air photo interpretation and field observation.

For road surface erosion and surface wash, sedimentation rates for different land uses (i.e., roads, harvest areas) are based on a USLE-type model. A revised USLE (i.e., RUSLE), which updates the USLE for steeper slopes and other conditions that were not originally included in the predominantly rangeland-based USLE, is currently in draft form. Other methods, such as physical models for surface erosion (e.g., WEPP), are currently under development but may not be available for several years. These methods can be integrated with GIS information on land use and roads to derive sediment yields. Sediment delivery, which defines how much of the sediment yield enters the stream channel, is based on regionally-compiled empirical data, available delivery equations (e.g., WRENSS) or professional judgement.

Grain sizes of transported material is integrated into the analysis. The sediment budget analysis is sufficiently detailed to quantify sediment production rates in all major sub-basins within the watershed.

Sediment Transport. Level II includes simplified techniques to evaluate sediment transport. For example, channel gradient, width, grain size and average flow rate can be used to determine whether a reach tends to erode or deposit bed sediments. Transport equations are selected to match the fluvial and sediment regime of the stream (e.g., alluvial, sand bed, bedrock, etc.). If available, existing monitoring data are used to support or calibrate model development. Results of the transport analysis are directly to the channel and habitat analyses and are presented on maps.

Erosion Hazard. The Level II analysis identifies existing slope stability models (e.g., LISA) that are potentially usable for detailed analysis of mass wasting hazard areas. However, since none of these models have been applied over an area equal to the size of a watershed as defined in this document, at this point in time use of the model in this manner is not recommended due to tremendous level of effort that is potentially needed to conduct a valid analysis. Therefore, stability models should be used only to refine the hazard maps developed in Level I, (e.g., to further define the gradient at which failure is predicted under typical soil conditions). A model that utilizes a GIS to predict stability may be useful, but none are expected to be implemented soon.

Estimated total level-of-effort for the Level II erosion assessment is 6-8 person-weeks.

3.2 Hydrology Hazard Assessment

3.2.1 Level I

The Level I hydrology hazard assessment addresses the effects of forest practices on peak flows generated during rain-on-snow events. The proposed assessment, which is still under development, consists of a broad watershed screening that:

- estimates the peak flow from a 24-hour, 2-year precipitation event (modified to account for snowmelt and forest stand condition) using stream gauge-based regression curves;

- compares the resulting peak flow to an acceptable percent increase (i.e., threshold) to determine if a hydrologic hazard exists; and

- if hazard exists, recommends detailed hydrologic modeling under Level II to determine specific flood hazards and forest hydrologic recovery.

Studies have shown that timber harvest and related activities (e.g., road construction and soil compaction) can result in potentially large increases in peak streamflows because of greater snowpacks and faster melt rates during rain-on-snow events. These effects are largely confined to the transient snow zone, which is believed to be between 1,000 and 4,000 feet in Washington but varies regionally. Recent TFW studies have investigated the effects of forest cover density on the rate of water input to soils during rain-on-snow conditions. While confirming that the water input to soil is potentially large after forest harvest, these studies have not addressed how this translates to increased streamflows at large distances downstream of the harvest areas. Flood hazards are most apparent in lower stream reaches because the summation of many small flow gains results in a large flow gain and lower elevation and lower gradient floodplains are particularly sensitive to flood damage. Therefore, hillslope and streamflow routing should be incorporated into a hydrology hazard assessment. Because no adequate methods were available that fit the objectives of the Level I watershed analysis (most screening methods derive only the increase in soil water entry), a new methodology was developed.

The proposed Level I method estimates the magnitudes of flood flows during a 2-year, 24-hour storm for different forest stand conditions (basins with elevations below the transient snow zone would not be subjected to the analysis). An estimate of peak flow is derived for the entire basin using available DNR stand data for current conditions, the precipitation amount for the 2-year, 24-hour storm and a snowmelt factor derived from snowmelt plot data. These data are input into regression equations, similar to ones developed for western Oregon by the USGS, that equate basin area, forest cover and precipitation to streamflow at the bottom of the basin. (Although equations have not be derived for Washington, creating them should not present a problem). The snowmelt factor incorporates the effects of rain-on-snow into the regression. The method results in a comparison of peak flow between different stand conditions (e.g., current, historical and future stand condition). The method largely relies on remotely sensed data already contained in the DNR's GIS.

The result of the Level I analysis, i.e., magnitude of increase in peak flow, is compared to a threshold value that defines the maximum increase in peak flow (in magnitude or percentage) that is acceptable for protecting downstream resources. The method assumes that a threshold can be applied to determine when a floodflow becomes a hazard, and that rain-on-snow hazards are of basin-wide concern only (i.e., local effects are not considered). Watersheds that exceed this value must be evaluated in greater detail using other models in Level II.

3.2.2 Level II

The Level II hydrology hazard assessment would further evaluate rain-on snow and also address other potential hydrologic impacts of forest practices. Basins determined in Level I to have a rain-on-snow hazard will be subjected to a more detailed analysis to delineate specific hazard areas within the basin (if definable) and forest stand condition (e.g., hydrologic recovery) needed to restore acceptable peak flow hydrology. A comprehensive hydrologic computer model of the basin required for this analysis. The model must combine snowmelt and precipitation with runoff and channel routing in an event-based model, and should be calibrated to historic streamflows if gauged records are available. Modeling results should be more directly compared to quantitative measures of flood damage, such as peak flood stage in downstream floodplains or shifts in the flood frequency curve. Because hydrologic modeling often requires considerable effort, it may be more practical to combine several contiguous basins for the modeling, resulting in a Sub-WRIA area or larger, rather than modeling at the scale of the Level I watersheds.

Other hydrologic impacts of forest practices, including increased annual water yield, change in spring melt timing and changes to base flow discharge, have not been adequately investigated to formulate methods for analysis. Modeling requirements for this analysis are fundamentally different than for rain-on-snow modeling, primarily because of the different time scale and greater amount of site data needed to evaluate annual changes. Level II should evaluate these hydrologic impacts when future research provides additional insight into these processes or if local conditions have been documented or are particularly sensitive to hydrologic change.

The level of effort to conduct a Level II hydrology assessment is approximately 10-20 person-weeks.

3.3 Riparian Function - LOD Assessment

3.3.1 Level I

The LOD assessment will assess the ability of the riparian zone to provide adequate inputs of large organic debris (LOD) to maintain acceptable fish habitats. This assessment will:

- produce a LOD hazard map by delineating areas where the existing riparian vegetation is too young or too sparse to satisfy LOD requirements;

- describe each LOD mapping unit in terms of hazard level and basis for hazard prediction;

- in a brief report, qualitatively discuss riparian condition, potential for future LOD deficiencies, and probable impacts to fish habitat; and

- identify areas that require further analysis in Level II.

