TIMBER - FISH - WILDLIFE PROJECT

Level 1 and Level 2
Cumulative Effects Analysis Methods

Summary Report
and
Draft Methods Manual

Submitted to:

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

Prepared by:

EA Engineering Science and Technology
Northwest Operations
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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 1" 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. Individual components of the Level 1 analysis can include some fieldwork or the use of more highly trained individuals if necessary to make initial assessments. The target level of effort for Level 1 is 4-5 person-weeks for 30,000 - 60,000 acre watersheds.

- "Level 2" 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 2 can be used both to verify results from, and resolve uncertainties related to, Level 1 studies. Level 2 studies are expected to require 16-24 person-weeks to complete (30,000 - 60,000 acre watersheds).

Level 1 documents a basic understanding of hazards, processes and risks in the watershed using mostly remote sensing data (i.e., aerial photographs and maps). Level 1 also identifies specific processes that require further analysis using Level 2 methods. Level 2 involves detailed analysis of the dominant processes identified in Level 1. It is expected that certain watersheds will not require a Level 2 analysis if cumulative effects (based on a relative ranking of hazard and resource vulnerability both locally and downstream) are determined to be low in the Level 1 analysis. In this sense, Level 1 is a screening analysis.

In December 1991, the Pacific Watershed Institute (PWI) published "Prototype Watershed Analysis". This document outlined a Level 1 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 2 methodology to complement the Level 1 methodology proposed by PWI.

EA, DNR and TFW agreed in January 1992 that the Level 1 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 1 methodology.

This report summarizes the status of the Level 1 and Level 2 methods being developed by EA as of 28 February 1992. In addition, a draft methods manual to conduct these analyses is presented. The general discussion focuses on the specific steps that comprise these methodologies as outlined in a series of flow charts prepared by TFW. The methods manual provides specific instructions on the methods and lists the decision criteria used to complete each step.

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 often this specificity makes such 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 DNR and TFW's desire for a generalized, broadly applicable, defensible and repeatable methodology suitable for forested ecosystems across the state. Therefore, a new methodology must be developed to achieve these goals. This 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;

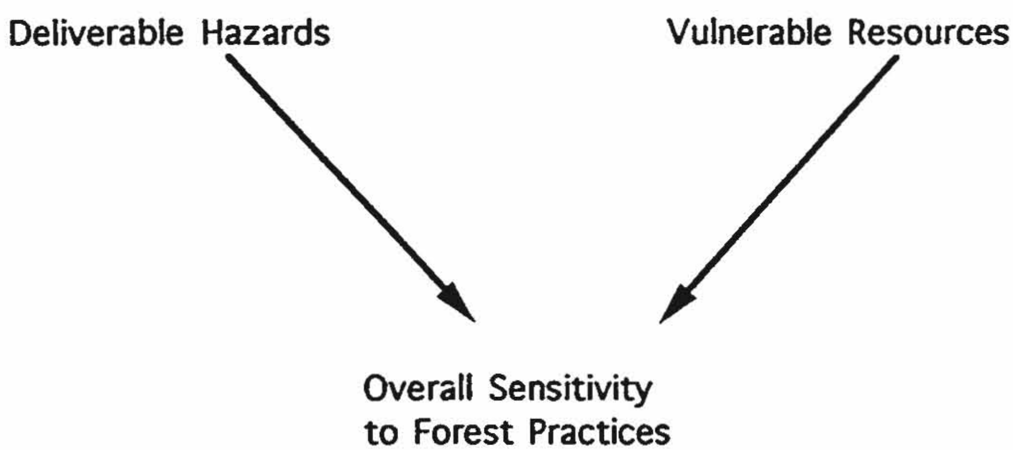
- discuss (qualitatively or quantitatively) how forest practices contributed to the occurrence of hazards and vulnerable resources, and what actions are predicted to mitigate vulnerability. Hazard is defined in this document as changes in the production of sediment, runoff or riparian function. Vulnerability is defined as impact or the potential for 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 usable by forest managers for developing forest practice prescriptions or other planning activities.

The CE methodology envisioned by DNR and TFW can be divided into two major components (Figure 1). First, analyses are conducted to determine if forest practices have now or could in the future lead to delivery of sediment and water to streams or to changes in the functions of the riparian zone. Second, fish habitat and geomorphic channel parameters are examined to determine existing conditions and the susceptibility of the streams to future impacts. When deliverable hazards are combined with resource vulnerability, decisions can be made regarding how sensitive the watershed is to forest practices. This sensitivity, in turn, can help in the process of selecting management prescriptions for the basin.

Figure 1



For example, a cumulative effects analysis of a hypothetical watershed might lead to the following conclusions:

1. Surface erosion of logging roads is occurring.

2. Fine sediment from this erosion is being carried to streams.

3. Salmonids are present in these streams.

4. The levels of fine sediment in spawning gravels within the streams are higher than desirable for successful egg incubation.

Referring again to Figure 1, conclusions in 1 and 2 are generated by the analysis of deliverable hazards, and information in 3 and 4 is from the assessment of resource vulnerability. Collectively, 1-4 indicate that forest practice activities (road construction) may be impacting public resources (fish) by contributing materials (fine sediment) that negatively affect stream conditions (percent fine sediment in spawning gravels).

To progress beyond this general approach, several decisions must be made concerning the scope of the cumulative effects methodology to be developed. 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 will be considered. 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 1 and Level 2 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 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, and alteration of baseflow discharge; and

  - riparian function: large organic debris (LOD) recruitment and shading/temperature.

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

  - anadromous and resident fish populations;
  - domestic, hatchery and irrigation water supplies;
  - public capital improvements (roads, bridges, etc.); and
  - channel condition, water quality and fish habitat.

Unfortunately, a good deal of scientific uncertainty is still associated with watershed analysis. The complexity of natural processes, current level of knowledge on what controls these processes and amount of available site data led to the following simplifying assumptions which presently limit the scope and detail of the cumulative effects analysis:

- Existing cumulative effects that are observable in watersheds are the result of the current state of forest management; therefore, current conditions must be used to quantify watershed hazard levels and reduction in hazards will lead to reductions in the impacts to stream resources.

- 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 vulnerabilities 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.

In defining the approach and scope of the CE analysis, another area concerns the level of certainty to be associated with the methods. Certainty, as used here, is a measure of how confident one is that a given conclusion is correct. TFW has defined four levels of certainty for the CE analysis:

C0: Less than a 50 percent certainty that a conclusion is correct

C1: A greater than 50 percent level of certainty - "more likely than not"

C2: A greater than 80 percent level of certainty - "very likely"

C3: 95 percent or greater level of certainty - "scientist's certainty"

Methods with increasing levels of certainty generally require increased amounts of time, money and field work but yield results with fewer assumptions and higher accuracy and resolution. Neither C0 or C3 level methods are included in the CE methodology presented here. C0 level methods have been excluded because this level of certainty is considered insufficient for making decisions on cumulative effects. C3 level methods have been excluded because the time, money and staff resources required are greater than those outlined for Level 1 and Level 2 studies. Although C0 level methods are likely to remain unacceptable, C3 level methods may be incorporated into the CE methodology in the future if a need for this level of certainty can be demonstrated.

Currently, the Level 1 methods presented here are consistent with a C1 level of certainty, and Level 2 are consistent with C2. This is due, in part, to the similarity in the data needs and resource expenditures of Level 1 studies compared to methods with a C1 level of certainty. However, it is also due, in part, to a desire to keep the relationship between analysis levels and certainty levels simple at this time. As the methods presented here are developed further, Level 1 and Level 2 analyses may include methods with more than one certainty level depending on the needs of the analysis teams and on the availability and quality of watershed data.

The remainder of this document discusses the details of the Level 1 and Level 2 methodologies. First, the basic structure of the methodologies is summarized by reviewing flow charts prepared by TFW. Subsequent chapters discuss the specific work items to be conducted at each step of these flow charts. This discussion is presented in a method manual format. The work items are discussed separately by subject (e.g, hydrology, erosion, etc.) where appropriate.

OVERALL STRUCTURE OF LEVEL 1 AND LEVEL 2 ANALYSES

Figures 2-7 outline the structure of the analyses that comprise the Level 1 and Level 2 methodologies. Figure 2 is an overview of the entire process, whereas Figures 3-7 detail the steps related to each of the major tasks outlined in Figure 2. These figures were developed by the Cumulative Effects Steering Committee of TFW and by EA.

Figure 2 shows the overall approach to be used for the analysis of cumulative effects. Six major tasks are numbered and identified in this diagram. A summary of the watershed processes and public resources examined as part of these tasks was presented in the introduction. Hazard assessment (#1 in Figure 2) is the identification of the significant hydrology, erosion and riparian function related processes operating in the watershed being analyzed. The resource condition assessment (#2) determines the public resources present within a watershed, selects the portion of the stream network that may respond to hazards and identifies the channel, water quality and fish habitat conditions in these areas. Deliverability assessment (#3) determines the extent to which identified hazards actually transport materials (sediment, water, etc.) to stream reaches within the basin. The resource vulnerability assessment (#4) examines existing conditions within streams and the potential for changes in these conditions to determine the susceptibility of resources to hazard related impacts. Sensitivity assessment (#5) combines the vulnerability of the stream resources with expected delivery of materials from upslope hazards to estimate the magnitude and types of cumulative effects impacts present or potentially present in the watershed. 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 3 outlines the hazard assessment process. Hazard assessments are 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. Identification of hazard areas (step 1.5) is the process of applying decision criteria to identify portions of the watershed producing hazards. Potential contributing activities (step 1.6) involves determining the extent to which current (or future) forest

Figure 2

Watershed Resource Assessment Process

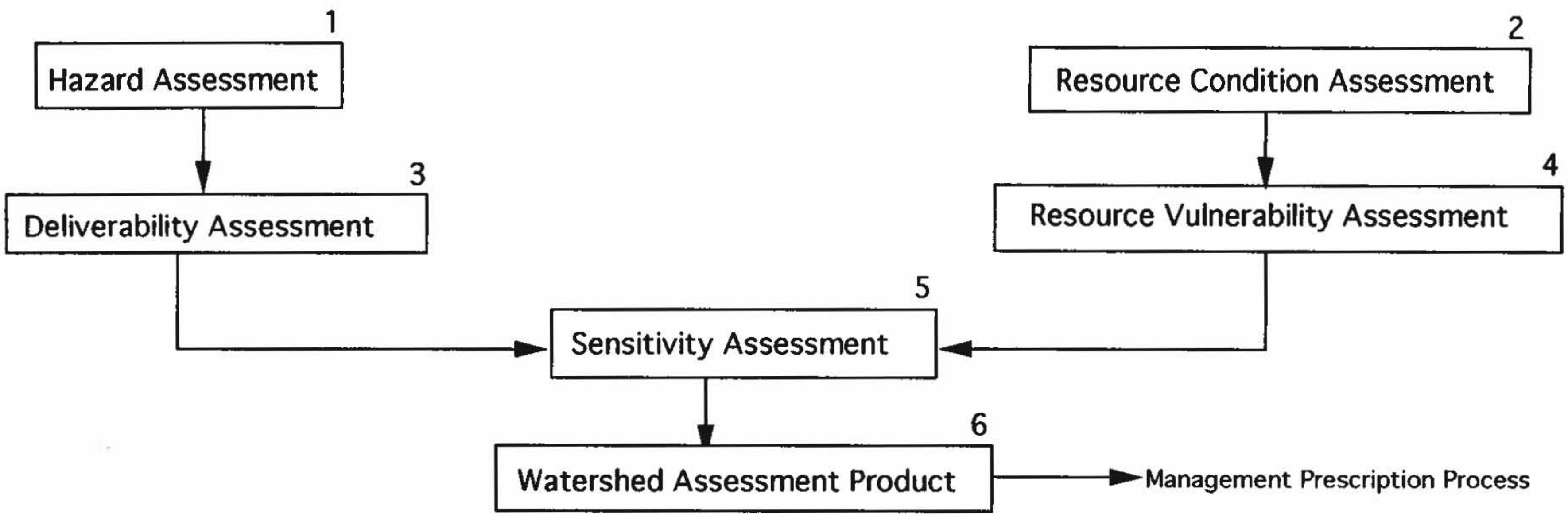
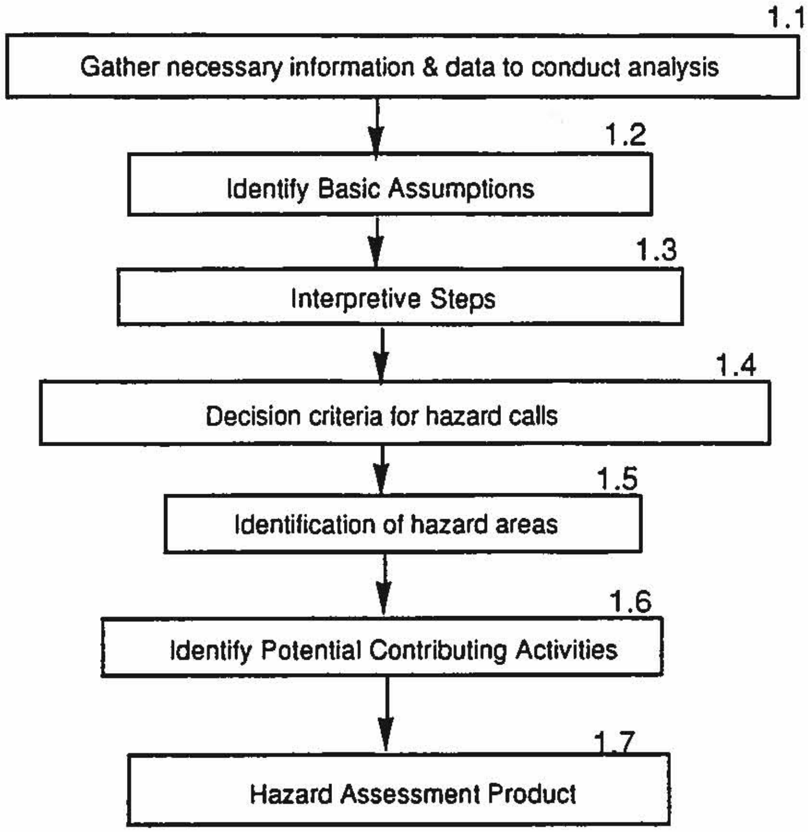


Figure 3

Hazard Assessment Process



Construct separate methods for

- ***Erosion***
- ***Hydrology***
- ***Riparian Function***

practices actions are (could be) responsible for the identified hazards. Finally, the hazard assessment product (Step 1.7) 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 hazards; and, a discussion of the cause-effect relationships between watershed processes and hazards.

Figure 4 details the resource condition assessment process. As with the previous assessments, the first step is to gather information necessary to conduct the assessment (step 2.1). Using information from the initial assessment of watershed hazards, certain areas ("potential response segments") with potential to be impacted by hazard are identified (step 2.2). The distribution of public resources in the basin is then determined (step 2.3). A number of risk indicator areas are then chosen for further study from areas within the potential response segments where public resources are present (step 2.4). Channel condition, the types/quality of fish habitat, water quality conditions and the values for resource condition indicators are then assessed within these risk indicator areas (steps 2.5, 2.6, 2.7 and 2.8, 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 condition assessment product (step 2.9) summarizes the results of the assessment. Final products from the condition assessment include: maps identifying the locations of response areas, descriptions of the channel, water quality and fish habitat conditions within the basin and the decisions used to identify them; and, a rating of habitat quality using observed values for the resource condition indicators.

Figure 5 outlines the deliverability assessment process. 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 streams within the basin. Interpretive steps (step 3.1) involve identifying and using methods to determine actual/potential deliverability of materials from hazard areas to downstream reaches. Decision criteria (step 3.2) are the standards used to decide if a given level/type of deliverability constitutes a significant input to the stream systems. Deliverability mapping (step 3.3) involves mapping hazards with significant deliverability. This mapping must identify the risk indicator areas affected, or potentially affected, by delivered hazards.

