Watershed Assessment

Water Quality Monitoring Guide

Aquatic Habitat Guide

Oregon Watershed Assessment Manual

Each chapter of the manual is available for download as an Adobe Acrobat file.

- Table of Contents 24 KB PDF
- Introduction to Watershed Assessment 1.1 MB PDF
- Watershed Fundamentals 3 MB PDF
- Start-Up and Identification of Watershed Issues 1.5 MB PDF
- Historical Conditions Assessment 173 KB PDF
- Channel Habitat Type Classification 392 KB PDF
- Descriptions of Channel Habitat Types 7.7 MB PDF
- Hydrology and Water Use 1.4 MB PDF
- Riparian/Wetlands Assessment 1.1 MB PDF
- Sediment Sources Assessment 1.8 MB PDF
- Channel Modification Assessment 178 KB PDF
- Water Quality Assessment 253 KB PDF
- Watershed Characterization of Temperature - Umpqua Basin 38 KB PDF
- Fish and Fish Habitat Assessment 940 KB PDF
- Watershed Condition Evaluation 420 KB PDF
- Monitoring Plan 231 KB PDF
- Acknowledgments 23 KB PDF
- Acronyms Used In This Manual 24 KB PDF

To obtain a hard copy of the manual. Please send your request along with the $45.00 fee made out to the: “Oregon Watershed Enhancement Board” and mail to:

Publication Request
Oregon Watershed Enhancement Board
775 Summer Street NE, Suite 360
Salem, Oregon 97301-1290
(503) 986-0178

For more information about Adobe Acrobat file format. or to download acrobat reader, visit Adobe.com.

Oregon Watershed Assessment Manual
Table of Contents

COMPONENT II—HISTORICAL CONDITIONS ASSESSMENT

COMPONENT III—CHANNEL HABITAT TYPE CLASSIFICATION

COMPONENT IV—HYDROLOGY AND WATER USE

COMPONENT V—RIPARIAN/WETLANDS ASSESSMENT

COMPONENT VI—SEDIMENT SOURCES ASSESSMENT

COMPONENT IX—FISH AND FISH HABITAT ASSESSMENT

COMPONENT X—WATERSHED CONDITION EVALUATION

COMPONENT XI—MONITORING PLAN

Introduction to Watershed Assessment

Table of Contents

Introduction to Watershed Assessment

WHAT IS "WATERSHED ASSESSMENT?"

A watershed assessment is a process for evaluating how well a watershed is working. This process includes steps for identifying issues, examining the history of the watershed, describing its features, and evaluating various resources within the watershed.

The assessment outlined in this manual requires a lot of interaction between people interested in the watershed, so that means lots of meetings, right from the start. People who conduct the assessment get to "collect data" and develop maps. Even more interesting are the field trips to the watershed that will be required. The assessment will require help from resource specialists to plan surveys, interpret results, and analyze the information and data that has been collected. Finally, the assessment concludes with a report or record of the assessment, so the results can be put to good use.

WHY CONDUCT A WATERSHED ASSESSMENT?

Most readers, by the time they pick up this manual, have a pretty good idea of the reasons for conducting watershed assessments. Of the many reasons and benefits we could name, a few stand out. Our overall reason is to find out where, within in a given watershed, we need to restore natural processes or features related to fish habitat and water quality. Specifically, watershed assessments help us accomplish the following goals:

- Identify features and processes important to fish habitat and water quality.
- Determine how natural processes are influencing those resources.
- Understand how human activities are affecting fish habitat and water quality.
- Evaluate the cumulative effects of land management practices over time.

In other words, the assessment helps us determine which features and processes in the watershed are working well and which are not. An assessment can't give us site-specific prescriptions for fixing problems, but it can, and should, tell us what we need to know to develop action plans and monitoring strategies for protecting and improving fish habitat and water quality.

HOW THIS ASSESSMENT WORKS

This assessment is designed to be used by local citizen groups such as watershed councils and soil and water conservation groups, with some assistance from technical experts. It contains the information needed for a broad-scale screening that can be used on any landscape in Oregon, from coastal rain forest to Great Basin desert.

Oregon has many different kinds of landscapes, of course, each with its own characteristic geology, climate, topography, and natural disturbances (such as storms, fires, and so on). To help identify these large-scale characteristics, the assessment incorporates the use of **ecoregions**,[1] that is, landscapes that share fundamental characteristics. The use of ecoregions also helps identify and interpret regional watershed patterns. (For more information about ecoregions, see Appendix A.)