The LOD assessment will consist of an evaluation of vegetation in the riparian zone of all fish bearing waters (i.e., type 3 or lower) in the basin (non-fish bearing waters are excluded from the analysis). Aerial photographs, information on stand age and type, and limited field surveys will be used in the analysis. Channel characteristics will be reviewed to identify stream reaches likely to respond to LOD inputs ("wood response regions"). Response regions include low gradient (3% or lower) reaches with low to moderate valley confinement (valley width/channel width ratios greater than 1.3), and total channel widths less than 20 m. Within wood response regions, the approximate age and density of trees will be determined. The riparian vegetation will also be characterized as deciduous, coniferous or mixed.

Decision criteria for determining LOD hazards are based on characteristics of the riparian vegetation. Once the age, density and type of vegetation is determined, they are compared to hazard rating tables to determine whether the LOD hazard levels are high, medium or low. Young forests (< 40 years) always represent high or medium hazard, as do deciduous forests. Low hazard is associated with dense, mature (40-120 year old) coniferous or mixed forest. Uncertain hazard is assigned to response areas that cannot be adequately assessed at Level I.

The level of effort to conduct a Level I LOD assessment is approximately 3-4 person-days.

3.3.2 Level II

The Level II LOD assessment utilizes field surveys to determine the size, density and type of riparian vegetation present in the wood response areas identified in Level I. In addition, in-stream LOD levels will be measured, either as part of the Level II resource vulnerability assessment, or as a separate effort if no Level II vulnerability analysis is conducted. In-stream LOD levels will be compared to criteria for good, fair and poor habitat as outlined in TFW's resource condition indicators (i.e., threshold parameter values). Current LOD levels, and the potential for future inputs from the riparian zone will be combined to determine the overall LOD hazard.

3.4 Riparian Function - Temperature Assessment

3.4.1 Level I

The Level I temperature assessment identifies stream reaches that are likely to exceed state mandated water temperature levels. This analysis reviews three characteristics for each reach: elevation, distance from basin divide and riparian shading.

Elevation is used as a simple screening process; all stream reaches above 3600 ft. in elevation are assumed to be able to meet state mandated temperature levels. Distance from the basin divide is used to stratify stream reaches. The size and width of mainstem rivers increases as distance from the divide increases. As width increases, the ability of the riparian vegetation to shade streams, and thereby control water temperatures, decreases. Consequently, all other factors being equal, water temperatures increase as distance from the basin increases. Distance from the basin is therefore used to stratify stream reaches into different temperature classes.

Aerial photography and spot field checks are used to determine the amount of shading provided by riparian zone vegetation. The amount of shading in each reach is then compared to tables indicating minimum levels required to maintain temperatures within each class. Potential temperature hazard zones are identified and mapped where measured riparian shading levels are less than the tabled values for the appropriate temperature class.

Simple decision criteria are used for determining when temperature hazards are present. First, potential hazard zones less than 1,000 ft. in length constitute "low" temperature hazards. It is assumed that low shade levels over distances less than 1000 ft. do not result in temperature increases above mandated levels. Second, if potential hazard zones are longer than 1,000 ft. then a "high" temperature hazard exists. Moderate hazard levels are not defined at Level I, but an "indeterminate" temperature designation is applied to all areas where uncertainty prevents making a clear decision about hazard.

The level of effort to conduct a Level I temperature assessment is approximately 3-4 person-days.

3.4.2 Level II

Level II temperature assessment utilizes field measurements of channel width, riparian condition and stream shading to increase certainty in results from the Level I analysis. These field assessments are conducted in all areas with an indeterminate (Level I) temperature hazard , and in representative sections of remaining stream segments. Decision criteria for Level II are the same as for Level I except that the indeterminate hazard category is eliminated. The approximate level of effort to conduct a Level II temperature assessment is 4-5 person-days.

3.5 Resource Vulnerability

3.5.1 Level I

The Level I resource vulnerability assessment has several components. First, the hazard assessment is reviewed to identify the types of processes that could impact stream resources within the basin. Second, areas of the stream network that could respond to these hazards are identified ("potential response segments"). Each hazard can be expected to affect certain types of stream reaches. For example, sediment inputs from landslides (hazard) are most likely to affect low gradient, unconstrained stream channels (response segment characteristic). For each hazard type, a list of these response segment characteristics is identified. Stream reaches are then screened using these lists. Current screening characters include stream confinement, slope, proximity to hazard, substrate characteristics, sinuosity and channel morphology. Third, the distribution of resources is determined. Fish distributions are determined from a variety of data sources. Other public resources are identified using the results of the public resource assessment. Fourth, resource distributions and response segments are combined to determine zones of overlap. Within these zones of overlap, certain stream sections (risk indicator areas) are identified for further analysis. Indicator areas are chosen using rules designed to ensure that all major overlap zones are analyzed. Fifth, channel and fish habitat condition and resource condition indicators (threshold parameters) are assessed in each risk indicator area. Conditions are assessed using aerial photography, reports, interviews and limited field observation. Finally, the vulnerability of stream resources is assessed by comparing the current conditions in the risk indicator areas to tabulated values.

Decision criteria are used to identify potential response segments, to select risk indicator areas and to determine vulnerability. At the present time, the vulnerability assessment methods are not sufficiently developed to clearly indicate decision criteria. A general outline of the criteria is provided for some perspective on decisions expected as part of the Level I vulnerability analysis.

Decision criteria for response segments are conservatively applied as follows:

- for each hazard type, characteristics have been defined to identify responsive stream sections. If a stream section contains any of these characteristics, it is considered a potential response segment; and

- if a stream section does not contain any of these characteristics, it is not considered a potential response segment.

Decision criteria for selecting risk indicator areas emphasize identification of unique combinations of location, hazard and resources. These decision criteria are:

- any unique overlap area (i.e., any unique combination of response and fish or public resource use) is automatically selected for further analysis.

- overlap areas with a limited distribution must be carefully reviewed. To the extent that overlap areas of a given type are found in close proximity to one another or in the same elevation band, drainage, etc., a subsample of sites can be selected and the results extrapolated to other areas. When overlap areas diverge in location or physiographic regime, then each area must be identified as a risk indicator area and studied individually.

- for overlap areas that are widely distributed, use the same process as for limited distributions to select risk indicator areas. The goal is to ensure that both major drainage units (e.g., major tributaries) and stream types (e.g., headwaters, mainstem rivers, etc.) are selected for further analysis.