Figure 4

Resource Condition Assessment Process

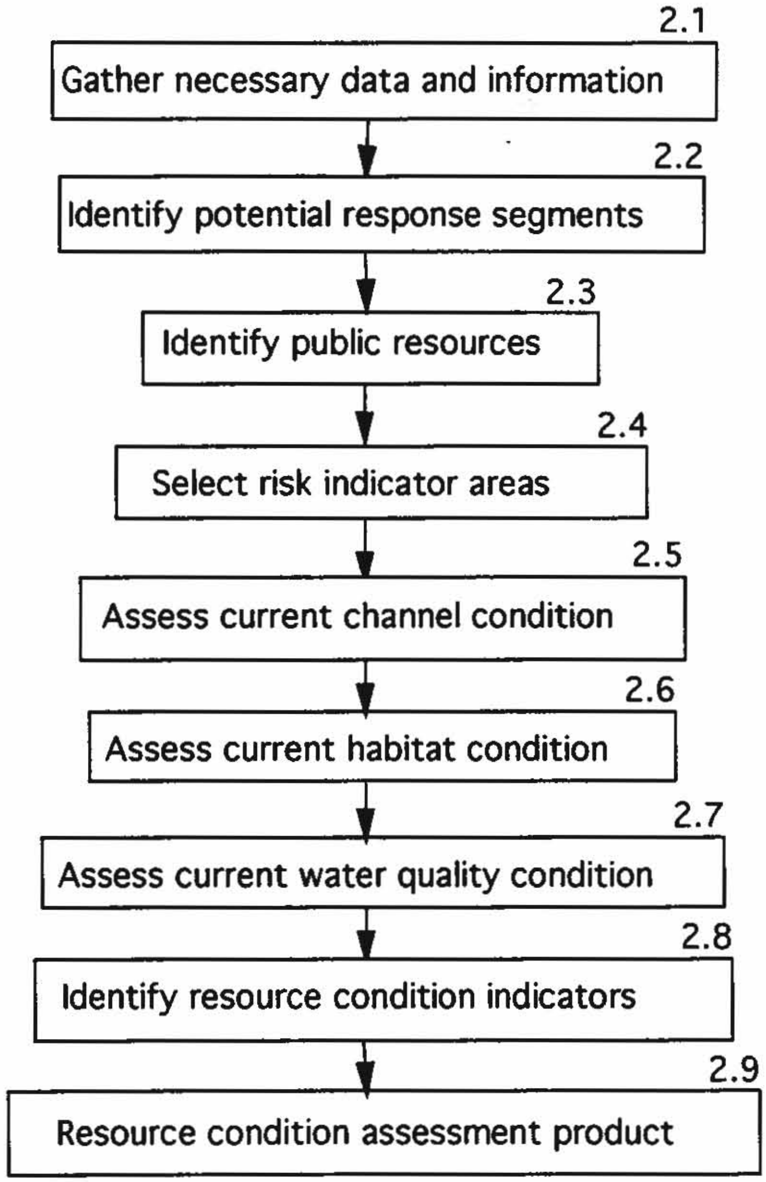
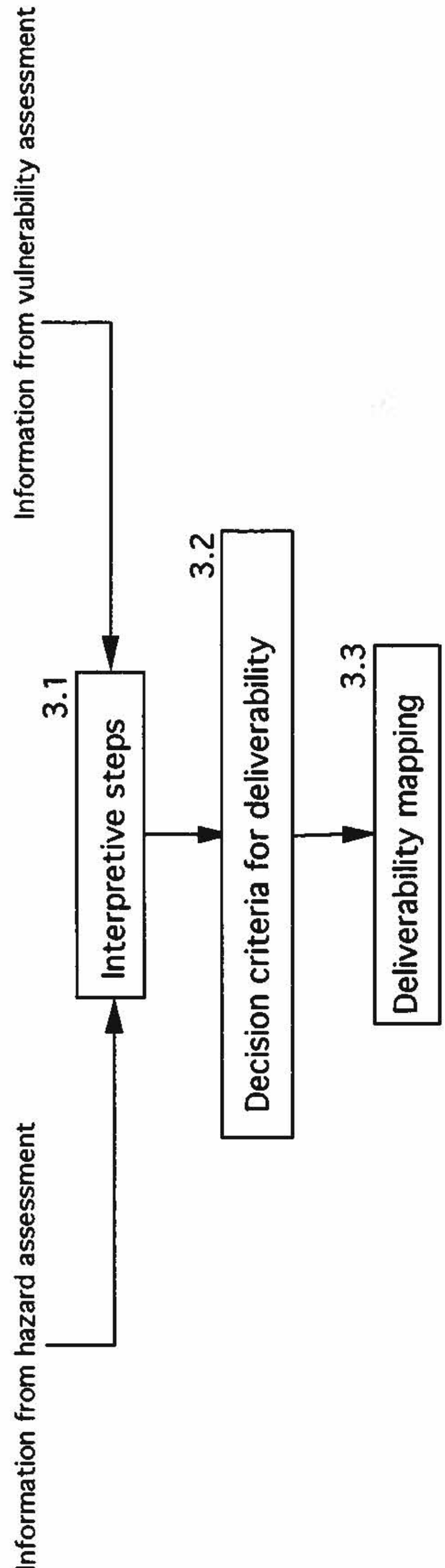


Figure 5

Deliverability Assessment Process



The resource vulnerability assessment process is outlined in Figure 6. First, channel and habitat data are reviewed to determine the likelihood that existing conditions will change in the future (Step 4.1). Interpretative steps (step 4.2) are then used to combine existing conditions and the likelihood of future change into a measure of resource vulnerability to each hazard type. Vulnerabilities to individual hazards (e.g., sediment, water, etc.) are then combined to determine overall resource vulnerability (step 4.3). The channel integration product (step 4.4) includes a map showing resource vulnerabilities in the watershed, a summary of the decision making process, and a discussion of any uncertainties or assumptions in the analysis.

Figure 7 summarizes the steps to conduct the sensitivity assessment process. 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).

The watershed assessment product (#8 of Figure 1), the last component of the Level 1 and Level 2 cumulative effects analyses, 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

RESOURCE VULNERABILITY ASSESSMENT PROCESS

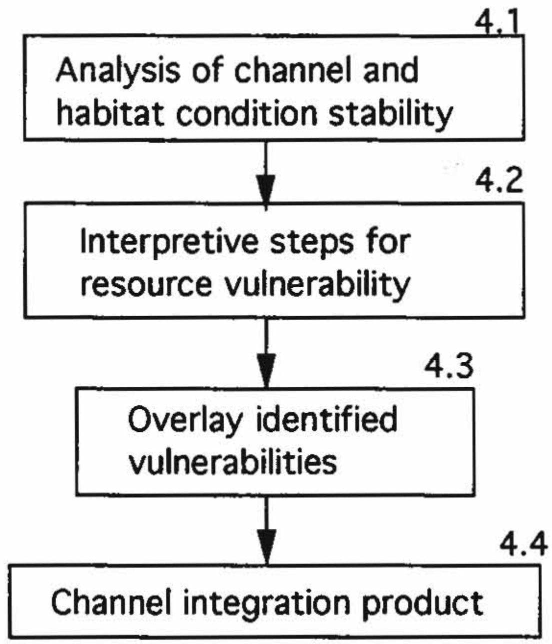
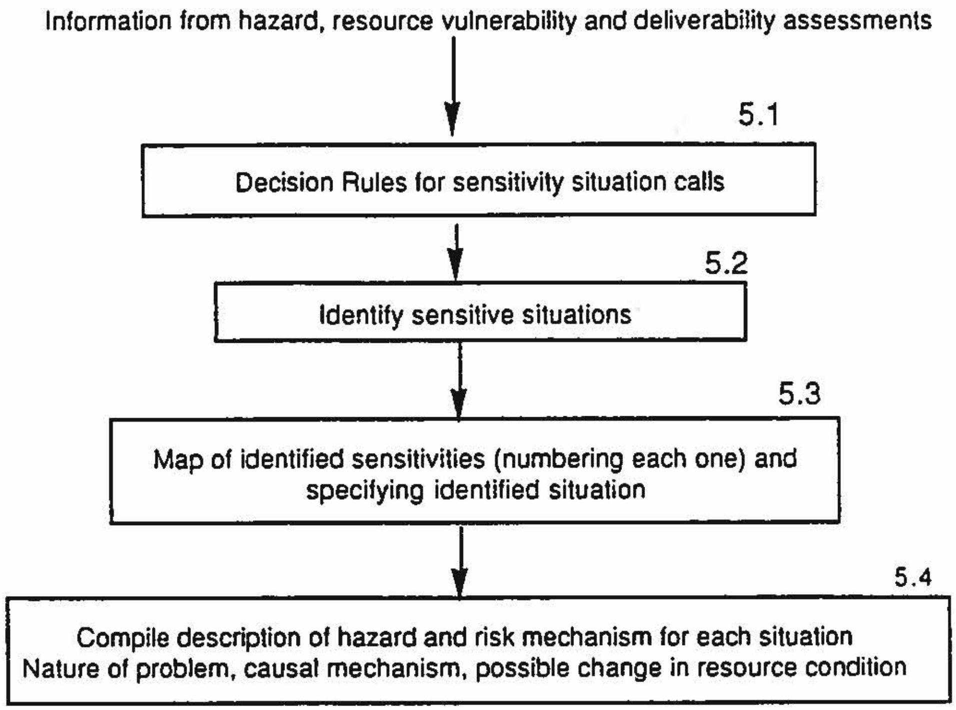


Figure 7

Sensitivity Assessment Process



1. HAZARD ASSESSMENT

The following sections discuss the proposed approach to conducting hazard assessments. Hazard assessments will be performed following the generalized task sequence shown in Figure 3 for the following process groups:

- erosion, including mass wasting and surface erosion;
- hydrology, including peak flow events, low flow and annual water yield; and
- riparian function, including large organic debris (LOD) recruitment and temperature/shading.

General discussions of the hazard assessments are provided below for both Level 1 and Level 2 analyses. Each discussion includes an overview of the methods followed by descriptions of specific method procedures. Decision criteria are also provided when available. Procedures will be refined during the testing period and will be documented in detail in the final methods manual.

At this time, several of the proposed Level 1 and Level 2 methods are only at the conceptual 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. In these cases, interim methods are presented and refinement of these methods will occur during the method testing period. It is expected that the interim methods will either be found to be acceptable in a watershed analysis framework, or will be replaced by other methods that are subsequently determined to be more appropriate. Analysis of certain processes will have to be deferred until adequate methods are available.

1.1 Erosion

1.1.1 Introduction

The erosion hazard assessment evaluates the two primary erosion processes, mass wasting and surface erosion, to determine relative, qualitative hazard ratings for specific areas within the watershed administrative unit (WAU). These two erosion processes will be evaluated independently in both Level 1 and Level 2 assessments.

1.1.2 Definitions

The published literature uses many different terminologies to describe erosion processes. For the purposes of standardizing these terms in the watershed assessment process, definitions of these terms and the specific processes to which they refer are provided below. The following discussion is modified from Pentec (1991). For more background and literature review information on mass wasting, see PWI (1991), Pentec (1991), and MacDonald and Ritland (1989).

Shallow-rapid landslide

Shallow-rapid landslides, or landslides, are a common landscape process from northern California to Alaska and involve the rapid failure of soil and weathered bedrock, typically to a depth of about 1 to 2 meters. Soil thickness is shallow compared to slope length or length of the landslide.

Shallow-rapid landslides are generally triggered by the build up of soil water in response to storms or rain-and-snowmelt events. Rapid refers to the speed at which the landslide debris moves downslope, often breaking apart and developing into a debris flow. Shallow-rapid landslides are often localized in converging bedrock topography (known as bedrock hollows, swales, or zero-order basins), which is characterized by thicker saturated layers and hence greater instability. Shallow-rapid landslides are also termed landslides, debris avalanches, and planar failures.

Debris flow

A debris flow is a highly mobile slurry of soil, rock, vegetation, and water that can travel many kilometers from its point of initiation. Debris flows are generally confined to steep, first-and second-order channels. Debris flows are initiated by liquefaction of landslide material, either concurrent with failure or immediately thereafter, as the soil mass and reinforcing roots break up. Debris flows contain 70 to 80 percent solids and only 20 to 30 percent water. Entrainment of additional sediment and organic debris in first-and second-order channels (Type 4 and 5 Waters) can increase the volume of the original landslide by 1,000 percent or more, enabling debris flows to become more destructive as their volume increases with distance travelled. Debris flows deposit in low-gradient channels and valley floors (Type 1 through 3 Streams).

Debris flows can deposit sediment in streams and affect fish habitat several kilometers from the initiating landslide (Swanson et al., 1987) and therefore are one of the more destructive forms of mass movement in forested watersheds (Eisbacher and Clague, 1984). Debris flows are also termed debris torrents, sluice outs, and mud flows.

Dam break flood

A dam break flood is a feature similar to a debris flow but is caused by the failure of a temporary sediment and organic-debris dam within a narrow valley floor or canyon. Water and debris, rather than a mud slurry, forms the destructive power of these features. These dams are formed from deposits of landslides and debris flows. When these dams break, the flooding destroys riparian vegetation and causes significant erosion and sedimentation along entire lengths of stream-order segments (Benda and Zhang, 1989). In the Pacific Northwest, debris flows and dam-break floods have often been referred to as debris torrents. Dam-break floods are also termed debris torrents and sluice outs.

Undifferentiated debris torrent

When debris flows and dam-break floods cannot be differentiated, either because of poor resolution of aerial photographs or inconclusive evidence in the field, these two processes are lumped together as undifferentiated debris torrents, or debris torrents.

Slump-earthflow

Slump-earthflows, or deep seated failures, are failures normally associated with specific geologic structures or lithologic soil units. The term slump-earthflow is used in the Northwest because many features have slump characteristics in the headwall area and develop earthflow characteristics downslope (Swanston and Swanson, 1976).

Slump-earthflows can initiate on slopes as gentle as 4 to 20 degrees (Sidle, 1980). In Washington they occur in altered sedimentary and volcaniclastic rocks and glacial sediments of the western Cascades, Olympics, and coastal ranges. Sites have also been identified and studied in the drier eastern Cascades (Swanston, 1981; Fiksdal and Brunengo in NCASI, 1985). The plane of failure is generally at least several meters below the ground surface. Slumping is the downward and backward rotation of a soil block or group of blocks. The main head scarp is often steep and generally bare of vegetation, and the toe is hummocky or broken by individual slump blocks.

Slumps are deep rotational failures, typically triggered by the build up of pore water pressure in mechanically weak and often clay-rich rocks (Swanston, 1974). Earthflows move through a combination of slumping and slow flow; they can remain active for thousands of years with periods of activity and dormancy (Swanson et al., 1987). Earthflows typically occupy a much larger portion of the landscape and move larger amounts of soil than do slumps. The toe of an earthflow is typically lobate and hummocky.

Surface erosion

Surface erosion refers to erosion of exposed mineral soils by rainsplash, sheetwash, rilling, gulleying, and dry ravel. Surface erosion in managed forests occurs on roads and adjacent margins (e.g., cut banks and fill slopes), recent landslide and debris flow scars, and disturbed soils within harvest units. Harvest unit erosion includes sediment generated from direct logging methods, skid roads, yarding, and slash burning.

The texture of sediment generated from surface erosion processes is typically fine, but is largely influenced by the geologic parent material. Texture of surface erosion particles largely determines how far material can transport on slopes, thereby determining sediment delivery, and how it behaves once it enters the stream (i.e., whether it deposits in the channel or flushes through as suspended sediment or washload). Because of this, soil erodibility classifications are typically based on soil texture. Soil erodibility is also largely influenced by cohesion, with coarse, cohesionless soils typically the most problematic because of their tendency to ravel continuously.

1.1A Mass Wasting

Erosion of soils by mass wasting is widely recognized as a dominant process in Washington, particularly west of the Cascade crest. The resulting quantity of sediment delivered to streams by landslides can be many times greater than that delivered by other erosion processes. Variations in geology, climate, and land use can result in large regional differences in the relative dominance of these processes. For example, sediment budgets have indicated that mass wasting accounted for as much as 95 percent of delivered sediment in the steep and wet terrain of the northern Cascades of Washington (Eide, 1990). By contrast mass wasting in the dryer, granitic terrain of the Idaho Batholith (which may be applicable to certain areas of Washington) accounts for only 19 to 23 percent of the sediment production (Megahan 1982, Megahan 1986). Relative magnitudes of sediment generation between the different types of mass wasting can also be quite large. For example, a single, large deep-seated earthflow may produce as much sediment as numerous shallow landslides. The erosion assessment methodologies must distinguish between these different processes, not only to aid in defining erosion hazard areas, but also, ultimately, to assist in selecting forest management prescriptions that can mitigate specific mass wasting hazards.