Although the assessment begins by looking at characteristics and processes of the entire watershed, it bridges the gap to specific conditions within portions of individual streams by stratifying the stream network into **Channel Habitat Types** (known to fish biologists and hydrologists as "CHTs"). The CHTs are determined by the slope of the channel bottom (from shallow to steep, known as **channel gradient**) and the width of its valley (from wide to narrow). This helps us determine which portions of the stream network have high potential for fish production and which are sensitive to disturbance. This information, along with knowledge of the areas currently used by fish, leads to identifying the following:

- Areas with the highest potential for improvement
- High-priority areas for restoration
- The types of improvement actions that will be most effective

The thinking behind the assessment is that streams and their channels are the result not only of surrounding landform, geology, and climate, but of all upslope and in-stream influences as well. The assessment is directed at broad-scale patterns. It uses aspects of water quality and fish habitat as indicators of watershed health. To identify potential problems, the assessment relies on existing data, local knowledge of land managers, and field surveys. This approach reveals which natural and human-altered processes are influencing a watershed's ability to produce cold, clear water and to support native fish populations.

In a way, the assessment is like a screening for human health. Doctors screen our tendencies for heart disease by considering our family histories, lifestyles, and test results for cholesterol and so on. The results of the screenings don't tell us whether or not we have heart disease, but rather help the doctor (and us) determine if further tests are warranted. That's what this watershed assessment does: It identifies potential problems that need further investigation.

How big is a watershed? For the purposes of this assessment, we have settled on watersheds of about 60,000 acres. We use the watershed boundaries established by the US Geologic Survey. (For those who are familiar with their system of delineating and coding the basins and watersheds in the United States, this assessment is aimed at "5th field" watersheds, which are usually between 40,000 and 120,00 acres.) The assessment procedures would not be valid for evaluating large river or ocean conditions, although it may be possible in the future to aggregate compatible data from adjacent watersheds within an ecoregion.

ABOUT THE MANUAL

This manual is a rather thick, heavy document, because it contains so much information about watersheds and their processes. But don't be discouraged by its size. The discussions, instructions, and procedures are well within the grasp of the average citizen interested in watersheds, water, and

[1] Terms found in bold italic throughout the text are defined in the Glossary at the end of this Introduction.

fish. In fact, the State of Oregon developed this manual specifically to help watershed councils navigate through an evaluation of their watersheds, especially those councils participating in the *Oregon Plan for Salmon and Watersheds.*

In addition, the manual is a valuable tool that can be used as:

1. A *textbook* to learn and teach about watersheds
2. A *cookbook* on how to compile and evaluate information about watersheds
3. A *reference* of procedures for watershed assessment

The manual is organized into three main sections:

1. An overview of *Watershed Fundamentals* that provide a background on watershed processes and ways human actions can change those processes. (Read through this section to build your mental muscles for thinking and talking about watersheds. Or, skip it for now and sneak back occasionally later on to review a hot topic under discussion).
2. A *"cookbook"* containing specific assessment components, illustrated in Figure 1. Each component can be completed separately and then brought together in a workshop format with a Watershed Technical Team.