Decision criteria to determine vulnerability have not been developed. It is anticipated that TFW's ongoing project to define resource condition indicators (work being conducted by Phil Petersen, University of Washington) will result in unambiguous criteria for assessing the overall suitability of fish habitat for target species. Criteria to assess vulnerability based on channel condition are being developed collaboratively with TFW.

The level of effort to conduct a Level I vulnerability assessment is approximately 5-8 person-days.

3.5.2 Level II

The overall approach of the Level II vulnerability assessment is to conduct extensive field measurements so that resource vulnerability can be assessed directly. As with other Level II work, this assessment is viewed as an adjunct to the Level I study aimed at resolving uncertainties. It is not a substitute for Level I. Accordingly, Level I and Level II studies utilize the same potential response segments and resource distributions. Initially, Level I's risk indicator areas will also be utilized. However, the Level II pedestrian survey (see below) may identify additional indicator areas, which would be mapped and analyzed.

The Level II resource vulnerability assessment utilizes a pedestrian survey of streams to identify clearly the channel and habitat conditions within the basin. Measurement techniques include Pfankuch's "Stream reach inventory and channel stability evaluation" (1978) and TFW's "Ambient Monitoring Field Techniques Manual" (1990), among others. The following variables have been identified as being potentially useful in the Level II analysis.

Discharge	Water quality (temperature, turbidity, etc.)
Habitat type	Habitat dimensions
Debris jams	Vegetative bank cover
Canopy closure	Channel capacity
Bank stability	Bank rock content
Large organic debris	Substrate embeddedness
Fine substrate deposition	Substrate angularity
Substrate brightness	Substrate consolidation
Substrate size distribution	Aquatic vegetation
Landform slope	Stream slope
Stream depth	Stream sinuosity
Channel width	Valley width
Mass wasting	

The actual variables used will depend on discussions with TFW collaborators, and on the outcome of TFW's resource condition indicators study.

Decision criteria for the Level II vulnerability assessment have not been specified. However, in general, these decision criteria are to be based on the quantitative measurements of channel and habitat condition provided by the pedestrian survey. Resource condition indicators will be used to assess the quality of habitat for fishes. Other decision criteria will be based on channel dimensions (e.g., width/depth ratios), substrate characteristics and on bank stability.

The approximate level of effort to conduct a Level II vulnerability assessment is 8-10 person days.

4. CONCLUSIONS

The preceding discussion outlined the overall approach for the proposed cumulative effects analysis and provided some details of the specific methods to be used for hazard and vulnerability assessment at Level I and Level II. As noted earlier, the existing Level I and Level II methods are still at an early stage of development. TFW in general, and individual cooperators in particular, have committed themselves to developing Level I methods in collaboration with EA during February 1992. This work is expected to culminate in a Level I methods manual on or before 28 February 1992. As the Level I methods are refined further, additional detail on the scope and methods to be used for the Level II analysis will emerge. EA has been assigned primary responsibility for the development of these Level II methods. This work will be conducted with thorough review and participation by TFW and DNR. A draft Level II methods manual is scheduled for completion on or before 1 March 1992.

Although changes in the methods used for individual tasks will be made in the next month, the general framework for the analyses, as reviewed in Figures 1-8, is expected to remain relatively constant. However, EA and TFW are interested in comments on all aspects of this document. To the extent that they are deemed applicable and useful, these comments will be incorporated into the methods manuals for Level I and Level II. Reviewers are asked to forward their comments directly to EA or to the TFW Cumulative Effects Steering Committee.

APPENDIX A

This appendix contains detailed discussions of the Level I methods to be used for the hazard and vulnerability assessments. The format of these discussions closely follows the flow charts in Figure 2 (hazard assessment) and Figure 4 (vulnerability assessment).

Of the materials presented in this appendix, only the resource vulnerability assessment methods were developed by EA. TFW collaborators developed the stream temperature and LOD hazard methods. Hydrology and erosion hazard assessment methods were developed jointly by EA and TFW. In each case, the discussions here represent the most detailed analysis of the Level I methods available at the time of printing of this document.

2.1.1 EROSION ASSESSMENT

2.1.1.1. Task 1 - Gather Necessary Information and Data

2.1.1.1.1. Maps

A. Base map. Obtain sub-WRIA map with basin boundary and stream network from DNR.

B. Geology map. Obtain Geology State Map (1:100,000) from DNR plus any additional larger scale maps if available

C. Landslide inventory. Obtain maps (1:24,000) if available.

D. Soils map. Obtain soil maps if available.

E. Precipitation. Obtain 2 year-24 hour precipitation map.

2.1.1.1.2. Remotely Sensed

A. Aerial photographs. Obtain most recent and a sufficient series of historical aerial photographs (1:12,000).

B. Other photos. If available, obtain orthographic and/or township photos if aerial photographs are insufficient.

2.1.1.1.3. Field data

A. Mass wasting. A one-day field reconnaissance of the basin should be conducted to verify instability conditions and remotely sensed data (e.g., determine if erosional feature is road-related or an in-unit failure) and to qualitatively determine if sediment delivery to streams is occurring.

B. Surface erosion. A one-day field reconnaissance should be conducted to inspect existing surface erosion problems in the basin, and qualitatively describe (using a standard form) the dominant cause and effect relationships in the basin.

2.1.1.2. Identify basic assumption

A. Mass wasting

1) Geology maps and landslide inventory maps are available or can be obtained in a timely manner

2) Remotely sensed information and tools are available

3) Landslides can be identified on 1:12000 air photos

4) Extrapolation from one sub-basin to another with similar characteristics is feasible based on remotely-obtained information

5) Field verification can be performed during a short (1 day) reconnaissance; therefore, access to basin will not be limiting

B. Surface erosion

1) Information is available to develop weighted average data for the USLE analysis (rainfall and soil). This is most efficiently performed on GIS on a state-wide basis.

2) Soil survey data contain soil erodibility values

3) Field reconnaissance can be conducted during a short (1 day) visit.

2.1.1.3. Watershed partitioning

A. Mass wasting

1) Slope gradient

2) Soil type (e.g., glacial, alluvial, colluvial)

3) Parent rock type (e.g., sandstone, basalt, schist)

B. Surface erosion

None; analysis is performed on watershed-wide basis.

2.1.1.4. Interpretive steps

A. Mass wasting

1) Mapping. Assemble data onto overlays

2) Extrapolation. Delineate erosion hazard based on the following factors:

- Geomorphic variables: slope gradient, slope form, slope position, proximity to streams, etc.

- Geologic variables: soil type, parent rock type, lithology, contacts, structure, etc.

- Other factors: temporal trends, historic land use practices, etc.