The Level 1 method for mass wasting erosion assessment is designed to identify the incidence of mass wasting, the location of hazard areas in the WAU, and the likelihood of sediment delivery to streams from each of the hazard areas.

Summary of Methods - Level 1

The Level 1 mass wasting erosion hazard assessment consists of erosion mapping, landform mapping and extrapolation to identify mass wasting sources and thereby determine *if* and *where* erosion *problems* exist. Mass wasting *problems* are identified as erosion mapping units that describe associated geomorphic, geologic, and land use characteristics. This assessment results in qualitatively-determined low, medium and high mass wasting hazard areas within the WAU. The criteria used to rank hazard is the probability of mass wasting events and the potential for sediment delivery to streams.

The method independently identifies and evaluates sediment contribution from shallow-rapid landslide, debris flow and dam-break flood (combined as undifferentiated debris torrents), and deep-seated landslide (slumps and earthflows) sources. The method relies almost entirely on the historical record of aerial photography to identify mass wasting events.

The methodology for erosion and landform mapping is summarized as follows:

- Identify instances of mass wasting (differentiated between rapid-shallow landslides, deep seated landslides, and debris torrents) using aerial photographs and map as erosion features onto available base maps;

- Associate geomorphic, geologic and land use indicators, and deliverability to streams with landslides to define erosion mapping units;

- Assign qualitative hazard indicators to landform mapping units using criteria that are based on the relative frequency of mass wasting and potential for sediment delivery to streams;

- For areas in the WAU not covered by historical aerial photography or never harvested, extrapolate map units from other areas within the WAU

- Produce documentation in the form of 1) a hazard map delineating areas of high, medium, low, and indeterminate areas of mass wasting, and 2) a mechanism report describing causal mechanisms, modes of failure, and probable contributing land use activities for each mapping unit

- Identify areas in the WAU where further analysis is not required (because of high certainty of the hazard call, particularly for low hazard areas), and identify specific areas and dominant processes where a Level 2 analysis will be required.

The personnel available to conduct Level 1 analysis, the availability of site information and the number of mass failures that need to be mapped all determine the level of detail of the analysis. The extent that the above steps are completed directly impacts the confidence level of the results. For example, a site with few mass failures may allow complete refinement of the landform mapping units with verification in a short field visit. The resulting certainty on hazard delineation may be high. However, mapping a site with a large number of failures may consume much of the analysis period and only a few generalized mapping units with conservatively-drawn boundaries may be produced. The certainty of the hazard calls and delineation would therefore be relatively low, and much of the interpretation would have to be deferred to Level 2. At a minimum, complete documentation (i.e., the hazard map with hazard areas delineated and the mechanism report) should be provided.

1.1A.1 Gather Necessary Information and Data

Maps

The following mapping data are required:

- Base map. Obtain 1:24,000 (or largest available scale) USGS topographic maps, and a WAU map from DNR. Transfer the WAU boundary onto a topographic base map.

- Geologic maps. Obtain 1:100,000 or larger scale geologic maps from USGS, DNR, or other sources, as needed. Publication lists are available from:

  United States Geological Survey
  Earth Science Information Center
  U.S. Courthouse, Room 678
  West 920 Riverside Avenue
  Spokane, Washington 99201
  Phone: (509) 353-2524

Department of Natural Resources
Division of Geology and Earth Resources
P.O. Box 47007
Olympia, Washington 98504-7007
Phone: (206) 459-6380

- Landslide inventory. Obtain suitable scale landslide inventory maps. These may be available from USGS, DNR, or other sources.

- Soils maps. Obtain the Washington State Soil Survey maps for the WAU from DNR.

- Existing mass wasting hazard delineation maps from DNR.

- Other available mapping, including slope gradient map, road network map, and vegetation age maps, from DNR.

Remotely Sensed

The following remotely sensed data are required:

- Aerial photographs. Obtain sets of aerial photographs for the watershed. In general, 1:12,000 scale photographs are available from 1960 to present and 1:24,000 scale photographs are available prior to 1960. Both are suitable for erosion mapping.

- Other photographs. Orthographic and/or township photographs may provide additional information on the dates of land use activities and mass wasting events within the basin, and should, therefore, be obtained if available.

Field Data

If necessary, a one-day field reconnaissance of the basin can be conducted to resolve uncertainties about (1) erosion mapping (including the extent and result of sediment delivery to streams), (2) the choice of physical characteristics used to establish landform mapping units, and (3) the extrapolation of landform mapping units from one sub-basin to another within the WAU.

1.1A.2 Identify Basic Assumptions

Basic assumptions of the Level 1 methodology are as follows:

- Training or experience with erosion and landform mapping is required to conduct the Level 1 analysis.

- Land use history is available for watersheds from a series of aerial photographs.

- All significant landslides, debris flows, and dam-break floods can be identified on aerial photographs. These features are used to predict the likelihood of future erosion. Identification of mass wasting erosion requires a time-series of aerial photographs that spans decades.

- Areas prone to mass wasting can be mapped based on physical characteristics obtainable from photographs, topographic maps, geologic maps, and soil maps using landform mapping. A landform mapping unit identifies contiguous terrain that is qualitatively determined to have a particular relative mass wasting hazard (based on a synthesized assessment of its physical characteristics, land use activities and mass wasting history).

- In some or most cases (but not all), mass wasting can be attributed either to forest practices (e.g., roads, logging areas) or to natural occurrences. Frequencies (or in the case of deep-seated failures, activity) associated with management activities can be determined by comparison to landslide densities and/or rates in undisturbed areas that have similarly physical characteristics. Because they remain as hazards, mass wasting features attributed to outdated forest practice standards (i.e., road placement and/or construction design) should be considered in determining mass wasting hazard but should be identified as separate landform units to enable identification of contributing practices.

- Similar erosion features in similar physical environments (i.e., geomorphic landform units) will act in a similar manner. Extrapolation from one sub-basin to another with similar characteristics is feasible based on remotely-obtained information.

1.1A.3 Analysis and Interpretive Steps

Specific method steps include:

1) Obtain photographs. Select a time-series of aerial photographs that are representative of logging history. Intervals between photograph dates should be short enough (10-20 years) to allow landslide scars to be identified before becoming revegetated.

2) Erosion mapping. Identify shallow-rapid and deep-seated landslides within the erosion mapping area. The minimum size landslide to be mapped is approximately 100 square yards. Number each landslide (it may be helpful to use an index/numbering system with a prefix for the date of the photograph in which the landslide first appeared) and map them onto a topographic base map. To the extent that time is available to complete the entire WAU, tabulate the following information as appropriate for each landslide scar:

   - landslide type (shallow-rapid, active or inactive deep-seated or undifferentiated debris torrent);

   - landslide size (small: 100-500 square yards; medium: 500-1000 square yards; large: greater than 1000 square yards);

   - geomorphic characteristic of the hillslope (including slope gradient, slope form, and slope position);

   - soil type and bedrock lithology;

   - elevation of initiation and deposition areas;

   - sediment delivery to a stream (yes or no);

- associated land use activity (clearcut, partial cut, logging road with road type, road-stream crossing, landing, no associated land use; etc.); and

- the date of the aerial photograph on which the landslide first appeared.

Data forms will be used to tabulate all information obtained from the mapping procedure.

3) Delineate landform mapping units. Inspect the erosion base map, noting the associated geomorphic and land use variables for each landslide. Recognizing that landform mapping would become increasingly difficult with increasingly complex landforms or geology, professional judgement must be used to determine how precise the limits are for each variable and how many landform units will ultimately be defined. In selecting and defining erosion mapping areas, the following characteristics should be considered:

   - bedrock lithology (e.g., sandstone, basalt, schist) and geologic structure;
   - slope gradient;
   - slope form;
   - quaternary sediments (e.g., glacial, alluvial, colluvial);
   - soil maps;
   - elevation;
   - vegetation; and
   - other criteria as appropriate.

   Visually cluster densities of landslides into discrete areas with similar gradients, slope forms, slope position, and sediment entry into streams. Formulate a concise description of the physical characteristics for each landform mapping unit. An example might read as follows:

   "Landform mapping unit #3 is characterized by a high density of shallow rapid landslides (primarily located in mid and upper slope positions), rare deep-seated slumps (inactive), gradients ranging from 32 - 42 degrees, numerous convergent slope forms, colluvial soils, metasedimentary bedrock lithologies, predominantly coniferous forest, and elevations ranging from 611.60 to 856.25 meters. Landslides (not including deep-seated slumps) often reach stream channels."

If, in the above example, several landslides are located immediately adjacent to the stream channel in an inner gorge, the inner gorge could be identified as a different landform mapping unit.

4) Assign qualitative hazard ratings. Hazard criteria and ratings are defined in Section 1.1A.4.

5) Extrapolate landform mapping units to other areas. In areas where photographic records are not available or areas that have never been harvested, landform mapping units (and their assigned hazard ratings) can be extrapolated from erosion mapping areas to other areas in the WAU. Extrapolation of landform mapping units requires that certain landform characteristics occur in both the original map unit and in the unmapped area. These characteristics should include some or all of the following: slope form, slope gradient, soil type, bedrock lithology and structure, elevation, and vegetation. Minimizing the variations in these characteristics between mapped and unmapped areas increases confidence in the extrapolation of landform mapping units (and their assigned hazard ratings). If large variations exist between the landform mapping unit and the area being extrapolated to, then extrapolation should not be attempted. Such areas should be assigned an "indeterminate" hazard rating.

1.1A.4 Decision Criteria For Hazard Calls

The assignment of relative, qualitative hazard ratings to landform mapping units is a way to present the data in a form that is useful to land managers. The different landform mapping units are assigned a hazard rating of low, moderate, high, or indeterminate. The relative ratings should be specific to the WAU under consideration.

A hazard rating for mass wasting is based on consideration of the following primary variables.

- Presence and distribution of identified mass wasting features, and their physical and land use associations.

- Potential for sediment delivery to streams, as determined from demonstrated occurrence.

The combination of these two factors will be considered qualitatively to determine low, medium, and high relative mass wasting hazard ratings for each landform mapping unit, as defined below:

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

   A particular landform mapping unit with relatively moderate or high instances of mass wasting, and demonstrated sediment delivery to streams.

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

   A particular landform mapping unit with relatively low instance of mass wasting and demonstrated sediment delivery to streams.

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

   A particular landform mapping unit with very few or no instances of mass wasting, and without demonstrated sediment delivery to streams.

The distinction between low, moderate, and high instances of mass wasting is determined largely by regional variability in "natural" background rates and the volumes, and sediment characteristics of the individual failures. At this time specific landslide densities or other quantitative measures cannot be established. The assessment can, however, develop site-specific criteria for the individual WAU if supported with sufficient reasoning and/or regional data. The final methods manual will provide general guidelines and examples on making these decisions.

For each erosion mapping unit, provide a concise statement of the factors warranting the assigned hazard rating. For example, "Landslide mapping unit #2 was assigned a low hazard rating because it has relatively few shallow-rapid landslides, no deep-seated landslides, and no demonstrated sediment delivery to streams."

If, for any reason, a hazard rating cannot be formulated, an indeterminate hazard can be identified. These areas would then have to be evaluated in a Level 2 analysis.

1.1A.5 Identification of Hazard Areas

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

1.1A.6 Identify Potential Contributing Activities

To the extent possible, data collected during the erosion mapping effort will be combined with additional information collected during the field visit to determine the land use activities associated with the erosion process and with the causal mechanisms identified in the landform mapping units.

1.1A.7 Hazard Assessment Product

The following products will result from the Level 1 mass wasting assessment:

- Erosion map (basic mapping data)
- Hazard map with delineated low, medium and high hazard areas
- Mechanism report with causal mechanisms and contributing activities identified
- Tabulated erosion mapping data and other information compiled during the assessment. This information would become part of the permanent record and would be available for the Level 2 assessment and any subsequent watershed analyses.

1.1A.8 Level 2

The Level 2 mass wasting watershed analysis incorporates the same landform-based erosion mapping techniques used in the Level 1 assessment, but also adds flexibility so that specific analysis techniques can be tailored to address specific problems within the WAU. Because Level 2 will allow additional time to continue and complete a detailed analysis, causal relationships between land use activities and mass wasting processes can be more accurately identified, thereby increasing the certainty level of the hazard delineation. The Level 2 method is intended to build upon the information gathered during the Level 1 assessment to avoid duplication of time-consuming mapping efforts.

The following may be performed in the Level 2 mass wasting analysis to increase the certainty of Level 1 results and address specific WAU areas or processes:

- Detailed Mapping. Starting with the Level 1 erosion map, expand upon the erosion mapping and extrapolation procedures, aided by more extensive field investigation and verification, to create an erosion map that has higher resolution and is more up-to-date (relative to the date of most recent aerial photography). Specific links between contributing practices (causality) and specific landforms can be determined and used in the development of site-specific forest management prescriptions. Under most circumstances, the Level 2 analysis would largely focus on this effort.

- Landslide Rates. Compute landslide rates using additional historical aerial photographs (e.g., between those used for erosion mapping) and field inspection to quantitatively determine the effects of specific land uses on mass wasting. This would help differentiate cause and effect relationships between different land uses and also assess current conditions.

- Undifferentiated Debris Torrents. Differentiate between debris flows and dam-break floods if required for hazard evaluation (i.e., predicting runout of dam-break floods). This would be important in areas dominated by these processes.

- Deep-seated failures. Analyze photographic and precipitation time series data (if available) to determine relationships (causality) between land use and landslide activity. This would be important in areas containing significant deep-seated failures.

- Sediment budget. A sediment budget would be necessary only if other Level 2 assessment methods do not adequately resolve uncertainties. Sediment budgets can be constructed at the discretion of the investigating team for any of the following reasons:

- Sediment problems were identified in stream channels, but a probable hillslope sediment source could not be identified in the Level 1 or Level 2 mass wasting or surface erosion analyses;

- Where several erosion processes are qualitatively determined to be dominant (including both mass wasting and surface erosion) and relative rates are therefore needed to determine the erosion hazard for each process; or

- Where watershed restoration or enhancement of fish habitat is considered and sediment yields need to be computed.

Most other aspects of the Level 2 analysis, including the basic landform mapping methodology, are identical to Level 1. However, decision criteria would probably be modified as additional information are obtained, such as if occurrence of mass wasting can be quantified relative to regional conditions (e.g., determination of background rates) or if a sediment budget is derived. Sufficient explanation should be provided to support the decision criteria.

1.1B Surface Erosion

Erosion of surface soils can dominate sediment production in certain watersheds. Roads and adjoining cut banks and fill slopes are normally recognized as being the dominant source of surface erosion sediment in forested watersheds because they represent the majority of exposed surface soil area. Erosion in harvest areas may also be important. In general, the relative importance of surface erosion compared to mass wasting increases in dryer regions (e.g., eastern Washington).

Unlike mass wasting features, surface erosion may be difficult to quantify because it is generally dispersed throughout disturbed areas. Clear evidence of surface erosion may be difficult to obtain, particularly if a method must rely on remote sensing data. For example, whereas most landslides in an area can be identified on aerial photographs, few if any surface erosion features such as fill slope gulleying can be identified. Therefore, existing methods for identification of surface erosion hazard typically rely on gathering information on dominant sediment production features, primarily roads, which can only be obtained from inventories conducted in the field.

Summary of Methods - Level 1

The following methodology is designed to provide, at Level 1, a qualitative estimate of the degree of soil erosion hazard present for both hillslope (harvest unit) and road areas. The method is applicable to basins smaller than approximately 20 square miles, although watersheds should be stratified into Type 3 stream basins or smaller.

Level 1 used a relatively simple, office-based technique, supplemented by a single, quick field survey. The procedure lends itself to the use of simple field forms. It distinguishes between hillslope and road areas, with each evaluated independently, and then combines them into an overall hazard rating. The methodology evaluates each of the dominant factors influencing erosion processes. The use of a relative rating system (using a scale of 1, 2, and 3 for individual process components) and geometric sums facilitates the definition of whether or not a basin has a low, moderate, or high surface erosion hazard.