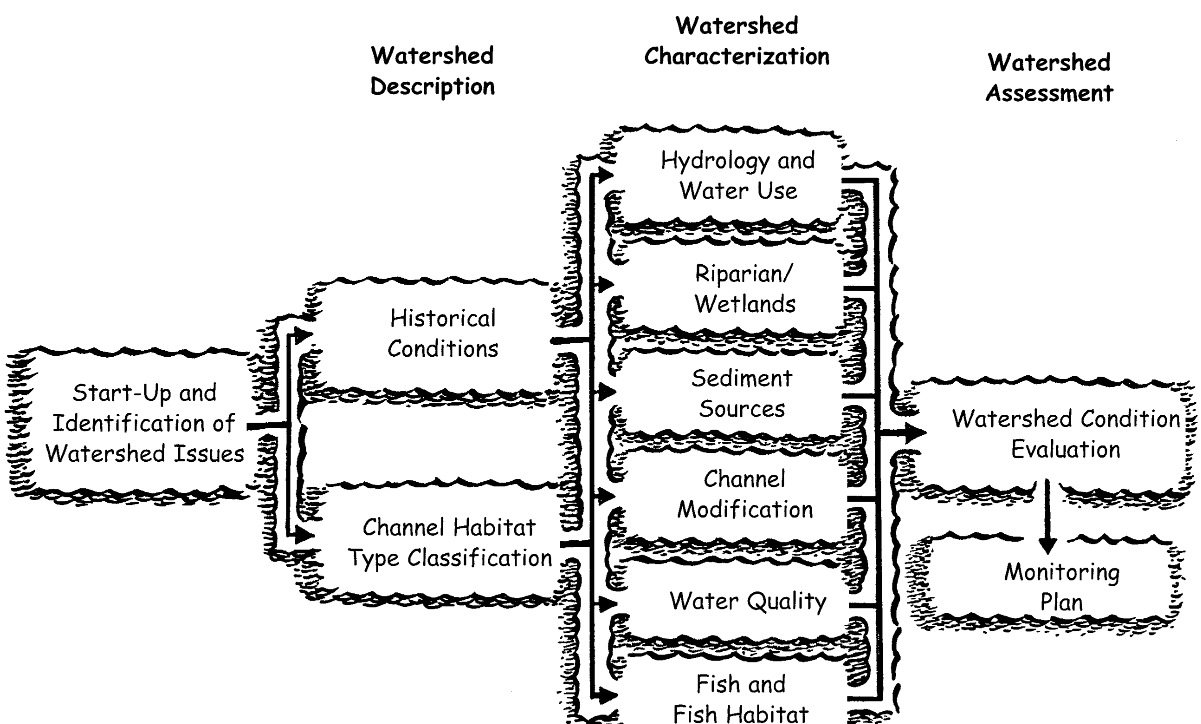


Figure 1. The Watershed Assessment Manual is divided into components so that watershed councils can identify and use those components that meet their needs. Different people can work on different components at the same time.

3. A concluding *Watershed Condition Evaluation* and *Monitoring Plan*. These components bring it all together after the other components have been completed. With this effort, you'll make sense out of all the maps and information you've worked on to this point.

As mentioned above, the main body of the manual is divided into *components* (see Figure 1) so that watershed councils—and others who conduct the assessment—can plan and allocate their resources and time. Different people can work on different components at the same time.

1. The first component, *Start-Up and Identification of Watershed Issues*, sets the stage for the assessment, and helps the assessment team compile background information needed later in the assessment.

2. The next two components, *Historical Conditions* and *Channel Habitat Type Classification*, involve developing basic maps and gathering background information.

3. Then there are six procedural components for watershed characterization and assessment; these are the guts of the assessment, what makes it work.

4. Finally, the last two components, *Watershed Condition Evaluation* and *Monitoring Plan* bring it all together, revealing which areas need protection and which have high potential for restoring water quality and fish habitat.

Each component begins with a set of standard topics:

1. A list of c*ritical questions* to guide the approach used in each component and let you know what's coming

2. The a*ssumptions* behind the component and its procedures to help you understand what's going on

3. The *skills needed* to complete the component, to help you figure out who should be working on this part, and whether or not you'll need additional technical expertise

How many components will be needed for an assessment? *The manual was developed so that watershed councils could identify and use those components that meet their needs*. The number of components that will be used will depend on the watershed in question and on resources available to conduct the assessment. Small watersheds with a history of little human activity may require only a few components for an assessment, while larger, more complex watersheds will require more. Likewise, for watershed councils that are just getting started and have few resources, only a few essential components may be possible, just enough to give them an idea of what they need to do next. Other watershed councils, those that have been in existence for some time and have more resources, may be able to complete a full complement of the components they need (although not necessarily all the components in the manual) for their assessment. Our advice: Get organized first, identify your human resources for the assessment, and get advice from resource experts before you decide how many components to use in your assessment.

Where did all the information come from to develop the manual? Many references and sources of expertise were used. Scientists usually include the sources of information they use within the body of their texts, but to maintain readability, the references used to develop this manual are shown at the end of each component.

Like any watershed assessment, the manual is a work in progress. We think we used the best current information available, but as new information becomes available, we'll be revising the manual. If you're using the manual to learn more about watersheds, or as a tool to teach others about watersheds, we hope you find it useful. If you are a member of a watershed council—using the manual as your guide, your cookbook, and your constant reference—we hope you wear it out soon. Good luck.

GLOSSARY

channel gradient: The slope of the stream channel floor (or the water surface) with respect to the horizontal, measured in the direction of flow.

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, **channel pattern**, and **confinement**. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

ecoregion: Land area with fairly similar geology, flora and fauna, and landscape characteristics that reflect a certain ecosystem type.