3) Interpretation. For each erosion mapping unit, determine (based on site visit, aerial photographs, literature, etc.) the following:

- Delivery significance to stream (low or high)

- Material type (texture and LOD)

- Potential delivery rate (if quantifiable)

- Process [mass wasting (shallow-rapid landslide, debris flow, dambreak flood, and deep seated landslide) and surface erosion]

- Causative activity (road, harvest area, and natural)

B. Surface Erosion

1) Mapping. Conduct GIS or other analysis to derive the three indices (rainfall erosivity, soil erodibility, and drought potential) for watershed.

2) Interpretation. Combine indices to create surface erosion potential index.

3) Compile erosion potential indices for watersheds in the region or for the entire state.

2.1.1.5. Decision criteria for hazard calls

2.1.1.5.1. Assumptions

A. Mass wasting

1) Past erosion features can be used to predict the likelihood of future erosion. The necessary time scale for evaluating erosion is decades or centuries, thus requiring air photograph documentation.

2) Similar erosion features with similar conditions will act in a similar manner. This allows extrapolation of erosion mapping units using slope conditions or landform characteristics.

3) Mass wasting can be attributed to forest practice (e.g., roads, logging areas) if such features are not found in undisturbed areas of similar geomorphology.

4) An erosion mapping unit identifies contiguous terrain that, based on existing features, is susceptible to mass wasting. However, mass wasting features that are solely attributable to outdated forest practice standards (i.e., road placement on steep slopes) and that would not be expected to occur today except in unusual circumstances (i.e., plugged culvert) should not be used as the basis for extrapolating erosion mapping units.

B. Surface erosion

1) A surface erosion potential index can be determined from rainfall, soil, and revegetation characteristics and can be used to rank relative surface erosion hazard.

2) Erosion conditions as measured by an erosion index are reflective of all hazard conditions that potentially exist in state watersheds. The problem of defining relative hazard (low, medium, and high) then reduces to defining the threshold boundaries between the hazard categories.

3) Defining threshold boundaries between low and medium, and medium and high hazard Because the surface erosion potential index cannot be compared to actual erosion rates, derivation of thresholds will require professional judgement and experience.

2.1.1.5.2. Criteria.

NOTE: THE FOLLOWING CRITERIA ARE PROVIDED AS EXAMPLES ONLY. THEY WILL LIKELY BE REVISED FOLLOWING REVIEW AND COMMENT BY CESC.

A. Mass wasting

1) A hazard rating for mass wasting is based on consideration of the following primary variables:

- Presence and distribution of existing mass wasting features as delineated in erosion mapping units, based on slope gradient, slide-prone geologic or geomorphic features, consideration of forest practices in effect at the time of failure, and other relevant factors.

- Proximity of slope to stream channel and potential for sediment delivery in terms of probable or not probable.

The combination of these two factors will define low, medium, and high hazard.

2) A high mass wasting hazard may be defined as:

   - A particular erosion mapping unit having moderate to high instances of mass wasting and sediment delivery to a stream is probable

   - Areas where the slope gradient is greater than X degrees, regardless of potential for sediment delivery to stream (e.g., X=25-35 degrees, defined locally).

3) A moderate mass wasting hazard may be defined as:

   - A particular erosion mapping unit having low or random instances of mass wasting and sediment delivery to a stream is probable

4) A low mass wasting mass wasting hazard may be defined as:

   - A particular erosion mapping unit and all remaining areas where very few or no instances of mass wasting

   - All areas where the slope gradient is less than Y degrees except where deep seated failures are located (Y=15-25 degrees, defined locally).

B. Surface erosion

1) A surface erosion hazard exists when the surface erosion potential index is ranked high relative to regional or state-wide values.

2) Index thresholds are defined based on a regional or state-wide comparison of index values compared to actual erosion conditions that have been previously documented. Thresholds are selected based on quantitative studies (if available), professional judgement, and field verification. Following this comparison, a hazard condition of low, medium, and high is selected based on the magnitude of the erosion index.

3) Alternatively, the surface erosion potential index is normalized to a scale of 0 to 100 (based on the range of state or regional values). The index is then discussed qualitatively.

4) A watershed that is ranked medium may require a Level II analysis (depending on whether it is a dominating process), whereas a high hazard watershed must undergo a Level II analysis.

2.1.1.6. Hazard location delineation

A. Mass wasting. Erosion mapping units are shown on a hazard map and relative hazards (low, medium, or high) are shown for each erosion mapping unit and the remainder of the watershed as appropriate.

B. Surface erosion. A surface erosion potential index is derived for the entire basin. A low, medium, or high hazard is assigned to the watershed.

2.1.1.7. Hazard assessment product

2.1.1.7.1 Causal mechanism report

A. Mass wasting

1) Summary of information used in analysis

2) Summary of current conditions, including qualitative assessment of dominating geomorphic processes contributing to mass wasting and surface erosion in the basin

3) Tabulation of erosion mapping units with delivery significance, material type, potential delivery rate, process, and causative activity identified.

4) Relative hazard ranking for each erosion mapping unit (low, medium, or high).

5) Recommendations for Level II analysis.

B. Surface erosion:

1) Summary of information used in analysis

2) Discussion of existing surface erosion features from site reconnaissance

3) Tabulation of erosion parameter calculations

4) Overall index of erosion potential for watershed, compared to thresholds that define low, medium, or high hazard

5) Recommendations for Level II analysis.

2.1.1.7.2 Location map

A. Mass wasting: Erosion hazard map delineating mass wasting hazard areas, indexed to erosion mapping unit

B. A surface erosion hazard map is not prepared for the level 1 analysis.

2.1.2 HYDROLOGY ASSESSMENT

2.1.2.1. Task 1 - Gather Necessary Information and Data

2.1.2.1.1. Maps

DNR GIS maps. Basin elevation, stand condition, rainfall (2-year, 24-hour maps are currently available from GIS.

2.1.2.1.2. Remotely Sensed

Air photos for verification of GIS data.

2.1.2.1.3. Field data

Field check stand condition.

2.1.2.2. Identify basic assumption

A. Regional regression equations basin on basin area, 2-year 24-hour storm, percent forested basin, etc. as well as rain-on-snow adjusted 24-hour precipitation provides a reasonable estimate of flood magnitude and frequency in ungauged basins.

B. Stand condition/rain-on-snow incremental yield relationships based on Harr's plot results provide reasonable estimates of potential increase of water available from the snow pack during rain-on-snow events.

C. Regression equations intrinsically route rain-on-snow water due to the fact that one of the primary independent variables is the 24-hour storm intensity.