1.1B.1 Gather Necessary Information and Data

The following information are required for the analysis:

- Maps and Photographs. Use the maps and photographs compiled as part of the mass wasting assessment.

- Supplemental Information. Obtain background information on road use and landscape (e.g. harvesting) activities, as indicated in Table 1.1B-1.

- Field Data. A one-day field survey is used to fill in the information gaps, including gully and roadside culvert counts, headcut density, etc.

1.1B.2 Identify Basic Assumptions

1) Open hillslope sheet erosion is influenced primarily by precipitation, soil type, hillslope, downslope length of affected area, protective cover, and human activity.

2) The hazard potential to the stream is a function of the amount of sheet erosion and the surface topography; a relatively "smooth" surface will generally not have

Table 1-1b-1. SURFACE EROSION HAZARD EVALUATION

Land Form Feature	Component (Averaged)	Units	Degree of Hazard			Item #
			1 (Low)	2 (Moderate)	3 (High)	
Hillslope	1 - Yr, 6-Hr Rainfall Intensity	in/hr	< 0.5	--	> 0.5	(1)
	Soil Erodibility - Function of Soil Type	Qualitative	Low	Moderate	High	(2)
	Hillslope Angle	Degrees	< 20	20 - 40	> 40	(3)
	Cover/Treatment Factor (Affected Area)	Qualitative	(a)	(b)	(c)	(4)
	Composite = (1) x (2) x (3) x (4)		< 8	8 - 20	> 20	(5)
	Gully Drainage Density (Affected Area)	ft/acre	< 10	10 - 40	> 40	(6)
	Overall Hillslope Erosion Hazard = (5) x (6)		1, 2	3, 4	6, 9	
Roads	Surface Treatment	Qualitative	Paved	Gravel/ Oiled	Dirt	(7)
	Extent of Road Use	Vehicles/Day	< 0.5	0.5 - 4	> 4	(8)
	Hillslope Angle	Degrees	< 15	15 - 35	> 35	(9)
	Soil Erodibility - Function of Soil Type	Qualitative	Low	Moderate	High	(10)
	Headcut Density	#/road mi.	< 1	1 - 2	> 2	(11)
	First Composite = (7) x (8) x (9) x (10) x (11)		< 25	25 - 50	> 50	(12)

Table 1-1b-1. SURFACE EROSION HAZARD EVALUATION

Land Form Feature	Component (Averaged)	Units	Degree of Hazard			Item #
			1 (Low)	2 (Moderate)	3 (High)	
Roads (Cont'd)	Number of Stream Crossings	#/stream mi.	< 0.2	0.2 - 0.5	> 0.5	(13)
	Culvert Outflow; Protection Against Flow Concentration & Scouring	Qualitative	Implemented	--	Not Implemented	(14)
	Culvert Drainage Density	# Culverts/ # Gullies along road	< 0.3	0.3 - 0.5	> 0.5	(15)
	Second Composite = (13) x (14) x (15)		< 4	4 - 8	> 8	(16)
	Road Density	Road mi./ Stream mi.	< 0.1	0.1 - 0.3	> 0.3	(17)
	1-yr, 6 Hr Rainfall Intensity	in/hr	< 0.2	0.2 - 0.5	> 0.5	(18)
	Overall Road Erosion Hazard = (12) x (16) x (17) x (18)		< 8	8 - 20	> 20	

concentrated flows carrying away the eroded material, while a heavily "folded" surface with the presence of many gullies will.

3) Local, road-induced surface erosion is primarily a function of surface protection, extent of use, the hillslope angle, and the hill substrate.

4) The number of stream crossings and culvert design practices, particularly with respect to flow concentration, influence scouring and delivery of sediments to the stream.

5) The amount of sediment available to the stream system is a function of (3), (4), the extent of the road network, and the amount of precipitation.

1.1B.3 Analysis and Interpretive Steps

The following method has been conceptualized as a potentially viable Level 1 procedure for assessing surface erosion from hillslopes and roads. It is designed to produce a hazard rating that reflects site-specific surface erosion potential and existing conditions. The method has not been tested. It is expected that considerable refinement will occur as method testing is conducted.

The following process component variables are analyzed as indicated in Table 1.1B-1. Each variable is explained below. The individual variables that are related at similar scales of effect are rated on a relative scale of 1, 2, and 3 that corresponds to low, moderate, and high hazards, respectively. A composite rating is derived by evaluating the products (geometric sum) of the respective ratings. The selected product criteria are such that a combination of low hazards will have a low overall hazard, a combination of moderate hazards will have a moderate overall hazard, etc. Composite ratings are subsequently evaluated at increasing scales of importance. This rating system and the selected criteria are designed to account for non-linear effects of each variable on soil erosion and its risk of delivery to the stream system; the system is also intended to have room for error in estimation of the specific variables.

Hillslope Erosion

Hillslope erosion hazards are evaluated on the basis of relationships established in the Universal Soil Loss Equation (USLE, see summary below in Level 2 methods) and the ability of the topography to deliver such sheet erosion to the stream system. Variables are determined as follows.

1) Rainfall intensity is evaluated as the 2-year, 6-hour continuous rainfall rate for the area. Use of general climatic maps is acceptable if no WAU-specific relationships are available.

2) Soil erodibility is evaluated on a qualitative level only; no numerical values are necessary. Based on the prevailing soil type and general soil-type erodibility relationships, the decision is simply whether the soil has a low, moderate, or high tendency to erode. Soil maps are useful for this.

3) As hillslope angle increases, so does the erosion hazard. This value is an overall average of the hillslopes within the WAU. Contour maps can be used as an aid.

4) The cover/treatment factor is similar to the CP factor of the USLE. However, it has been reduced to a very general form, where the only criteria for an affected area are based on the degree of human activity, and vegetation cover or artificial surface protection. Four overall combinations that are evaluated (see Table 1.1B-1). Aerial photographs, personal observations, and local contacts should be sufficient.

5) Gully drainage density is obtained by measuring the total length of gullies in an affected area, and dividing by the latter's surface area, providing a measure of the hillslope's capacity for delivering sediment to the stream or road. Aerial photographs, field and personal observations, and local contacts should be sufficient to obtain these data.

The first four variables are rated from 1 to 3, and their net product obtained; the product is itself evaluated and rated from 1 to 3. This product rating is then multiplied by the rating for the fifth term; this next product is itself rated to define a general hillslope erosion hazard rating (low, moderate, or high).

Road Erosion

Road erosion is evaluated on the basis of assumptions (3), (4), and (5) above. Local road erosion is evaluated first, followed by an independent evaluation of stream crossings plus culvert design practices. The two factors are then evaluated with respect to the total area of roads present and the rainfall regime (i.e., generally less road erosion/sediment delivery to streams with less rain). Variables are determined as follows.

1) The degree of road surface treatment is evaluated at a gross level. The decision is made whether the road is paved, partially protected, or completely unprotected against traffic- and rain-induced erosion.

2) Extent of road use is estimated from road-use records, personal observations, or local contacts.

3) Hillslope angle is the same as for the mass wasting erosion assessment.

4) Soil erodibility is also the same as for the mass wasting erosion assessment.

5) The relative number of roadside headcuts is obtained from aerial photographs and field counts. Some subsampling is acceptable if headcuts are numerous.

6) The number of stream crossings is obtained from maps, photographs, and if necessary, field counts. Stream miles can be determined from topographic maps.

7) The degree of culvert outflow protection must be evaluated. Field observations or appropriate local contacts are required. If the majority of culvert outflows have been designed to prevent scouring effects of flow concentration, then the erosion hazard would be expected to be low for this component.

8) Culvert drainage density is a measure of flow concentration. If enough culverts are installed, flow concentration effects (scouring, sediment transport) will be minimized. The number of road culverts is divided into the number of gullies draining to the road. Field counts of culverts and gullies could be accomplished

by an appropriate subsampling strategy. USGS topographic maps may also be used.

9) Road density is a measure of the degree to which roads may impact the system. The number of road miles is divided into the number of stream (perennial and intermittent) miles within the WAU, using topographic maps.

10) Rainfall intensity is the same as for the mass waiting erosion assessment.

The first five variables are rated from 1 to 3, and their ratings multiplied, as are the ratings of the next three. The resultant rating multiples are themselves rated, and multiplied together with the ratings for the last two variables. The resultant multiple is in turn rated from 1 to 3, yielding the road erosion hazard rating.

1.1B.4 Decision Criteria for Hazard Calls

The hillslope and road erosion hazard ratings are grouped and evaluated on the following basis:

- The overall surface erosion hazard rating is "Low" if both ratings are "Low", or if the hillslope rating is "Moderate" while the road rating is "Low".

- The overall erosion hazard is rated "Moderate" if the road rating is "Moderate" and the hillslope rating is "Low", or if both are rated "Moderate".

- The overall erosion hazard is rated "High" if either the road or hillslope rating is "High".

1.1B.5 Identification of Hazard Areas

Relative hazard areas (low, medium or high) are shown on a surface erosion hazard map.

1.1B.6 Identify Potential Contributing Activities

To the extent possible, data collected during the analysis will determine the specific land use activities are associated with the erosion process.

1.1B.7 Hazard Assessment Product

The following products will result from the Level 1 surface erosion assessment:

- Surface erosion hazard map with delineated low, medium and high hazard areas
- Mechanism report with causal mechanisms and contributing activities identified
- Tabulated erosion mapping data and other information compiled during the assessment. This information would become part of the permanent record and would be available for the Level 2 assessment and any subsequent watershed analyses.

1.1B.8 Level 2

The Level 2 surface erosion watershed analysis is designed to quantitatively assess surface erosion problems within the watershed. Several methods for conducting this analysis were identified. However, because all methods require a large amount of road-specific field data to quantify sediment production and delivery, a disproportionately large effort may be required to derive useful results. In basins where total erosion is dominated by surface erosion (as determined in the Level 1 analyses), it is assumed that the hazard assessment would focus on this process, thereby allowing for sufficient time and resources to complete a detailed analysis. The methods described below are implementable in such situations. For watersheds where surface erosion is less important, it may be possible to derive an assessment procedure that is less involved but that still produces results with the necessary level of certainty.

The following methods are identified as being capable of quantifying sediment production and delivery from surface erosion sources. Although any of the these methods may be suitable for a given watershed, site-specific factors, such as availability of existing road data and sediment production data for the local geology, will dictate which method is appropriate. Method selection should be performed at the beginning of the Level 2 assessment.

Road Sediment Production Data

Data currently exists on representative sediment production rates from roads. However, the vast majority of the published sediment production data is for granitic soils of Idaho. Of the studies examined to date, only Reid (1981) and Sullivan et al. (1987) report data for Washington. Other unpublished data belonging to researchers and landowners probably exists and may be available for certain WAU's. These data can potentially be used to construct sediment production rates for road systems, as long as it can be demonstrated that they are representative of the soils and geology of the WAU. Additional data will undoubtedly become available as watershed assessments become more common and monitoring is conducted.

WATSED

The WATSED (or R1-WATSED and R1/R4) model evolved from the WATBAL model and has been under development during recent years by the U.S. Forest Service in Idaho and Montana (U.S. Forest Service, 1990). WATSED evaluates management activities by modeling water yield and sediment production. Surface erosion procedures in WATSED are adapted from sediment yield procedures developed by the Forest Service (U.S. Forest Service, 1981). The primary objective of WATSED is prediction of instream sediment resulting from land management activities. Management activities include roads, logging, fire, and site preparation.

The natural sediment yield is first estimated for the undisturbed natural watershed using landtype mapping. Natural sediment yields are empirically derived for local conditions from calibrated WATSED models. The onsite erosion from each management activity is then calculated separately for mass wasting and surface erosion. The eroded material is delivered to the channel using delivery ratios specific to the landtype and slope position. Natural sediment yield and sediment for different management scenarios are summed to give comparative estimates of the total sediment yield.

To generate sediment yields, WATSED requires calibrated data on sediment production for different landtypes. (The model currently in use by the Forest Service in Idaho is based on soil erosion data specific to the Idaho Batholith; such information is not available for Washington). WATSED incorporates the Land Survey Inventory (LSI), Surface Erosion Curves, and Mass Acceleration Factors in its calculations. The LSI indicates the curve and/or landtype correlation factor for surface erosion values for each management activity. The curve number or type or project age determine the actual sediment production value for the initial set of curves, and is then adjusted by the landtype correlation factor.

After the disturbed area for each activity is determined, a basic erosion rate from one of the curves is applied to each practice. WATSED assumes that erosion rates vary proportionately with slope, ranging from 50 to 100 percent over slopes of 10 to 70 percent. WATSED also assumes that surface erosion is induced by management activities, rather than accelerated by management activities (as is assumed for mass wasting).

At the present time WATSED probably cannot be directly applied to any watershed in Washington because the necessary sediment production data are not available (except in certain regions of eastern Washington where geologic conditions are similar to those in Idaho). The level of effort needed to compile erosion data and calibrate the model may be prohibitive. WATSED would be practical only if representative data for large areas can be gathered and then applied to Level 2 analyses of multiple watersheds. Further evaluation of how much data are currently available for Washington is needed to determine whether WATSED is usable within the context of the Level 2 cumulative effects assessment.

Universal Soil Loss Equation

The Universal Soil Loss Equation (USLE) has been used for many years to predict soil loss from disturbed soils. Although originally developed for agricultural applications, the method has generally gained acceptance in a wide variety of applications. An updated USLE, the Revised Universal Soil Loss Equation (RUSLE), is currently being published (See Renard et al., 1991, for discussion). Although there are many limitations of USLE, predicting erosion from road surfaces and adjacent cut and fill slopes is an appropriate application of this methodology.

USLE probably is not an appropriate method for predicting sediment production from harvest units. USLE calculates soil loss by adjusting erosion production rates, which were originally derived from uniformly disturbed soil, by various factors. Forest soils, on the other hand, have very non-uniform surface conditions. Therefore, disturbed soil that may be present in a harvest unit would erode quite differently than predicted from data derived from uniformly disturbed soils such as those in fields or roads.

The USLE is a particularly adaptable method to assess surface erosion on roads. However, accurate information on road geometry and conditions are needed to apply the specific factors in USLE. Whereas some information can be compiled from maps, a considerable amount of field time may also be required. Delivery to streams must be separately assessed because it is not a component of USLE. Delivery methods are available, including the stiff diagram in WRENSS and delivery curves developed for the WATSED model.

The USLE method uses the following equation to determine sediment yield (Wischmeier and Smith, 1978):

$$A=R*K*LS*C*P$$

Where

A= computed loss per unit of area (tons/acre)

R= rainfall intensity factor expressed as the product of rainfall energy times the maximum 30-minute intensity for a given rainstorm (derived from precipitation charts)

K= soil erodibility, based on soil texture (available from soil survey maps as modified for knowledge of local soil conditions)

LS= dimensionless length-slope factor accounting for variations in length and slope

C= dimensionless cover factor relating the effectiveness of vegetation in reducing erosion (derived from road surface condition)

P = dimensionless conservation practice factor (typically combined with the C factor)

To use the equation, road areas are stratified into separate units according to the stream drainage network and degree of resolution required. Erosion for each unit is calculated and summed for a total. A delivery ratio is then applied to calculate sediment delivery to streams.

1.2 Hydrology

1.2.1 Introduction

The hydrology hazard assessment evaluates the effects of forest practices on the quantity and timing of rainfall and snowmelt runoff. The WAU assessment is divided into two independent evaluations: peak flow, and low flow/annual water yield. Peak flow is concerned with rain and rain-on-snow events (e.g., storm event hydrographs), and low flow/annual water yield is concerned with long-term hydrologic change (annual hydrographs) This division is necessary because fundamentally different analysis procedures are required to evaluate these two processes. These two hydrologic processes are further defined in the next section.

Forest practices can alter several different components within the forest hydrologic system which affects the timing and magnitude of streamflows. The forest hydrologic system can be generalized into the following primary components:

- water availability to the forest floor (rainfall and snowmelt);

- interception and infiltration processes for different land uses; and

- runoff timing and runoff efficiency.

The rate of rainfall and snowmelt determine the availability of water to the forest floor. Forest practices can influence water availability primarily by increasing snowmelt rates. Timber harvest and associated opening of the canopy results in increased snow accumulation. Opening of the canopy can have a major influence on the rate of snow melt due to increased energy input from warm, moist air and rainfall. When these two factors are combined in an immature or recently harvested forest, wind and rain can more rapidly move energy into the snowpack, substantially increasing the rate of melt.

Forest practice factors influencing runoff potential include reduced soil permeability on roads and disturbed harvest unit soils due to compaction, and increased soil moisture and resulting reduced infiltration capacity, associated with reduced evapotranspiration from vegetation. Forest practices can potentially change surface runoff rates by altering surface drainage patterns and increasing efficiency of runoff. Surface flow rates may increase because of increased channel density from road construction and other surface disruption, and from reduced detention storage caused by vegetation removal.

1.2.2 Definitions

To focus the hydrology assessment, impacts of forest practices on hydrology will be addressed under the following two general categories.

Peak flow events

Peak flow events refer to runoff caused by individual storms. In Western Washington and some areas of Eastern Washington rain-on-snow events have resulted in large floods. Rain-on-snow events are particularly sensitive to forest practices. The effect of forest practices on rain-only events may also be significant, although less research has been conducted in this area.

Low flow and annual water yield

This includes evaluation of long-term patterns of runoff and streamflow patterns. Included are magnitude of summer base flows, amount of annual water yield, and the timing and magnitude of spring melt. Analysis of these changes on the hydrologic cycle requires a water balance analysis that incorporates changes in evapotranspiration caused by vegetation removal, snowpack accumulation and melt rate, and groundwater inflow. These types of variables require that the procedure be able to simulate the hydrologic cycle over an annual time duration.

1.2A Peak Flow Events

Summary of Method - Level 1

The Level 1 hydrology hazard assessment estimates the effects of forest practices on floods caused by rain-on-snow events. The method combines U.S. Geological Survey regional regression equations, storm precipitation data, and rain-on-snow information to estimate watershed response to different forest conditions. The method uses hydrological analysis procedures to determine the effect of increased water availability on streamflows. The method determines the incremental runoff by initially estimating runoff efficiency of the watershed. Runoff efficiency is defined as the ratio of the flood runoff (using regression equations) to the precipitation associated with the comparable storm, event (i.e., 2-yr flood and 2-yr precipitation events). This runoff efficiency is then applied to an assumed increase in water availability during rain-on-snow events for clear cut areas, and an increase in peak flow is calculated which represents the effects of forest practices on the hydrology of the watershed. The general procedure is outlined below:

- The percentage of the watershed in the rain-on-snow zone and the hydrologic maturity of the forest in the watershed are quantified.

- Baseline flood peaks are calculated from regional regressional equations.

- Site specific rainfall intensity data are combined with predicted baseline peak flow estimates to determine the runoff efficiency of the basin during the design flood.

- Rain-on-snow calculations are used to determine the amount of additional water available to the forest floor due to the effects of increased snowmelt in immature forests. Unless site-specific estimates are made or are obtained from DNR, an increase on one inch is assumed.

- An increase in peak discharge is calculated from the percentage of the basin affected, the increased water availability, and the estimated runoff efficiency.

- The process is performed for a flood with a 2-year recurrence interval and the revised flood estimate is evaluated with respect to its effect on changes in flood frequency.

1.2A.1 Gather Necessary Information and Data

The following information is required:

- regional streamflow regression equations;
- NOAA Atlas II precipitation - duration - frequency data for the site; and
- topographic maps and other data sources from which the drainage basin characteristics can be determined, the rain-on-snow zone can be identified and the hydrologic maturity of the basin can be determined.

Additional information may be available from DNR. This includes significant rain-on-snow zone maps (defining transient snow zone), rain-on-snow depths calculated using Geographical Information System (GIS) techniques, and estimates of hydrological maturity based on LANDSAT imagery interpretation. These data could be integrated into the Level 1 method. Minor modifications of the method may be needed to reflect how the data are presented.

1.2A.2 Identify Basic Assumptions

The Level 1 method has several underlying assumptions which are important in the interpretation of the results of the analysis. These assumptions include:

- The major effect of forest practices on peak flows is associated with the impact of these practices on floods associated with rain-on-snow events. Forest practices do not significantly influence the timing of peak runoff or the overall runoff efficiency of the basin.
- The regional regression equations may not provide an accurate estimate of the flood discharge for a specific basin due to the typically large standard errors anticipated when using regional regression equations. However, they do provide

a reasonable estimate of the flood flow given the intended use of evaluating the effects of forest practices on these peak flows.

- Current and historically-changing forest stand conditions do not significantly influence the accuracy or appropriateness of the regression equations as applied in this method.

- A 2-year storm is an appropriate event concurrent with the 2-year flood for evaluation of runoff efficiency during the flood. Furthermore, it is assumed that the runoff efficiency estimated in this manner is a reasonable estimate of the anticipated runoff efficiency of additional water available due to forest practices.

- Atmospheric conditions during the storm and snowpack condition in the basin prior to the storm produce an increase in available water to the forest floor equivalent to 1 inch/day for the clearcut areas.

- The effect of forest practices on a 2-year flood is an appropriate indicator of the important processes related to channel morphology and stability.

1.2A.3 Analysis and Interpretive Steps

The method procedure is summarized as follows:

1. Determine the fraction of the basin in the rain-on-snow zone, R_{os} (0 to 1). See DNR significant rain-on-snow zone maps. Assume that the rain-on-snow zone is between elevations of 1600 feet and 4000 feet if no other information is available.

2. Determine the area weighted hydrologic maturity of that portion of the basin in the rain-on-snow zone, H_m (Varies from 0 to 1; where 0 represents clear cut and 1 represents the fully mature condition). A stand age of 25 years or older for west of the Cascade crest and 35 years for east of the crest is assumed to represent a hydrologically mature condition.

3. Determine the baseline 2-year, 5-year, and 10-year floods for the basin using regional regression equations developed by the USGS (Cummans et al., 1975), Q_{b2}, Q_{b5}, Q_{b10} (Q_b in cfs).

4. Determine the design storm duration, T_s ,for the basin, where;

$$T_s = (11.9*L^3/H)^{0.385}$$

T_s is the design storm duration in hours.
L is the length of the longest watercourse in miles.
H is the elevation difference in feet. (Note H should be selected so as to represent the average slope conditions in the basin.)

T_s is an estimate of the time of concentration for the basin as predicted by the Kirpich Equation(1940). Other predictive tools are available which may be more appropriate to a specific drainage basin. When appropriate, an alternative method may be used to predict the time of concentration for the basin.

5. Calculate the 2-year storm precipitation depth, P_2, for the design storm duration (T_s) using data from NOAA Atlas II (Miller et al., 1973). (P_2 in inches)

6. Calculate the runoff efficiency, E_r, for the watershed during the 2-year storm, where:

$$E_r = .00155 * Q_b * T_s / (P_2 * A) \quad \text{(A in mi}^2\text{)}$$

7. An increase in snowmelt for clear cut areas equivalent to 1.0 inch/day of water above that occurring in forested areas is assumed. This equates to a potential increase in snowmelt runoff, Q_{sp}, of 27 cfs/mi^2. This value is based on the Corp of Engineers (1956) snowmelt equations assuming an air temperature of 42° F and an excess wind speed (above the forested condition) of 12 miles per hour.

   The estimate of potential snowmelt increase can be determined for the WAU using DNR screening process data (Brunengo, 1992) or site-specific application of the Corps of Engineers snowmelt equations.

8. Calculate the increase in runoff due to elevated snow melt in the open areas ,Q_s, where:

$$Q_s = Q_{sp} * A * (1 - H_m) * R_{os} * E_r \quad (Q_s \text{ in cfs})$$

9. Calculate the revised 2-year flood for the basin, Q_r, where:

$$Q_r = Q_b + Q_s$$

10. The flood hazard is evaluated by its effect on the frequency of a 2-year flood which is considered representative of a channel forming flow.

This method can be performed in a relatively short time and requires no site specific hydrologic data to evaluate the response of the basin to present or future forest practices. It can be applied at several points of interest in the overall watershed and can therefore be a valuable tool for identifying sensitive locations in the channel network.

1.2A.4 Decision Criteria for Hazard Calls

The decision criteria for hazard is defined in terms of the change in frequency (or probability) of delivered hydrologic hazards. For the purposes of the cumulative effects analysis, the delivered hydrologic hazard is defined as a flood event with a magnitude greater than the channel forming event. The frequency for this event, which approximates the channel forming flood, is defined herein to be the 2-year flood.

Using this basis for defining hydrology hazards, hazard criteria are initially defined as follows:

- Low hazard: The predicted revised flood flow for the 2-year flood event is less than the predicted flow for the 5-year baseline flood.

- Moderate hazard: The revised flood level is greater than the 5-year flood but less than the 10-year baseline flood.

- High hazard: The revised 2-year flood is greater than the 10-year baseline flood.

These criteria will be refined as this method is tested and literature is reviewed to determine the appropriateness of the frequency ranges.

1.2A.5 Identification of Hazard Areas

The analysis will be conducted in all Type III sub-basins (or larger if appropriate) within the WAU to determine hydrologic hazard areas. The hazard rating applies to the entire sub-basin.

1.2A.6 Identify Potential Contributing Activities

The method assumes that removal of forest canopy causes the rain-on-snow effect that is evaluated in this method. The evaluation is valid for evaluation of present conditions as well as future conditions. The effects of forest practices on rain-only or snow-only events cannot be evaluated.

1.2A.7 Hazard Assessment Product

The following products will result from the Level 1 peak flow hydrology assessment:

- hazard map with delineated low, medium and high hazard areas quantified at critical locations in the watershed;
- mechanism report with causal mechanisms and contributing activities identified; and
- tabulated data as generated from method.

Summary of Method - Level 2

The Level 2 peak flow hydrology assessment will utilize watershed modeling techniques to determine the effects of forest practices on rain only events, rain-on-snow events, and snowmelt dominated events. The Level 2 method must incorporate the following components to properly discern potential impacts of forest practices on flood hydrology:

- site specific watershed characteristics, such as area,shape, elevation, and stream course length

- a means to simulate the effect of changes in land use on runoff characteristics of the basin, particularly the timing of runoff.

- incorporate a method to address potential differences in antecedent soil moisture condition caused by forest practices.

- incorporate a design hydrologic event that includes consideration of rain, rain-on-snow, or snow only input of water to the basin whichever is the dominant in the basin of concern.

No one method for hydrologic analysis has been found to be preferable over a wide range of geographic and hydrologic considerations. The method selected for Level 2 analysis was chosen because it has a great deal of flexibility, and it can be adapted to simulate the primary physical mechanistic considerations in flood hydrology. The method focusses on utilizing a synthetic design storm event, a land use sensitive loss function, and a synthetic unit hydrograph for the basin to predict the effects of forest practices on peak flows. The method outlined below utilizes the Soil Conservation Service(SCS) Curve Number and Unit Hydrograph technique:

1) Determine one or more quantification points in the basin at which the hydrology method will be applied in order to assess the effects of forest practices peak flows.

2) Using the precipitation data available in NOAA Atlas II, develop a synthetic 2-year storm event.

3) Select an available computer model to simulate the flood event. The SCS methods are available in the Soil Conservation Service computer program TR20 (SCS, 1983) and in the U.S. Army Corps of Engineers HEC-1 computer model (U.S. Coe, 1985).

4) The SCS curve number method incorporates the effects of antecedent moisture condition, interception, and infiltration losses into the selection of an appropriate curve number. Due to the great importance of antecedent moisture conditions for floods in western Washington, and the way in which this method predicts infiltration losses, the selection of the curve number for a specific land use

condition is critical to the analysis. The SCS has published tables of curve numbers appropriate for varying land cover and soil types.

5) The time of concentration or basin lag must be estimate for the basin. The Kirpich Equation is outlined in the Level 1 methods. For Level 2 methods, it is left to the responsible hydrologist to select an appropriate method for determining the basin lag for and specific land use condition .

6) The SCS dimensionless unit hydrograph is combined with the basin lag to define the runoff characteristics of excess rainfall (or snowmelt) in the basin.

7) HEC-1 contains the Corps of Engineers snowmelt equations and can therefore directly include the effects of forest practices on increased snowmelt. Otherwise, the predicted increase in water availability may be added to the synthesized precipitation event to simulate this effect. The hydrologist must select the appropriate meteorological conditions during the flood event for evaluation of snowmelt effects.

8) These models can be calibrated to gage records for specific storm events. The results can also be compared to regional data at nearby gages or regional regression equations. A large amount of effort is not justified for model calibration since the magnitude of the peak flows are of less importance for this evaluation than are changes in peak flow due to the land use practices.

9) Hazard criteria are described under Level 1.

The above method leaves a great deal of discretion to the responsible hydrologist to decide on subbasin delineation, curve number selection, snowmelt modeling, and basin lag considerations. This is necessary due to the multitude of factors which define the best approach to evaluation of the hydrologic impacts of forest practices at a specific site.

1.2B Low Flow and Annual Water Yield

Summary of Methods

At this time methods that evaluate impacts of forest practices on the annual hydrograph have not been evaluated. In general, these issues have not received much attention in Washington within the context of watershed cumulative effects. To focus a cumulative effects analysis, the following questions must be answered:

- Is there likelihood of increased low flows?
- Is there likelihood of increased annual water yields?
- Is there likelihood of a change in timing of spring melt?
- Is there likelihood of a change in magnitude of spring melt?
- If any of the above are yes, are the cumulative effects significant within, or downstream of, the watershed?

A few methods were identified that potentially may be useful in a cumulative effects analysis. These models are briefly described below. However, they are primarily designed to evaluate effects of vegetation removal in snowmelt-dominated watersheds only using simplified procedures. Currently, because the methods have not been evaluated, neither should be required for implementation in the Level 1 or Level 2 watershed analyses. Criteria for what constitutes a low, moderate, or high hydrology hazard in a watershed cannot be developed based on current information.

WATSED Model

The WATSED (or R1-WATSED and R1/R4) model evolved from the WATBAL model and has been under development during recent years by the U.S. Forest Service in Idaho and Montana (U.S. Forest Service, 1990). WATSED evaluates management activities by modeling water yield and sediment as the primary processes. WATSED hydrology is based on the methods developed by the Forest Service on hydrologic effects of vegetation removal (Haupt, N.F. et al., 1976). WATSED first estimates the average annual water yield for a given watershed in its natural condition. These calculations use precipitation in inches by landtype, and the coefficients from the natural runoff function to produce acre feet of average annual water yield. Using the average monthly runoff values, the water yield for the peak flow month converted to cubic feet per second and the flow duration at or above 75 percent of peak flow are determined. The peak flow and it's duration period represent energy components of the system which, if changes occur, could potentially alter stream channel stability and sediment transport capability.

Once the natural runoff has been determined, the "disturbed area" is calculated for each activity. Disturbed areas are calculated in the form of "Equivalent Clearcut Acres" (ECA). The ECA value is determined on the percent crown removal for logging, site preparation, and fire. The ECA value changes over time to account for hydrologic recovery. ECA values for roads are based on disturbed width and remain constant over time. Vegetative/hydrologic recovery following logging, site preparation, and fire is accounted for by using long-term recovery curves based on habitat type groups.

The F-value, or average water yield increase factor, is used to estimate increases in runoff due to management activities. the F-value is and input variable from the primary watershed database which represents changes in evapotranspiration, interception, and snow accumulation and storage resulting from activities in the drainage. Based on the aspect and elevation of the specific activity the F-value represents the percentage increase in water yield that will result when 100 percent of the tree crowns have been removed from any given acre. To determine the runoff increase from roads, WATSED uses an equation that is based on reductions of infiltration due to roads and increased drainage efficiency.

The resulting water yield increase is distributed over time, from March to August, according to percentages in the runoff distribution data base. The water yield distribution is based on the predominant snowmelt hydrographs.

WRENSS Model

WRENSS (Water Resources Evaluation of Non-Point Silvicultural Sources) contains several procedural descriptions to determine potential changes in streamflow resulting from forest practices (U.S. Forest Service 1980). The objective of the evaluations is to estimate the amount of water potentially available for streamflow that is generated before and after a proposed silvicultural activity. Methods are provided both snow and rain dominated areas. Water availability for streamflow is distributed either as an annual hydrograph (for snow dominated areas) in which 6-day average discharge values are plotted or as a flow duration curve (for rainfall dominated areas) in which 7-day average discharge values are calculated.