D. USGS gauge information used in the development of regression equations is not substantially influenced by rain-on-snow in the historical record.

E. Rain-on-snow impacts are of concern only at downstream locations. Local impacts (e.g., increased channel density, erosion) are not evaluated.

2.1.2.3. Watershed partitioning

A. Partitioning by stand condition (GIS or remotely sensed)

B. Partitioning by basin elevation band and geographic region (e.g., definition of transient snow zone)

2.1.2.4. Interpretive steps

A. Determine basin elevation. Determine if basin meets definition of sensitive basin.

B. Select regression equation for area.

C. Compile information from data source (maps, GIS)

D. Determine flows for mature basin (pre-harvest), existing condition, and condition being planned for.

E. Determine acceptable change in peak flow based on comparison to threshold. Threshold value may be regionally or locally defined and are is based on floodplain inundation, property loss, channel erosion, spawning bed scour, etc.

F. If threshold is exceeded, go to Level II.

2.1.2.5. Decision criteria for hazard calls

2.1.2.5.1. Assumptions

A. A hydrologic hazard exists if rain-on-snow events cause peak flows to increase above a threshold percentage solely due to changes to forest stand condition.

B. Changes to peak flows are evaluated relative to mature stand conditions.

C. The rainfall event used in the analysis is the 2-year, 24-hour event. Other durations and/or frequencies may be appropriate.

D. Hydrologic impacts are assessed only at downstream locations where cumulative increases in flow cause flood hazards in lower gradient rivers and floodplains.

E. Other impacts of forest practices on hydrologic (i.e., base flows, annual water yield, peak flow timing) are not evaluated in Level I.

2.1.2.5.2. Criteria.

NOTE: THE FOLLOWING CRITERIA ARE PROVIDED AS EXAMPLES ONLY. THEY WILL LIKELY BE REVISED FOLLOWING REVIEW AND COMMENT BY CESC.

A. Basins with less than X percent above the 1000 foot elevation are not sensitive to rain-on-snow events and therefore will not require a Level I analysis (e.g., X=0-25 percent).

B. A hazard exists if the increase in peak flows relative to mature stand conditions is greater than a threshold of Y percent (e.g., Y=10-25 percent).

C. The peak flow threshold value is determined by evaluating the sensitivity of the resource to floods, and ability of downstream floodplains and channels to handle increased peak flows (a tremendous task). A threshold may be based on field checking of selected basins to qualitatively determine at which point hydrology impacts occur. This assumes the percent increase in peak flow correlates well with observable flood impacts.

D. Alternatively, the percent increase of peak flow is compared to state or regional values. A certain percentile among the population or an inflection in the cumulative frequency curve is chosen as the threshold.

2.1.2.6. Hazard location delineation

A. Basin is identified as either having rain-on-snow hazard or not having rain-on-snow hazard. Further delineation will be conducted in Level II.

2.1.2.7. Hazard assessment product

2.1.2.7.1 Causal mechanism report

The report will include:

- Summary of information used in analysis
- Predicted increase in flooding for mature, existing, and future stand conditions
- Relative hydrology hazard ranking (low or high)
- Recommendations for Level II analysis.

2.1.2.7.2 Location map

A hydrology hazard map is not prepared for the Level I analysis.

2.1.3. RIPARIAN FUNCTION ASSESSMENT -- LOD LOADING

2.1.3.1 Gather necessary information and data

2.1.3.1.1 Maps

- 1:24,000 USGS topographic maps
- DNR water type maps with revisions

2.1.3.1.2 Remote assessment tools

- 1:12,000 aerial photo stereo pairs covering entire fish-bearing stream network
- Stereoscope
- Low altitude aerial video (optional)
- Stand age information for stands adjacent to riparian zone.

2.1.3.1.3 Field data

- Basal area, average tree size (DBH; 4.5 ft) and density of dominant riparian tree species, location along channel where stream bankfull width reaches 20 m.

2.1.3.2 Identify basic assumptions

- This method is designed to assess hazard situations for existing and potential LOD recruitment as an aspect of fish habitat in fish bearing waters. LOD function for sediment storage in no fish-bearing waters is not addressed.

- LOD has the greatest influence on channel geometry and fish habitat in low gradient ($\leq 3\%$) reaches with low to moderate valley bottom confinement (VBW/ACW > 1.3).

- For high gradient, confined, boulder bedrock reaches of fish-bearing streams wider than 2 m, LOD recruitment will be met under existing RMZ leave tree regulations.

- All bankslope angles are treated equally.

- The majority (> 90%) of in-channel LOD is recruited from within 50 ft of the stream (Murphy and Koski 1989).

- LOD recruitment for stream channels in excess of 20 m is adequately addressed by existing riparian leave regulations.

- All trees of sufficient size within 50' of stream are assumed to be candidates for LOD, regardless of which direction they fall (no probabalistic methods are used for level 1 [see discussion in PWI])

- For western Washington, if a riparian zone has been harvested in the past, and if trees in the riparian zone are of a noticeably larger average size than adjacent upland stands, then assume the age of the riparian stands is > 50 years.

2.1.3.3 Watershed Partitioning

- Mark upper assessment boundary at the confluence of type 3 and type 4 waters.

- Mark the lower assessment boundary where the channel exceeds 20 m and on average remains this wide or wider for the remainder of its downstream length (i.e., no reaches $\geq$ 20 channel widths have a stream width of less than 20 m or if they do they are in a confined or high gradient section). In the absence of field information, the channel width can be assumed to be > 20 m approximately 29 km from the divide.

- Delineate a 50' wide riparian assessment area on air photos. At the 1:12,000 scale, 1/10"~100 ft.

2.1.3.4 Interpretive steps

- First, identify wood response reaches. These are defined as areas where channel gradient is less than 3% (slightly higher gradient than sediment response reaches) and the valley bottom is unconfined to moderately confined. Higher gradient or confined reaches may be included where the channel width is less than 2 m.

- Second, using aerial photo paris or aerial video, identify dominant vegetation type along both sides of the stream in each response reach:

  Conifer Dominated = ≥ 70% coniferous
  Hardwood Dominated = ≥ 70% deciduous
  Mixed = all other cases

- Third, classify the average size of the dominant tree species using the following age class guidelines (from PWI):

	Age Class (years)		
Vegetation Class	Young	Mature	Old
Conifer[1]	< 40	40-120	> 120
Mixed	< 40	40-80	> 80
Deciduous[2]	< 40	40-80	> 80

[1]Based on growth characteristics of Douglas Fir in western Washington.
[2]Based on growth characteristics of Red Alder in western Washington.