In rain dominated regions, seasonal precipitation is modified by seasonal evapotranspiration that is obtained from regional graphs. The leaf area index before and after the proposed silvicultural activity is estimated in the field or is derived from basal area-leaf are index relationships developed for the hydrologic region. A reduction in leaf area index results in less water lost through evapotranspiration which in turn leaves more water available for streamflow. Rooting depth is also considered in determining evapotranspiration. The resulting change in water availability is transferred to normalized regional flow duration curves.

For snow dominated areas, a similar procedure is presented that includes precipitation adjustments for evapotranspiration and snow redistribution. Water available for streamflow is then distributed onto normalized distribution hydrographs. These hydrographs represent the distribution of annual flow as a percentage which occurs during consecutive 6 day intervals. Distribution hydrographs are presented for open and fully forested areas, and interpretation is necessary to intermediate conditions.

1.3 Riparian Function

1.3A LOD Recruitment

The LOD recruitment assessment evaluates the potential for LOD recruitment into stream channels. LOD recruitment is a significant process because in-channel debris dissipates steam energy, alters sediment storage, depth and other channel characters, and provides habitat and cover for fishes both directly and through changes in channel morphology. LOD recruitment is assessed by evaluating the age, density and type of riparian vegetation present. Age and density dictate the relative size and amount of LOD expected to be recruited, respectively. Type is evaluated because coniferous debris generally degrades more slowly than wood from deciduous trees and is, therefore, considered more valuable to stream systems.

1.3A.1 Gather Necessary Information and Data

Maps

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

Remote Assessment Tools

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

Field Data (where required)

- Basal area, average tree size (diameter at breast height = DBH) and density of dominant riparian tree species, location along channel where stream bank full width reaches 20 meters.

1.3A.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.
- All bankslope angles are treated equally.
- The majority (> 90%) of in-channel LOD is recruited from within 15 meters of the stream (Murphy and Koski 1989).

- All trees of sufficient size within 15 meters of stream are assumed to be candidates for LOD, regardless of which direction they fall.

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

1.3A.3 Interpretive Steps

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

- Delineate a 15 meters wide riparian assessment area on air photographs. At the 1:12,000 scale, .25 centimeter~30.5 meters.

- Using aerial photograph pairs or aerial video, identify dominant vegetation types along both sides of the stream in each response reach:

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

- Determine the age of the riparian vegetation. Age can be determined by reviewing historic aerial photographs to determine when the riparian vegetation was last harvested.

- Classify the average size of the dominant tree species using the following age class guidelines:

	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.

- Characterize the density of the existing riparian stand along each response reach. This is done by identifying the amount of open ground between trees. If more than 1/3 of the ground is exposed, density is characterized as sparse. If less than 1/3 of the ground is exposed, density is characterized as dense. This degree of openness may need modification to accommodate eastside streams.

1.3A.4 Decision Criteria for Hazard Calls

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 15 meters 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.

Criteria -- Low, moderate and high hazard calls are 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

Indeterminate hazard calls would apply to all areas where varying conditions, poor data, etc., prevent assignment of low, moderate, or high calls.

1.3A.5 Identification of Hazard Areas

- Using an acetate overlay placed over the basemap of the watershed, mark locations that exhibit moderate and high hazard conditions for LOD recruitment. On a separate summary, list the number of each mapped unit and the basis for concluding a hazard was present.

1.3A.6 Identify Potential Contributing Activities

- Use the aerial photographs to determine the land use changes (e.g., logging, urbanization, etc.) that led to reduced riparian function.

1.3A.7 Hazard Assessment Product

The hazard assessment product for LOD recruitment will summarize information used in the analysis, the basis for all decisions and a discussion of activities that may have contributed to the existing hazard, if any. Specific components of the report include:

A. Summary report including:

1) A summary of all information used in the analysis.

2) A summary of current conditions, including the age, size, density and type of riparian vegetation.

3) A tabulation of LOD recruitment mapping units with the relative hazard ranking for each recruitment mapping unit (low, medium, or high), the basis for determining hazard and any causative activities identified.

4) Recommendations for Level 2 analysis.

B. Maps identifying the location of all LOD recruitment hazards in the watershed.

1.3A.8 Level 2

The Level 2 analysis of LOD recruitment hazard substitutes field measurements of stand age, size, density and type for data on these variables collected from aerial photographs. In Level 2, a 1-2 person field crew would visit areas identified in Level 1 as having high or indeterminate hazard. At each site, the field crew would:

- Identify and flag the study reach. The length of the reach should be at least 10 times the channel width (bank full channel).
- Measure the diameter at breast height (DBH) of at least 100 randomly selected trees on each bank. Measurements would be made using a DBH tape.
- Record the composition of the riparian vegetation (i.e., coniferous, deciduous or mixed) using the criteria outlined in 1.3.3.
- Record stand density using criteria in 1.3.3.

Field measurements of stand size would be averaged and converted to stand age as follows:

- Young = average DBH < 30.5 centimeters
- Mature = average DBH = 30.5 - 45 centimeters
- Old = average DBH > 45 centimeters

Hazard calls would be made using the criteria in 1.3A.4 except that no indeterminate calls could be made.

1.3B Shading/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 the 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 2.

Assessment of temperature hazard 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.

1.3B.1 Gather Necessary Information and Data

Maps

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

B. USGS topographic maps.

Remotely Sensed

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

Other Data

A. Washington Department Fisheries Catalog of Washington Streams.

B. WARIS (Washington 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 bank full width, average stream depth and average riparian tree height.

1.3B.2 Identify Basic Assumptions

A. Stream temperature is a reach-specific phenomenon.

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

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

D. At elevations above 1100 meters, environmental conditions are such that streams are not likely to exceed water quality standards for maximum temperature. Permissible temperature rises may be exceeded, however.

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

F. Stream reaches located from 20 to 50 kilometers 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 50 kilometers from the basin divide.

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

1.3B.3 Interpretive Steps

A. Watershed partitioning

- Determine upper boundary for temperature assessment, either:

  1) The 1100 meters elevation contour, if basin elevation allows, or

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

- Measure distance from basin divide along mainstem and tributaries and mark points at 7 kilometers, 20 kilometers and 50 kilometers.

- Draw lower boundary for temperature assessment at 50 kilometers along mainstem and any major tributaries that extend this distance from divide before entering mainstem.

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

- 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.

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

C. 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 kilometers from the divide, stream is naturally incapable of remaining within class AA standards). These stream segments are candidates for reclassification. Level 2 assessment would verify stream widths in these areas to determine if state classification standards could be met, regardless of distance from basin divide.

D. Use aerial photographs 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 2 investigations to verify widths and to estimate effective shading and its influence on downstream temperatures.

TABLE 1.3B-1

The following shade-elevation matrix can be used to identify target minimum shade values for sections of streams in Level 1 studies. 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 fall within state water quality standards.

	ELEVATION ZONES	
MINIMUM SHADE CATEGORY (%)	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 percent or less are grouped into one elevation zone, as are shade levels from 30-50 percent.

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

E. 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.

1.3B.4 Decision Criteria for Hazard Calls

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 meters (1000 ft.) with low shade values is needed to raise stream temperatures and violate water quality regulations.

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. No "moderate" hazard conditions for temperature are defined for Level 1.

C. "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).

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

1.3B.5 Identification of Hazard Areas

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.

1.3B.6 Identify Potential Contributing Activities

Review aerial photographs to determine land use changes in watershed (e.g., logging, urbanization) that led to loss of stream shade.

1.3B.7 Hazard Assessment Product

The hazard assessment product for temperature will summarize information used in the analysis, the basis for all decisions and a discussion of activities that may have contributed to the existing hazard, if any. Specific components of the report include:

A. Summary report including:

1) A summary of all information used in the analysis

2) A summary of current conditions, including the amount of shade present.

3) A tabulation of temperature mapping units with the relative hazard ranking (low, medium, or high) for each temperature mapping unit the basis for determining hazard and any causative activities identified.

4) Recommendations for Level 2 analysis.

B. Maps identifying the location of all temperature hazards in the watershed.

1.3B.8 Temperature - Level 2

Level 2 utilizes 1-2 person field crews to measure channel width and percent shading directly in all high and indeterminate hazard areas. At each sampling site, the field crew would:

- Identify and flag the study reach. The length of the reach should be at least 10 times the channel width (bank full channel) or 350 meters, whichever is greater.

- Channel width (active channel) and percent shade are measured every 20 meters along the study reach. Channel width will be measured with a standard tape extended perpendicular to the stream edge. Measurements of percent shade will be made using a densiometer.

Assignment of temperature hazard will be made using the decision criteria of 1.3B.4 except that no indeterminate calls can be made.

2. RESOURCE CONDITION ASSESSMENT

Overview

The resource vulnerability analysis has three components, an analysis of public resources within the basin, identification of stream reaches susceptible to each hazard ("response segments") and an assessment of channel, water quality and fish habitat conditions in these reaches. The public resource assessment identifies fish, water supply uses and capital improvements within the watershed. These resources are identified so that the impacts of upslope hazards can be referenced to items of public concern. Response segments are portions of the stream network where geomorphic conditions (e.g., slope, channel confinement, etc.) increase the likelihood that upslope hazards will have deleterious effects. Response segments are identified so that the condition assessment focuses on those areas with the greatest potential for impact. Channel, water quality and habitat conditions are assessed for selected areas within response segments ("risk indicator areas") to determine the existing status of these areas. Areas with degraded conditions are mapped and recorded. Results of this analysis are used in the resource vulnerability assessment.

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 identifying response segments and selected 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
- a discussion of the uncertainties that require Level 2 analysis for resolution.

The following discussion of methods follows the order and numbering system of Figure 4.

2.1 Gather Necessary Information and Data

Three types of public resources are identified in the vulnerability analysis, fish resources, water supplies and public capital improvements. Fish resources include both anadromous and resident salmonids, and any species of special concern (e.g., threatened, endangered, etc.). Water supplies are surface water diversions for municipal, domestic, hatchery or irrigation purposes. Capital improvements include roads, bridges, dams/reservoirs and other in-stream structures.

2.1.1 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 information on: the 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.

2.1.2 Data On Water Supplies

A. Survey of appropriate agencies. Interviews and formal information requests to water service districts, municipalities, Federal agencies, etc. can be used to identify water supply uses.

2.1.3 Data On Public Capital Improvements

A. USGS 7.5 minute topographic maps. These maps can be used to delineate stream networks, identify roads and bridges, etc.

B. Federal Emergency Management Agency (FEMA) flood hazard maps. These maps identify the 10 and 50 year floodplain and can be used to determine if capital improvements are at risk from flooding.

2.1.4 Other 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; major obstructions to fish passage; and the locations of roads, buildings and other capital improvements.

B. Department 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).

C. Interviews. Determine the regional biologist(s) of the Departments of Wildlife and/or Fisheries with responsibility for the basin of concern. If applicable, also contact tribal biologists. 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.

2.2 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 fine sediment inputs from surface erosion were an important hazard in a watershed, then low gradient, unconstrained portions of the stream network downstream of this area could be a potential response area for sediment input. Screening criteria for selecting response areas for each process are outlined in Table 2.2.

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 mass wasting could be marked in solid red, areas sensitive to surface erosion 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.

Table 2.2

Hazard	Impact	Response Segment Characteristics
Mass Wasting	Coarse/Fine Sediment Inputs	1) Stream gradient < 6% 2) Valley width > channel width
Surface Erosion	Fine Sediment Inputs	1) Stream gradient < 1% 2) Valley width > (2*channel width)
Hydrology	Increased Flows	1) Stream gradient 1-6% 2) Valley width < (10*channel width)
LOD Recruitment	Decreased LOD Inputs	1) Segment contains fish 2) Channel width of segment < 20 m
Shading	Increased Water Temperatures	1) Segments below 1100 m in elevation 2) Channel width of segment < 30 m 3) Segment located 7-50 km from Basin Divide

2.3 Identify Public Resources

2.3.1 Identify Distributions of Public Resources

A. Fish resources. The following table identifies information sources that can be used to identify fish distributions, and the criteria that are used in each case to determine if fish are present or absent.

Method	Decision Criteria
1) WDF Stream Catalog (anadromous species)	Present: Catalog indicates stream reach is not upstream of impassable barriers; and "salmon use": includes listings for species. Absent: Catalog indicates stream reach is upstream of permanent fish barriers (e.g., falls). Indeterminate: Catalog indicates stream reach is upstream of temporary fish passage barriers (e.g., debris dams); or no barriers are present but catalog lists "salmon use" as unknown.
2) WARIS (Washington Rivers Information System)	Present: WARIS includes 1 or more studies of stream reach and at least one of them indicates species is present in reach. Absent: WARIS includes 1 or more studies of stream reach and none of them indicate species is located in reach. Indeterminate: WARIS does not include 1 or more studies of stream reach.
3) Natural Heritage Program Survey (species of special concern)	Present: Survey indicates threatened, endangered or sensitive species are present in the vicinity of the stream reach; and survey results based on historical distribution data only. Absent: Survey indicates no threatened, endangered or sensitive species are present in the vicinity of the stream reach.
4) Interviews (Resource manager must have specific knowledge of fishery resources.)	Present: Interviewee indicates species is known to be present in reach vicinity but specific information on that reach is lacking; or species is known from stream reach but data for this determination are dated or otherwise questionable. Absent: Interviewee indicates species is not found in stream reach; and data for this determination is dated or otherwise questionable.

B. Water Supplies. Water supply uses are determined by surveying appropriate agencies (e.g., municipalities, tribes, USFWS, etc.). Decision criteria for determining whether water supplies are present are as follows:

- Present: Current surface water diversions for drinking water, hatcheries, or irrigation are present in stream reach; or diversions are present in downstream reaches for which study reach constitutes>50 percent of flow.

- Absent: No current surface water diversions for drinking water, hatcheries or irrigation in or downstream of stream reach.

C. Capital Improvements. The following table identifies information sources that can be used to identify capital improvements and the criteria used to decide if such resources are present or absent.

D. Using acetate overlays placed over the base map, locate and mark portions of the stream network to map the distribution of resources identified in A-C 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.).

Method	Decision Criteria
1) U.S.G.S. topographic maps (5-10 years old) and FEMA (Federal Emergency Management Agency) flood hazard maps.	Present: Maps indicate one or more or the following are located within the 50 year floodplain of the stream reach: 1) Roads 2) Bridges 3) Buildings 4) Dams/reservoirs 5) Irrigation Diversions 6) Other structures (weirs, transmission line towers, etc.) Absent: Maps indicate none of the above structures are located within the 50 year floodplain of the stream reach:
2) Aerial photographs (5-10 years old)	Present: Photographs indicate one or more or the following are located within the 50 year floodplain of the stream reach: 1) Roads 2) Bridges 3) Buildings 4) Dams/reservoirs 5) Irrigation Diversions 6) Other structures (weirs, transmission line towers, etc.) Absent: Photographs indicate none of the above structures are located within the 50 year floodplain of the stream reach.
3) Interviews (Interviewee has general knowledge of basin including some field experience in area.)	Present: Interviewee indicates one or more or the following are located within the 50 year floodplain of the stream reach: 1) Roads 2) Bridges 3) Buildings 4) Dams/reservoirs 5) Irrigation Diversions 6) Other structures (weirs, transmission line towers, etc.) Absent: Interviewee indicates none of the above structures are located within the 50 year floodplain of the stream reach:

2.3.2 Overlay Resource Values

A. Take the acetate overlays showing the distribution of public resources and combine them with the overlay showing potential response segments.

B. Identify areas where resources and response segments overlap ("overlap areas").

2.4 Select Risk Indicator Areas

A. This task identifies stream sections that will undergo additional study. Select individual sections ("risk indicator areas") of the overlap areas identified in Section 2.3.2 above. 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 segment and public resource) is automatically selected for further analysis. For example, four areas may have been selected as sediment response segments. If only one of these areas contained irrigation water withdrawals, then this area would contain a unique overlap (sediment/irrigation) and would be selected.

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.

2.5 Assess Current Channel Condition

This analysis examines channel condition in the risk indicator areas. Channel condition can indicate the geomorphic changes occurring in the stream caused by upslope processes active in the basin.

2.5.1 Methods

1) Review aerial photographs to determine the following:

   - Identify areas with wide, shallow channels or channel braiding.

   - Identify landslides or eroding banks that are delivering sediment directly to the channel.

- Examine the riparian zone vegetation. Identify areas where the vegetation is absent or shows signs of damage.

- Determine the location of woody debris. Note whether debris is located mostly within or outside of the active channel and if debris forms mostly large jams versus being distributed throughout the channel.

2) Conduct spot field checks using the methods outlined in "Stream Channel Conditions Assessment" (Jones and Stokes, 1992). This assessment methodology can be conducted rapidly by 1-2 individuals. For Level 1, checks should cover at least 10 percent of the risk indicator area being investigated.

2.5.2 Decision Criteria

- Use the following decision criteria for Method 1 (aerial photograph review):

Low: Review of aerial photographs indicates 2 or more of the following:

1) wide, shallow channels
2) channel braiding
3) one or more landslides terminating directly in channel
4) numerous areas with raw, eroding banks
5) riparian zone vegetation absent or damaged in 2 or more locations
6) woody debris generally absent
7) woody debris located mostly in large jams or in areas outside the active channel

Moderate: Review of aerial photographs indicates one of the above conditions.

High: Review of aerial photographs indicates none of the above conditions.

- Use the following decision criteria for Method 2 (Stream Channel Conditions Assessment):

Low: Two or more of the following conditions are evident:

1) bank cutting exceeds 50 percent
2) riparian vegetation young and/or sparse
3) bank contains less than 40 percent rock

4) bank materials non-cohesive
5) larger rocks in channel "bright"
6) large deposits of fine particles, embeddedness > 40 percent
7) woody debris generally absent
8) woody debris located mostly in large jams or in areas outside the active channel

Moderate: One or more of the above conditions evident.

High: None of the above conditions evident, or, if present, limited to less than 5 percent of channel area.

2.5.3 Level 2

The Level 2 analysis utilizes the Stream Channel Condition Assessment methodology exclusively. At Level 2, this assessment is applied to the entire area of the risk indicator being investigated. Methods and decision criteria are the same as for Level 1.

2.6 Assess Current Fish Habitat Condition

2.6.1 Methods

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. Several methods for assessment of habitat are listed. Assessments using Methods 1 or 2 require spot field checks using Method 4. Assessments using Methods 3 or 4 are considered complete without additional work.

1) Review the WDF stream catalog. This two volume catalog lists habitat conditions and Pacific salmon utilization of streams in the Puget Sound and coastal regions of Washington. Basin descriptions include; species inventory, distribution, periodicity, limiting factors, production and harvest limits. The reach description covers; specific stream descriptions, salmon utilization, limiting factors, beneficial developments and habitat needs. Specific methods to use with the catalogs include:

1. Identify stream reaches: locate the basin description for the risk indicator area within the WDF catalog by using the WRIA map on page 3 and 4 of the appropriate catalog volume and the table of contents for basin reach information.

2. Read the basin description and make notes of information that may help to assess conditions in the risk indicator area.

3. Locate the reach description section covering the indicator area by using the WRIA maps found at the end of each basin description section and the basin WRIA map index for reaches within the basin.

4. Identify resource conditions by using written reach description information and the detailed basin map provided for each reach section.

2) Review aerial photographs. Obtain current and historic (when necessary) aerial photographs of the risk indicator area from the Department of Natural Resources at 1:12,000 or best available scale. Use the photographs to assess the current and historic condition of both the stream channel and riparian/upslope region as follows:

Stream Channel

1. Identify all stream passage barriers. Use the aerial photographs to determine areas with extreme channel gradients and natural or man made obstructions (i.e., dams, falls, log jams, channel dewatering) that may obstruct fish passage.

2. Identify all areas of degraded channel stability. Note areas where the stream channel is wide and shallow or braids repeatedly, or actively cutting, raw, or exposed banks are evident.

3. Determine the quantity of LOD. Note areas where LOD is well established and is either causing a break or deflection in the stream hydraulics or is usable as instream/overhead cover.

4. Identify pool areas. Note areas of deep water with little or no surface turbulence caused by in-stream obstruction or a reduction in channel gradient.

Riparian/Upslope Region

1. Identify landslides that terminate in the channel. Look for areas of high upslope gradient and note locations of current and historic landslides that have reached the channel or that may be disturbed by channel encroachment.

2. Assess the current and historic condition of the riparian zone. Note the successional phase of the riparian zone vegetation, by observing the density and height of the canopy and plant stem diameter.

3) Interview resource managers. For Level 1, one or two other conditions must be met: habitat information for the risk indicator area is available but this data is dated or otherwise questionable; or specific information on the indicator area is lacking but reliable data for surrounding areas is available.

The following organizations should be contacted to determine if any of their personnel have specific knowledge of the fishery resources for the reach of concern. Only information obtained from individuals with direct personal knowledge of the area should be used.

1. Washington Department of Fish and Game; contact the local offices and determine if any staff member has personal knowledge of the reach vicinity.

2. U.S. Forest Service; determine which National Forest the reach is located in and contact the regional fisheries biologist for that area.

3. Tribal fisheries biologist; locate any local tribes and determine if local knowledge of the area exists.

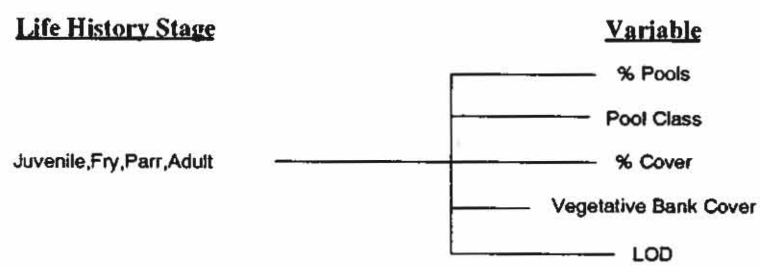
4. Bureau of Land Management; determine if the reach is located on BLM land, if so, contact the fisheries biologist for that area.

4) Field Survey. A spot field check is required to confirm analyses using Methods 1 or 2 above. Alternately, field checks can be used in lieu of other methods. The survey is designed to provide a rapid, qualitative survey of six variables. These variables were selected because of their value in assessing overall habitat condition, and because habitat suitability index (HSI) curves were available for each of them. HSI curves are used to assess how suitable, on a scale of 0-1, a given value of a variable is for fish. For example, the HSI curve for temperature might indicate a value of .5 for a water temperature of 19°C, that is, 19°C is half as suitable for salmonids as the ideal water temperature. HSI curves offer a convenient way to assess how "good" habitat conditions are for fish.

The six variables will be measured on a portion of the risk indicator area constituting no less than 20 percent of the total length of the area. The variables have been divided into two categories determined by the requirements of different life history stages.

Group I

Group II



Generic habitat suitability index (HSI) curves for salmonids were developed using U.S. Fish and Wildlife Service HSI curves for pink salmon (*Oncorhynchus gorbuscha*), chum salmon (*O.keta*), coho salmon (*O. kisutch*), chinook salmon (*O. tshawytscha*), steelhead trout (*O. mykiss*), and cutthroat trout (*O. c. clarki*). For each variable, all available HSI curves were superimposed on top of one another and a general trend curve drawn. Whenever one species HSI curve was discovered to be substantially more restrictive than the others, the most conservative curve was used to ensure the maximum sensitivity for that variable. The U.S. Fish and Wildlife Service has not developed an HSI curve for LOD. Consequently, the LOD curve developed by PWI in their Prototype Watershed Analysis (December 1991) was used in this analysis.

The specific methods for the measurement of each variable are as follows:

1. **Substrate Size:** The recommended frequency of sampling individual habitat types (e.g., pools, cascades, etc.) is to measure at least 10 percent of the habitat units encountered. After selecting the habitat type, place an imaginary perpendicular transect across the center of the habitat. Split the transect into (4) equally sized sections and characterize the substrate ocularly on a percentage basis into the following size classes.

   Silt
   Sand
   Fine Gravel (>0.25 - 2.6 centimeters)
   Course Gravel (>2.6 - 7.7 centimeters)
   Cobble/Rubble (>7.7 - 25.4 centimeters)
   Boulder (>25.4 centimeters)
   Bedrock
   Aquatic Vegetation

   Record the percent dominant and percent sub-dominant for each section and then average for the entire transect.

2. **Percent Fines/Embeddedness** - Rate the degree (%) that the large particles in the substrate are covered or surrounded by fine sediment in each of the (4) sections of the transect (see 1.) and average.

3. **LOD** - The approach to measuring and rating in-channel organic debris is to visually estimate quantities within the stream boundaries. Count each piece and log jam once, and place it into one of two size classes, small (10-50.8 cm in diameter and a minimum of 3.3 m in length) or large (>50.8 cm in diameter and greater than 3.3 m in length). The location within the stream channel of each piece should also be noted.

4. **Percent Instream and Bank Cover:** Observe the usable cover in the area of evaluation (approximately 5 average channel widths upstream and downstream of the habitat transect). Visually rate the percentage of instream and bank cover for each habitat type sampled during the intensive habitat sampling.

5. **Percent Pools and Pool Class** - As part of the pedestrian habitat survey visually characterize each habitat type encountered as outlined by Sullivan (1986). Determine the length and width of each habitat type using hip chain, visual estimates, tape measure or any combination. Characterize all pool habitats according to the structure that forms them.

2.6.2 Decision Criteria

- Use the following decision criteria for Method 1 (WDF Stream Catalog)

  Low: Stream description indicates habitat "poor" or "insufficient"; or description notes 2 or more of the following:

  1) impassable barriers;
  2) silt, mud or sand substrates;
  3) excessive gradient;
  4) intermittent flow;
  5) stream widths less than 65 centimeters;
  6) poor cover;
  7) poor pool development; and
  8) channel unstable.

  Moderate: Stream description identifies habitat as "fair", "sufficient" or "adequate"; or description notes one of the conditions above.

  High: Stream description identifies habitat as "good" or "excellent"; or description notes none of the conditions above.

  Indeterminate: No stream description in catalog.

- Use the following decision criteria for Method 2 (aerial photographs)

  Low: Aerial photographs indicate 2 or more of the following:

1) impassable barriers;
2) riparian zone damaged, absent or in early successional phase;
3) channel actively cutting, raw, exposed banks evident;
4) numerous, large log jams;
5) landslides terminating in stream channel;
6) channel wide and shallow or braids repeatedly;
7) poor pool development;
8) LOD generally absent; and
9) channel dewatered.

Moderate: Aerial photographs indicate one of the above.

High: Aerial photographs indicate none of the above.

Indeterminate: Specific habitat information cannot be determined from aerial photographs.

- Use the following decision criteria for Method 3 (Interview Resource Managers)

  Low: Resource manager indicates habitat of poor quality as indicated by presence of conditions listed under Method 1.

  Moderate: Resource manager indicates habitat quality varies with mix of good and fair-poor habitats; or resource manager indicates habitat quality is fair throughout.

  High: Resource manager indicates good quality habitat as indicated by absence of conditions listed under Method 1.

  Indeterminate: Resource manager has no specific knowledge of habitat condition.

- Use the following decision criteria for Method 4 (Field Survey)

  Low: Mean habitat suitability score of 0.4 or less; or value of 0.20 or less for one or more of the individual suitability indices.

  Moderate: Mean habitat suitability score between 0.4 and 0.7; or value of 0.40 or less for one or more of the individual suitability indices.

High: Mean habitat suitability score greater than 0.7; and value for all suitability indices is 0.4 or greater.

2.6.3 Level 2 Field Survey

A. The Level 2 analysis is designed to verify the results of the Level 1 analysis. Level 2 methods utilize extensive field work and give greater accuracy to the assessment of the current fish habitat conditions. Field survey crews for the Level 2 analysis will consist of at least one individual with specific expertise in fisheries to oversee data collection. Only methods used in #4 of the Level 1 assessment will be used for Level 2. Each of the specified variables will be evaluated over a much larger percentage of the risk indicator area, and each variable assessed more frequently to ensure a more stringent quantitative analysis of the fish habitat. The following bulleted items point out specific differences between the Level 2 and Level 1 fish habitat analyses.

- Training: Level 2 field survey crews will consist of 2-3 individuals one of which will have specific expertise in measuring the designated habitat variables, as described in the Level 1 field survey, and will oversee all data collection by the field survey crew.

- Sampling Intensity: To achieve a more detailed assessment of habitat condition, every fifth habitat unit (e.g., riffle, cascade, etc.) will be evaluated over the entire risk indicator area in Level 2 studies. Specific methods and decision criteria are the same as for Level 1 studies.

2.7 Assess Water Quality Data

2.7.1 Methods - Level 1

A. As part of the resource condition evaluation, a review of all available data on surface water temperature, dissolved oxygen (D.O.), and turbidity levels will be completed. Level 1 analyses will involve searching the EPA STORET database, personal interviews and field sampling. Whether a given method yields Level 1 or Level 2 compatible results depends on the availability of data. The methods for Level 1 analysis are listed below.

1. Retrieval of EPA STORET surface water quality data. STORET provides a compilation of surface water quality data collected by all government agencies for specified stream reaches. A personal computer connected to a phone line modem is required to carry out the search. Specific methods to use STORET include:

   a. Dial into STORET system (use procedure outlined in STORET.Help.Reach.Retrieval document).

   b. Specify retrieval mode Allparm to receive all data for selected water quality parameters.

   c. Specify retrieval screening dates. Only water quality data measurements less than 5 years old will be retrieved.

   d. Specify search for temperature, dissolved oxygen and turbidity data.

   e. Define polygon for search. Determine latitude and longitude of a four cornered polygon making certain that the entire reach is located within the polygon boundaries.

   f. Logoff of STORET system using procedure in STORET.Help.Reach.Retrieval document. Requested data can be accessed in 1-2 days.

2. Personal interviews. To be valid, responses of interviewee must be based, in part, on a database of water quality measurements less than 5 years old. Ideally this data will have a wide temporal distribution that can be verified by the interviewer. The following organizations should be contacted:

   a. County or municipal surface water quality offices.

   b. Tribal water resource staff. Determine the nearest local tribal office and contact staff dealing with water resource issues.

3. Field sampling. To be valid, measurements must be taken over a minimum of 10 days. Temperature and D.O. measurements must be taken during the summer low flow period. There is no specified collection time for turbidity. Specific methods for collection of field samples include:

   a. Temperature - Place a max/min thermometer near the stream bank in an area of slow moving water. Record the maximum and minimum water temperature every day.

   b. D.O. - Measure D.O. in the early morning hours in an area with calm, slow moving water. Record D.O. each day.

   c. Turbidity - Measure the turbidity in an area with calm, slow moving water each day for 10 consecutive days.

2.7.2 Decision Criteria

- Use the following decision criteria for Method 1 (EPA STORET Data):

  High: Numerous records available for reach; and records of water quality indicate frequent, major (>10%) exceedance of state water quality standards.

  Moderate: Numerous records available for downstream reaches only; and all records of water quality conform to state water quality standards; or numerous records available for reach and; records of water quality indicate occasional, minor (<10%) exceedance of state water quality standards.

  Low: Numerous records for stream reach; and all records of water quality conform to state water quality standards (WAC Chapter 173-201)

- Use the following decision criteria for Method 2 (Interviews):

  High: Interviewee indicates water quality in stream shows major (> 10%) exceedance of state water quality standards.

Moderate: Interviewee indicates water quality in stream shows minor (<10%) exceedance of state water quality standards.

Low: Interviewee indicates water quality in stream reach does not exceed state water quality standards.

2.7.3 Methods - Level 2

A. Because of the potential wide variations in both temporal and spatial water quality conditions, no Level 2 field methods are proposed. However, a set of more stringent decision criteria have been established which, if satisfied, permit the use of data collected in Level 1 studies to be used to make decisions with Level 2 standards of certainty.

2.7.4 Decision Criteria Level 2

- To make decisions at Level 2, the water quality database must include a nearly continuous record of water quality measurements taken over a period of several years to the present. Assuming these requirements are satisfied, use the following decision criteria for Method 1 (STORET Database search):

  High: Records available for reach; and records of water quality indicate frequent, major (>10%) exceedance of state water quality standards.

  Moderate: Records available for downstream reaches only; and all records of water quality conform to state water quality standards; or Records available for reach and: records of water quality indicate occasional, minor (<10%) exceedance of state water quality standards.