- Fourth, characterize the density of the existing riparian stand along each response reach. This is simply done by identifying riparian areas that are greater than 40 years old and exhibit areas of open ground between trees. If more than 1/3 of the ground is exposed, density is characterized as inadequate. This degree of openness may need modification to accommodate eastside streams.

2.1.3.5 Decision criteria for hazard calls

2.1.3.5.1 Assumptions

- Riparian stands with average tree age less than 40 years are presently incapable of supplying adequate LOD regardless of stocking density and species.

- Riparian stands with adequate average tree size (even under existing rules) may be insufficiently stocked to provide an adequate LOD supply.

- Riparian areas presently dominated by Red Alder within 50' of the stream may be incapable of sustaining adequate LOD inputs into streams.

- Older, diverse and well stocked stands will provide sustained LOD supplies under current rules.

2.1.3.5.2 Criteria -- Hazard Calls assigned using the following table:

	Age Class & Density					
	Young		Mature		Old	
Vegetation Class	Sparse	Dense	Sparse	Dense	Sparse	Dense
Conifer	H	M	M	L	M	L
Mixed	H	H	H	L	M	L
Deciduous	H	H	H	M	H	M

2.1.3.6 Hazard areas location delineation

- Mark locations on the basemap of where LOD response reaches exhibit moderate and high hazard conditions.

2.1.3.7 Hazard assessment product

2.1.3.7.1 Causal Mechanism Report

- Loss of riparian function as a sustained supplier of LOD.

2.1.3.7.2 Location Map

- Displays hazard areas identified in subsection 2.1.3.6.

2.1.3.7.3 Probable contributing activities

- Repeated removal of large trees with successive riparian re-entry in high hazard areas.

2.1.3.7.4 Hazard calls

- ---?--- already done in 2.1.3.5

Note: This method was crafted to supplement current riparian rules in an adaptive fashion. RMZ rules were partly designed to address LOD recruitment, and in most cases will maintain or restore satisfactory riparian function as a supplier of stable in-channel LOD. However, since adoption of RMZ rules, further research and field experience indicates that in certain situations loss of existing in-channel LOD could outstrip recruitment from riparian areas and result in an upset of a stream's wood budge. Adverse declines in wood-associated fish habitat would attend this upset. This level 1 assessment seeks to identify these situations.

- Asks the question: Do riparian areas presently provide the amounts and kinds of trees of the proper age/size to supply a sustained flow of LOD to the channel now and in the future?

2.1.4. RIPARIAN FUNCTION ASSESSMENT - TEMPERATURE

The temperature assessment will assess the ability of the riparian zone to maintain acceptable water temperature through shading. The assessment will:

- Produce a temperature hazard map by delineating existing and potential areas where water temperatures exceed state mandated levels. This analysis is based on elevation, distance from watershed divide and stream shading;

- Describe each temperature mapping unit in terms of variance, from state water quality standards, and basis for temperature predictions;

- In a brief report, qualitatively discuss riparian condition, potential for future temperature impacts, and probable downstream effects; and

- Identify areas that require further analysis in Level II.

Evaluation of temperature will consist of a basin-wide evaluation of: condition (density, height, etc.) of vegetation in the riparian corridor; evaluation of canopy closure and shading from riparian vegetation; distance from the watershed divide; and, elevation.

This analysis will utilize both existing sources of information, such as aerial photographs, and results from rapid assessment techniques in the field.

2.1.4.1. Task 1 - Gather Necessary Information and Data

2.1.4.1.1. Maps

A. Base map. Obtain sub-WRIA map with basin boundary and stream network from DNR (GIS is preferred).

B. USGS topographic maps.

2.1.4.1.2. Remotely Sensed

A. Aerial photographs. Obtain most recent and a sufficient series of historical aerial photographs (1:12,000).

2.1.4.1.3. Other data

A. WA Dept. Fisheries Catalog of Washington Streams.

B. WARIS (WA Rivers Information System). This database is available through the Department of Wildlife.

C. Water quality standards for surface waters of the State of Washington (Chapter 173-201 WAC).

D. Existing data, if any, on temperature, shade, stream bankfull width, average stream depth and average riparian tree height.

2.1.4.2. Identify basic assumptions

A. Stream temperature is a reach-specific phenomenon.

B. Tributaries contributing less than 10% volume to receiving waters will not influence temperatures of those receiving waters.

C. Within 7 km of the basin divide, the influence of Type 4 and 5 waters on Type 3 temperatures persists for only 150 m downstream of the tributary confluence.

D. At elevations above 3600 ft., environmental conditions are such that streams are likely to be cool even when no shade is present.

E. Stream reaches located within 20 km of the basin divide maintain temperatures within class AA standards when provided with riparian shade.

F. Stream reaches located from 20 to 33 km of the basin divide maintain temperatures within class A standards when provided with riparian shade.

G. Riparian shade is incapable of controlling water temperatures in stream reaches located further than 33 km from the basin divide.

H. Riparian shade is incapable of maintaining stream temperature within class A standards if the channel width exceeds 30 m.

2.1.4.3. Watershed partitioning

A. Determine upper boundary for temperature assessment, either:

   1) The 3600 ft. elevation contour, if basin elevation allows, or

   2) The upper limit of fish-bearing waters (Type 3-4 transition)

B. Measure distance from basin divide along mainstem and tributaries and mark points at 7 km, 20 km and 33 km.

C. Draw lower boundary for temperature assessment at 33 km along mainstem and any major tributaries that extend this distance from divide before entering mainstem.

D. Lower assessment boundary can be moved upstream if channel width is known to exceed 30 m.

E. Use the water quality standards for surface waters (Chapter 173-201 WAC) to identify stream classifications within the assessment area. If no standard is available, use the default class of the downstream receiving waters.

2.1.4.4. Interpretive steps

A. Use elevation-shade matrix (Table 2.1.4-1) to identify target shade values for each segment of class AA, A, and B.

B. Note stream segments where state water quality classification conflicts with natural AA, A, or B achievable zones based on distance from divide (e.g., where the stream is classed as AA at a distance greater than 20 km from the divide, stream is naturally incapable of remaining within class AA standards). These stream segments are candidates for reclassification and such changes should be petitioned well in advance of any planned RMZ harvest. Level II assessment would verify stream widths in these areas to possibly override distance from divide conditions predicted on basis of distance from basin divide.

C. Use aerial photos to identify stream segments that may be anomalously wide relative to their position within the drainage (distance from divide). These areas are candidates for Level II investigations to verify widths and to estimate effective shading and influence on downstream temperatures.

TABLE 2.1.4-1

Shade-elevation matrix to identify target minimum shade values for sections of streams in Level I Watershed Analysis. Class B streams are not shown owing to the fact that the elevations of streams in this category are relatively low and hence shade will not be effective in controlling stream temperatures to within state water quality standards.