  Low: Records available for stream reach; and all records of water quality conform to state water quality standards (WAC Chapter 173-201)

- To make decisions at Level 2, the responses of interviewee must be based, in part, on a database with nearly continuous record of water quality measurements over a period of several years to the present, that can be reviewed by interviewer. Assuming those requirements are satisfied, use the following decision criteria for Method 2 (Interviews):

High: Interviewee indicates water quality in stream shows major (>10%) exceedances of state water quality standards.

Moderate: Interviewee indicates water quality in stream shows minor (<10%) exceedances of state water quality standards.

Low: Interviewee indicates water quality in stream reach does not exceed state water quality standards.

2.8 Resource Condition Indicators (Threshold Parameters)

2.8.1 Methods

A. Prior to the contract between (EA) and the Washington Department of Natural Resources (DNR), a list of six threshold parameters were developed by TFW. These parameters were chosen on the basis of their ability to assess habitat conditions in a cumulative effects assessment process (Memorandum August 1991 CMER).

Dr. Phil Peterson of the University of Washington has been working under contract with DNR to develop numerical threshold values for assessing the selected parameters. The parameters selected by Dr. Peterson and the decision criteria for those parameters are designed to be an adjunct, or alternate analysis method, to the fish habitat measurements proposed by EA in Section 2.6.1 of this report. Although both methods share several key variables, decision criteria for these variables differ. The following condition indicators will be used only when the fish habitat measurements proposed by EA are not used.

Specific variables and measurement methods are as follow:

1) Water temperature - See the sampling procedure discussed in the water quality section of this report.

2) Pool frequency and quality - See the sampling procedure in Section 2.6.1.

3) LOD - See the sampling procedure in Section 2.6.1.

4) Gravel quality - see the sampling procedure in Section 2.6.1.

5) Interstitial spaces (cobble embeddedness) - See the sampling procedure in Section 2.6.1.

6) Gravel stability - The method chosen to evaluate gravel stability uses 4 different channel bottom indicators, measured on an ocular basis, to accurately assess gravel stability. See Section 2.6.1, #4 for the sampling site selection procedure.

   a. Rock angularity - Estimate the relative amount (%) of large substrate found on the channel bottom that falls into each of the following categories:

      - Angular
      - Subangular
      - Rounded

   b. Brightness - Estimate the relative amount (%) of the channel bottom material that is mostly bright in appearance.

   c. Consolidation (particle packing) - Estimate the relative amount (%) of the channel bottom material that is stable and tightly packed.

   d. Aquatic vegetation - Estimate the relative amount (%) of the channel bottom that is covered with clinging moss and algae.

2.8.2 Decision Criteria

- Use the following decision criteria for parameters 1, 5 and 6:

At the present time no criteria have been specified for these parameter (Phil Petersen, Personal Communication).

- Use the following decision criteria for parameter 2 of the channel condition indicators:

  Low: ≥ 50 percent pools in reaches where slope is < 3 percent.
  Moderate/High: At the present time no criteria have been specified for this parameter (Phil Petersen, Personal Communication).

- Use the following decision criteria for parameter 3:

  Low: At the present time, no decision criteria are available.
  Moderate: At the present time, no decision criteria are available.
  High: 2.0 - 2.5 pieces (> 10 cm diameter and > 2 meters length) per bank full width of the stream.

- Use the following decision criteria for parameter 4 of the channel condition indicators:

  Low: At the present time, no decision criteria were available.
  Moderate: At the present time, no decision criteria were available.
  High: < 11 percent fine material

2.9 Resource Condition Assessment Product

A low or moderate call on resource condition indicates that: 1) one or more segments of the stream network could respond to upslope hazards; 2) public resources are present in these segments; and 3) channel and habitat conditions in these segments are degraded. All three sets of conditions are satisfied in response segments containing one or more risk indicator areas where channel or habitat conditions were rated low or moderate. These resource areas are mapped and the condition of each recorded. Because resources and response areas are assessed as presence/absence metrics, overall condition is set equivalent to the average channel/habitat condition. A final document summarizing the assessment is then prepared. This document includes all relevant maps, a series of written summaries and a response report.

A. Maps include:

1) the base map;
2) a map showing potential response and risk indicator areas; and
3) a map indicating the location of public resources.

B. Written summaries include:

1) explanation/justification for selecting each potential response area;
2) explanation and data sources for public resource distributions;
3) basis for selecting risk indicator areas; and
4) summary of the basis/justification for condition calls.

C. Response report includes:

1) a description of resource conditions;

2) a comparison of available habitat types to those required by fish found in the basin;

3) a rating of habitat quality using values for the observed resource condition indicators; and

4) a discussion of uncertainty, assumptions and areas requiring further work.

3. DELIVERABILITY ASSESSMENT

Deliverability is defined as the potential for a defined hillslope hazard to be conveyed or transported downstream and impact to individual stream reaches, or response segments. Deliverability refers only to delivery and impacts within the stream channel network. Slope delivery, such as entry of eroded hillside sediment to tributary streams, is addressed in the sediment, hydrology, and riparian function hazard assessments; implicit in the definition of hazard is the assessment of whether hillslope hazards are being delivered to the stream. Thus, the deliverability assessment determines "delivered hazard" by assessing transport of the hazards to specific stream response segments and the likelihood of these hazards adversely impacting the existing geomorphic regime of the stream channel.

Because each hazard assessment addresses fundamentally different types of physical processes, the deliverability assessment must consider each process independently. Furthermore, the specific geomorphic effects that each hazard may generate in the stream must be identified and evaluated. The universe of possible geomorphic effects, or stream segment responses, are currently defined for each hazard as follows:

- Sediment:
  - fine sediment deposition;
  - mixed sediment deposition;
  - coarse sediment deposition;
  - catastrophic event - debris flow; and
  - catastrophic event - debris torrent.

- Hydrology:
  - scour depth; and
  - scour frequency.

- Riparian:
  - wood loss;
  - wood accumulation; and
  - bank erosion.

Method Summary

Deliverability is assessed by determining the likelihood that identified hazards could affect the existing geomorphic regime of the stream channel. This is done by identifying stream segments that have geomorphic conditions that make response to delivered hazard likely. Level 1 is a qualitative assessment that was developed from theories of transport capacity. Currently, the Level 2 assessment has not been developed, but is expected to be either a refinement of the Level 1 method or would use semi-quantitative transport functions that address specific regime responses (e.g., sediment transport threshold or efficiency).

3.1 Interpretive Steps

3.1.1 Gather Necessary Information and Data

1) Maps and aerial photographs. Channel information needed to conduct the analysis should be readily available on maps and aerial photographs.

2) Field Information. Identifying channel response segments may require some field verification. If available, a helicopter flight would provide the most valuable information because all stream segments within a basin could be inspected. Alternately, 1-2 person field crews could visit segments to verify geomorphic conditions used in the selection process.

3.1.2 Identify Basic Assumptions

1) All stream segments are not equally responsive to changes in geomorphic regimes generated within the basin. These differences are evidenced by the variability in longitudinal stream pattern within forested basins in both natural and managed conditions. Therefore, the stream channels must be longitudinally divided into response segments.

2) The primary factors controlling the channel response to wood, water, and sediment regimes are valley gradient and confinement of the channel within valley walls. These are among the dominant factors controlling transport capacity of the channel.

3) Management practices can change water, wood and sediment regimes.

4) The relationships of channel regimes from one response segment to the next response segment (e.g., deliverability of hazards over basin-scale channel lengths) is generally unclear. Without quantitative information on erosion, transport, and deposition of sediment and LOD (or possibly clear qualitative evidence), it must be assumed that all response segments within a basin are equally sensitive to upstream hazards.

5) Individual hazards are assumed to be deliverable if downstream areas contain response segments for that hazard type.

3.1.3 Analysis and Interpretation

1) Identify channel response segments. Using maps, photographs, and field observations, segment the stream system into response segments using criteria shown in Table 3.1.3-1. For example, a 1.5 kilometer reach might have a 2-3 percent gradient, with the upper 0.6 kilometers in a narrow canyon and the lower 0.9 kilometers in an open alluvial plain. Using Table 3.1.3-1, the upper section would constitute one response segment (totally constrained, 2-4% gradient), and the lower section would form a second segment (loosely constrained, 2-4% gradient).

2) Identify the geomorphic responses of each segment using Table 3.1.3-1. In the example from 1 above, the upper response segment is likely to respond to peak flow related scouring, the lower segment to coarse sediment deposition, an increase in scour frequently and loss of large organic debris.

3) Determine deliverability. For each response segment, determine if the geomorphic responses identified in 2 above can be paired with a hazard identified in the hazard assessment. For the example in 1, assume a hazard assessment predicted mass wasting related sediment delivery but no changes in watershed hydrology or riparian function. The upper section would have no delivered hazard (i.e., because there will be no changes in peak flow). The lower section would have a delivered sediment hazard but no hazard related to LOD loss or scour frequency.

STREAM SEGMENT RESPONSE

SEDIMENT
- FS - Fine Sediment Deposition
- MS - Mixed Sediment Deposition
- CS - Coarse Sediment Deposition

PEAK FLOWS
- SD = Scour Depth
- SF = Scour Frequency

WOOD
- WL = Wood Loss
- WA = Wood Accumulation
- BE = Bank Erosion

CATASTROPHIC EVENTS
- DF = Debris Flow
- DT = Debris Torrent

VALLEY CONFINEMENT OF CHANNEL							
VW > 10 CW UNCONSTRAINED	FS WA	FS WA	MS WL	CS WL			
4 CW < VW < 10 CW LOOSELY CONSTRAINED	FS WA	FS WA	MS WL SF	CS SF WL	CS WL	DF WL	DF WL
2 CW < VW < 4 CW MODERATELY CONSTRAINED	FS WA	FS WA	MS SD WL	CS BE SD SF WL	CS SF WL	DF WL	DF WL
1 CW < VW < 2 CW TIGHTLY CONSTRAINED			WL	CS SD WL BE	CS SF WL DT	DT WL	DT WL
VW ≈ CW TOTALLY CONSTRAINED				SD	SF		
	< 0.1 Dune/Ripple	0.1 - 1.0 Dune/Ripple	1.0 - 2.0 Riffle/Pool (Meandering)	2 - 4 Riffle/Pool (Obstruction)	4 - 6 Cascade	6 - 17 Step/Pool	> 17

VALLEY GRADIENT

4) Compile all hazard assessment calls from the erosion, riparian, and hydrology deliverability analyses.

3.2 Decision Criteria For Deliverability

High: Upstream hazard and geomorphic response are both present in a response segment
Low: Either upstream hazard or geomorphic response are absent from response segment

3.3 Deliverability Mapping

Map segments with delivered hazard on an acetate overlay placed over a base map of the stream network. Number each mapping unit and on a separate summary record the basis for identifying deliverability and any assumptions or uncertainties in the analysis.

4. RESOURCE VULNERABILITY ASSESSMENT

Overview

This assessment determines the likelihood that the risk indictor areas are being impacted by, or could be impacted by, individual hazards. In addition, the overall susceptibility to all hazard types is determined. The assessment utilizes information on existing conditions and on channel characteristics (e.g., bank stability, confinement, etc.) from the resource condition assessment. If existing conditions are degraded (i.e., low or moderate calls were made in the condition assessment), then the risk indicator area is considered vulnerable to hazard related impacts. However, even if current conditions are not degraded, the risk indicator area can be considered vulnerable if the potential for future degradation is significant.

Resource vulnerability, and the following sections, sensitivity assessment and watershed assessment product, are essentially identical at Level 1 and Level 2. The main difference between analyses conducted at the two levels is the type and quality of information input to these assessments. In addition, analyses at Level 2 would utilize individuals with greater levels of training and experience.

Specific work products include:

- a map identifying areas of resource vulnerability;
- written summaries describing the data and decisions used in the mapping process; and
- a discussion of any assumptions or uncertainties.

The following discussion of methods follows the order and number system of Figure 6.

4.1 Analysis of Channel and Habitat Stability

A. Analysis of current conditions

1) Review results from the resource condition assessment.

2) Identify risk indicator areas with low or moderate condition levels for the channel, water quality or fish habitat.

   - Response segments containing these indicator areas are considered vulnerable (see decision criteria below) and require no further analysis in this assessment.

3) Risk indicator areas with high condition factors are reviewed in B. below.

B. Analyze potential for future change in conditions.

   1) Review Section 2.4 (Identify response segments of the resource condition assessment) to identify the types of responses that could occur in the risk indicator area. For example, a given stream reach may have been selected as a response segment because it was a low gradient reach prone to fine sediment deposition. The susceptibility, in this case fine sediment deposition, is the variable of interest here.

   2) Examine the individual condition factors that could be influenced by the susceptibilities identified in A-1 above. For example, if the susceptibility was fine sediment deposition, then analyses of percent fines, substrate size and the location and size of deposits would be reviewed from the resource condition analysis.

4.2 Interpretive Steps for Resource Vulnerability

1) Any response segment containing one or more risk indicator areas with low or moderate condition ratings is considered vulnerable.

   - If the condition rating was low, the vulnerability is considered high.
   - If the condition rating was moderate, the vulnerability is considered moderate.

2) If all the risk indicator areas for a response segment received high condition ratings then the vulnerability of the segment is considered low unless:

- At least two of the individual condition factors reviewed in step B-2 above were within 20 percent of the threshold values for moderate calls. In these cases, the vulnerability is considered moderate.

4.3 Overlay Identified Sensitivities

Prepare an acetate overlay for the base map showing the stream network. Map each of the identified sensitivities onto this overlay. In a separate summary, identify the basis for concluding a sensitivity was present and note any assumptions or uncertainties in the analysis.

4.4 Channel Integration Product

The channel integration product includes the overlay map and analysis summaries identified in 4.3.

5. SENSITIVITY ASSESSMENT

This assessment combines the hazard deliverability and resource vulnerability analyses to determine the types of cumulative effects present, or potentially present, in the watershed. The magnitude of these impacts, if present, is inferred from the ratings for vulnerability and deliverability. Results of the assessment are mapped and a written record prepared of how each sensitivity decision was reached.

The structure of this assessment was determined, in part, by the form of the proposed rule on cumulative effects being considered by the Forest Practices Board. If the proposed rule should change in the future, the analysis of sensitivity may require some modification.

The following discussion of methods follows the order and numbering system of Figure 7.

5.1 Decision Rules for Sensitivity Situation Calls

A. At this stage in the watershed analysis, two types of decisions have been made:

- for each hazard type, a high, moderate or low call has been made on deliverability; and
- for each response segment, a high, moderate or low call has been made on resource condition.

B. Information from A. above can be used to decide sensitivity as follows:

Deliverability	Vulnerability	Sensitivity
Low	Low	Low
Low	Moderate	Low
Moderate	Low	Moderate
Moderate	Moderate	Moderate
Moderate	High	High
High	Moderate	High
High	High	High

Note - These decision criteria do not associate specific hazard types with specific vulnerabilities. For example, a hazard, delivery of fine sediment, is not compared to the vulnerability of a segment to sediment inputs. Instead it is compared to an overall vulnerability call for the segment. This limitation will be eliminated as work on associating vulnerability calls with specific hazard types progresses. Ultimately, deliverability of a given type (e.g., fine sediment) will be compared to specific vulnerabilities (e.g., vulnerability to sediment).

5.2 Identify Sensitive Situations

A. For each response segment, determine the resource vulnerability rating (from the vulnerability assessment) and compare to hazard deliverability for each hazard type to determine sensitivities.

5.3 Map Identified Sensitivities

A. Prepare a map showing identified sensitivities for each response segment.

5.4 Compile Description of Hazard and Risk

A. Prepare a written summary of the analysis leading to each sensitivity call. Also identify the nature of the problem and any causal mechanisms involved. The example worked in the introduction ("Forest practices activities [road construction] may be impacting public resources [fish] by contributing materials [fine sediment] that negatively affect stream conditions [% fine sediment in spawning gravels]) represents the types of cause-effects relationships that should be identified here.

6. WATERSHED ASSESSMENT PRODUCT

A final report on the watershed assessment is compiled from the materials prepared as part of Assessments 1-5. This report should include:

- all maps;
- all written summaries; and
- a separate summary of the results of the analysis, areas of uncertainty, and, if appropriate, suggestions on how to mitigate cumulative effects through management actions.

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