MINIMUM SHADE CATEGORY (%)	ELEVATION ZONES CLASS AA	CLASS A
< 10	NA	NA
10-20	3280-3600	1960-2320
20-30	2960-3280	1640-1960
30-40	2400-2960	1320-1640
40-50	1960-2400	1000-1320
50-60	1640-1960	680-1000
60-70	1160-1640	440-680
70-80	680-1160	120-440
80-90	320-680	120
> 90	NA	NA

The following is a revision to streamline the method while being conservative on the side of extra shade. Necessary shade levels of 30% or less are grouped into one elevation zone, as are shade levels from 30-50%.

TARGET MINIMUM SHADE CATEGORY (%)	ELEVATION ZONES CLASS AA	CLASS A
0-30	2960-3600	1640-2320
30-50	1960-2960	1000-1640
50-60	1640-1960	680-1000
60-70	1160-1640	440-680
70-80	680-1160	120-440
80-90	320-680	120
> 90	NA	NA

D. Hazard areas are found where field spot checks or aerial photograph interpretation in a given target zone show shade to be below minimum levels required to meet water quality standards.

2.1.4.5. Decision criteria for hazard calls

2.1.4.5.1. Assumptions

A. When riparian shade levels in a target zone are below target minimums, water quality standards will be violated and fish will suffer decreased growth and survival.

B. In a particular temperature target zone, a length of stream at least 305 m (1000 ft) with low shade values is needed to raise stream temperatures and violate water quality regulations.

C. No "moderate" hazard conditions for temperature are defined for Level I.

D. "Indeterminate" hazard calls are made for areas needing field verifications for width and existing or predicted maximum shade values (e.g., anomalous reaches or areas where water quality classifications and natural achievable maximum temperatures conflict).

E. "Low" hazard calls apply to all other stream reaches.

2.1.4.5.2. Criteria

A. High temperature hazards occur when riparian shading, averaged over the target zone, is less than the minimum required to meet water quality standards.

B. An alternative to the target zone shade average would be a reach of stream length ___ m in fish-bearing waters, where the critical length has to be defined - suggested value = that length of under-shaded stream sufficient to raise maximum stream temperatures either:

1) above water quality standards, or
2) more than 1-2° C or some other biologically significant amount.

2.1.4.6. Hazard areas location delineation

A. Prepare an acetate overlay for use with the base (stream network) map for the basin.

B. On overlay, delineate upper and lower boundaries of assessment area, water quality classifications for each stream reach, and temperature regime or channel width if known.

C. On overlay, delineate areas that satisfy decision criteria for hazard calls. Number each such "hazard" and prepare a written summary describing hazard, basis for identification, and any uncertainties associated with the analysis.

1) Indeterminate hazard zones are also mapped.

2) Low hazard zones are not mapped.

2.1.4.7. Hazard assessment product

2.1.4.7.1 Causal mechanism report

A. Causal mechanism for this temperature pathway is loss of riparian shade. Report will summarize riparian conditions in assessment area and basis for all hazard calls.

2.1.4.7.2 Location map

A. Work product from Task 2.1.4.6.

2.1.4.7.3 Probable contributing activities

A. Removal of riparian shade trees. Some riparian harvest may be possible without reducing net shade levels, but this must be investigated.

2.1.4.7.4 Hazard calls

A. Areas marked under subsection 2.1.4.7.2 and associated written summaries identify hazard calls for particular stream segments.

3.0 RESOURCE VULNERABILITY ASSESSMENT

3.0.1 Overview

The resource vulnerability assessment identifies portions of the stream network that might show responses to upslope processes identified in the hazard analysis. Certain of these areas that contain fish or have other public resource value are selected as risk indicator areas. Channel condition and the types and quality of fish habitat present in these indicator areas are then determined. Areas with degraded resource conditions are mapped and recorded and form the basis for determining current resource vulnerability. Specific work products include:

- A base map indicating the stream network in the basin.
- A fish distribution map showing the known or expected distributions of anadromous and resident salmonids in each basin.
- Maps of potential response areas and selected risk indicator areas.
- Maps of channel condition and habitat type/quality at risk indicator areas.
- Written summaries describing the data and decisions used in the mapping process.
- A report describing existing resources in the risk indicator areas and the degree to which these resources have been impacted by watershed hazards.
- A discussion of the uncertainties that require Level II analysis for resolution.

3.1. Gather Necessary Information and Data

Evaluation of fish habitat will require four types of data collection and analysis. First, existing documents on fish distribution and abundance, habitat types and habitat quality must be reviewed. Second, several types of GIS and remotely sensed data must be analyzed to determine channel and habitat condition and to assist in map preparation. Third, watershed managers, fish biologists, and other individuals with a personal familiarity of the basin under study, must be contacted and interviewed. Finally, results from the public resource assessment must be reviewed and incorporated into the vulnerability analysis.

3.1.1 Data on Fish Distributions

A. WA Dept. Fisheries Catalog of Washington Streams. These stream catalogs (two volumes) cover streams and rivers flowing into Puget Sound or the Pacific Ocean. They include several types of information including: distributions of the five Pacific salmon species; the location of fish migration barriers; summer and winter channel widths; stream substrate characteristics; the location and type of beneficial developments including hatcheries, fish passage facilities and habitat improvements; and river mileages and stream lengths.

B. WARIS (WA Rivers Information System). This database is available through the Department of Wildlife. WARIS contains data on the distribution of anadromous and resident fishes, spawning, rearing and migration areas, and threatened and endangered species. The amount and quality of information available varies among basins.

C. Natural Heritage Program, Dept. of Natural Resources. The Natural Heritage Program can provide definitive information of the presence/absence and location of sensitive/threatened/endangered species in the study area.

3.1.2 Maps

A. USGS 7.5' Topographic Maps. These maps can be used to delineate stream networks, identify stream order, determine slopes, etc.

B. Dept. of Natural Resources ARC-INFO maps. Two "coverages" from this GIS based system are of interest. The stream network coverage can be used to confirm the stream networks identified on the USGS maps. The land use/land cover coverage can be used to determine the type of riparian vegetation present (e.g., forest, agricultural, etc.) and the types of inputs likely to enter the stream from adjacent upland areas (e.g., sediment and fertilizer from agricultural areas).

3.1.3 Remotely Sensed Data

A. Aerial photographs. Where available, ortho-photographs (distortion adjusted) are preferred. If possible, obtain several sets of photographs taken over a period of decades. These photographs can be used to determine some or all of the following: the condition and type of riparian vegetation present; channel braiding and meandering; active landslides or eroding banks; pool/riffle distribution; quantity and location of large organic debris; and major obstructions to fish passage.

3.1.4 Interviews

A. Interviews. Determine the regional biologist(s) of the Departments of Wildlife and/or Fisheries with responsibility for the basin of concern.

Similarly, contact local landowners and watershed managers. Interview these individuals to obtain information on fisheries resources, habitat availability and condition., land use, riparian zone and channel condition, fish passage barriers, etc.

3.1.5 Public Resource Assessment Results

A. Public resource assessment results. Output from this assessment should include a map locating significant public resources within the basin, as well as some description of what the resources are and why they are important.

3.2 Identify Potential Response Segments

A. Construct a base map showing the stream network for the basin. If available, DNR's stream network coverage can be used for this task.

B. Review the hazard analysis to determine which processes are operating in the basin (e.g., shallow landslides, rain on snow, etc.).

C. For each active process, identify the portion of the stream network that could show a response to the resulting disturbance. For example, if sediment inputs from shallow landslides were an important hazard in a watershed, then low gradient, unconstrained portions of the stream network downstream of this watershed could be a potential response area for sediment input. Screening criteria for selecting response areas for each process are outlined in Table XX3 (under development).

D. Using an acetate overlay placed over the base map, locate and mark portions of the stream network to map the information from C above. For example, areas thought to be sensitive to sediment inputs from shallow landslides could be marked in solid red, areas sensitive to deep-seated landslides marked in striped red, etc. Number each component of the database as it is mapped. On a separate summary, list the number of the mapped unit, the basis for mapping the unit, and any additional information available (e.g., certainty level).

3.3 Identify Resource Use

A. Review data on fish distributions, including data obtained through interviews. Identify both the distribution of individual species and the habitat use for those species (e.g, spawning, rearing, etc.). Be sure to identify the location and type of any fish passage barriers. These could include falls, log jams, dams, etc. The WDF stream catalog contains an extensive, though dated, listing of fish passage barriers. Fish passage barriers can be used to map the upstream limits of anadromous populations.

B. Review data from the public resource assessment. Identify the location, type and value of each resource utilized by the public.

C. Using acetate overlays placed over the base map, locate and mark portions of the stream network to map the information from A and B above. Number each component of the database as it is mapped. On a separate summary, list the number of the mapped unit, the source of the information, and any additional information available (e.g., age of data, confidence, etc.).

3.4 Select Risk Indicator Areas

A. Combine the overlays of potential response areas, fish distribution and public resource use.

B. Identify areas where potential response and fish distribution or resource use overlap ("overlap areas"). Map these overlap areas separately on an acetate overlay.

C. Select individual sections ("risk indicator areas") of the overlap areas for further study. Map and number these indicator areas. Prepare a written summary explaining the basis for selecting each indicator area. Use the following guidelines when selecting areas :

1) Any unique overlap area (i.e., any unique combination of response and fish or public resource use) is automatically selected for further analysis.

2) Overlap areas with a limited distribution must be carefully reviewed. To the extent that overlap areas of a given type are found in close proximity to one another or in the same elevation band, drainage, etc., a subsample of sites can be selected and the results extrapolated to other areas. When overlap areas diverge in location or physiographic regime, then each area must be identified as a risk indicator area and studied individually.

3) For overlap areas that are widely distributed, use the same process as in 2 above to select risk indicator areas. The goal is to ensure that both major drainage units (e.g., major tributaries) and stream types (e.g., headwaters, mainstem rivers, etc.) are selected for further analysis.

3.5 Assess Current Channel Condition

A. This review is aimed at detecting geomorphic changes in channel condition related to upslope processes active in the basin. For each risk indicator area, review available data relating to the variables identified in Table XX4 (under development). Because the availability of information will vary with basin, some response variables might not be identifiable in a Level I analysis. In general, however, several types of analysis should be conducted:

1) Identify the slope and valley width of individual stream reaches using USGS topographic maps.

2) Identify any landslides or eroding banks that are delivering sediment directly to the channel.

3) Determine if the stream channel is excessively sedimented. Visual cues include wide, shallow channels and channel braiding.

4) Identify and map the type and condition of vegetation in the riparian corridor in the risk indicator areas. Is there evidence of damage from flooding, etc. The ability to conduct tasks 2-4 will depend on the availability of aerial photographs and the extent to which the stream channel is visible in these photos.

B. For each risk indicator area, determine the extent that channel conditions indicate a response to the watershed processes identified in the hazard analysis. Assign each response a unique number. List them on the risk indicator area map, and on a separate summary list the number, a description of the response, the basis for concluding a response was present and any additional information (e.g., uncertainty).

3.6 Assess Current Fish Habitat Condition

A. This review is aimed at determining the types and quality of fish habitat present at each risk indicator area. As with the review of channel condition, the availability of information for each basin will determine the types of analyses that can be conducted. Types of analysis could include:

1) Identify the types of stream habitat expected given the slope and valley width identified in task 3.5. The classification scheme outlined in Table XX (under development) can be used as a reference.

2) Review the riparian vegetation analysis in task 3.5. Use the classification scheme in Table XX5 (under development) to identify likely impacts on habitat type/quality.

3) Review the WDF stream catalog and aerial photos to identify specific habitat types. For example, aerial photography may allow assessment of in-channel LOD, pool/riffle ratios, etc.

3.7 Identify Resource Condition Indicators

A. Identify the fish species found within the risk indicator areas by reviewing the fish distribution map prepared in task 3.3.

B. Determine the resource condition indicators and values that apply to each species identified.

C. Determine the values of the selected resource condition indicators.

[These indicators (also known at "threshold parameters") are being developed by Phil Peterson of the University of Washington, under contract to T/F/W. Until the indicators are defined and values selected to indicate habitat quality, it is not possible to define methods for their measurement.]

3.8 Resource Vulnerability Assessment Product

A. Maps

1) Base map

2) Potential response areas

3) Fish distribution

4) Overlap and risk indicator areas

5) Channel condition at risk indicator areas

6) Fish habitat types/quality at risk indicator areas

B. Written summaries

1) Explanation/justification for each potential response area

2) Explanation and data sources for mapped fish distributions

3) Basis for selecting risk indicator areas

4) Explanation/justification for channel response mapping

5) Explanation and data sources for fish habitat mapping

C. Response Report

1) Description of resource conditions and degree affected by watershed hazards

2) Comparison of available habitat types to those required by fish found in basin

3) Rating of habitat quality using values for the observed resource condition indicators

4) Discussion of uncertainty, assumptions, areas requiring further work in a Level II analysis