Watershed Fundamentals

Table of Contents

Table of Contents (continued)

Watershed Fundamentals

INTRODUCTION

Making decisions about a watershed is an important responsibility; decisions must be based on a solid understanding of the characteristics of the watershed and how physical processes shape watershed conditions. This section provides basic background information on watershed functions and processes to help users understand the assessment procedure and the results of the assessment process. Watershed "processes" refer to those natural physical, chemical, and biological mechanisms that interact to form aquatic ecosystems. For example, the input and routing of water, ***sediments***,[1] and large wood through stream channels involve many inter-related processes occurring both in-channel and upslope.

WHAT IS A WATERSHED?

The term "watershed" describes an area of land that drains downslope to the lowest point (Figure 1). The water moves by means of a network of drainage pathways that may be underground or on the surface. Generally, these pathways converge into a stream and river system that becomes progressively larger as the water moves downstream. However, in some arid regions, the water drains to a central depression such as a lake or marsh with no surface-water exit.

Watersheds can be large or small. Every stream, tributary, or river has an associated watershed, and small watersheds aggregate together to become larger watersheds. It is a relatively easy task to delineate watershed boundaries using a topographical map that shows stream channels. The watershed boundaries will follow the major ridge-line around the channels and meet at the bottom where the water flows out of the watershed, commonly referred to as the mouth of the stream or river.

Figure 1. Watershed is an area of land that drains downslope to the lowest point.

The ***connectivity*** of the stream system is the primary reason why aquatic assessments need to be done at the watershed level. Connectivity refers to the physical connection between tributaries and the river, between surface water and groundwater, and between wetlands and these water sources. Because the water moves downstream in a watershed, any activity that affects the water quality, quantity, or rate of

[1] Terms found in bold italic throughout the text are defined in the Glossary at the end of this component.

movement at one location can change the characteristics of the watershed at locations downstream. For this reason, everyone living or working within a watershed needs to cooperate to ensure good watershed conditions.

WATERSHED TERMINOLOGY

Definitions

"Watershed" can refer to drainage areas of a wide variety of sizes, and this may create confusion about what is being discussed. Words such as draw, drainage, basin, and sub-basin are also used to describe areas that drain water. The term basin usually refers to a larger river basin, and the terms drainage and draw are usually a component of a watershed or subwatershed. The Federal Guide to Watershed Analysis suggests using specific terms for the different levels (Figure 2). In addition, the hierarchical structure of the watershed system allows for the systematic assignment of identification numbers. The US Geological Survey (USGS) has developed maps that assign a ***Hydrologic Unit Code*** (HUC) number to the larger watersheds. This number is often referred to as the watershed **HUC Number** and consists of four pairs of numbers or "**fields.**" Thus, HUC Number 17090001 denotes the watershed that is the Middle Fork of the Willamette River and is referred to as a 4th field HUC. The State of Oregon has 49 4th field HUC's. These 4th field HUC's are quite large and the State of Oregon has subdivided them further into 5th field HUC's. There are 1,063 5th field watersheds, with an average size of 58,218 acres. Further subdivision is possible, and portions of the assessment process summarize information by subwatershed. The State of Oregon is currently working on delineating 6th field subwatersheds statewide.

Assessment Size

The assessment is designed to provide a consistent process and repeatable results across the state. In order to maintain consistency, it is necessary to define an appropriate watershed size that establishes a standard approach to assessing watershed conditions. Performing a large-scale screening assessment of a very large basin, as in the case of the Bradbury Process (Bradbury 1995) or the Upper Columbia Ecosystem Management Project, may help establish regional priorities, but will not be of much value for specific project prioritization and development. A comprehensive assessment of a very large basin can be a daunting task because it is difficult to compile large amounts of data and then portray and interpret them in a meaningful way. The resulting maps can become too large to handle or the scale will become so small that it is impossible to portray information with any degree of resolution. On the other hand, a comprehensive assessment in a very small basin may produce useful site-specific information but there will be no context to evaluate this information to larger areas. For these reasons **THIS ASSESSMENT MANUAL WAS DESIGNED for 5TH FIELD WATERSHEDS, OR WATERSHEDS OF ABOUT 60,000 ACRES.** The existing 1,063 5th field watersheds defined by the State of Oregon should be used as the basis for assessment. The assessment process can be applied to several connected watersheds, which will allow the results to be combined and form a composite assessment of a larger basin or ***ecoregion***.

See Start-Up component, which describes how to identify and subdivide your watershed.

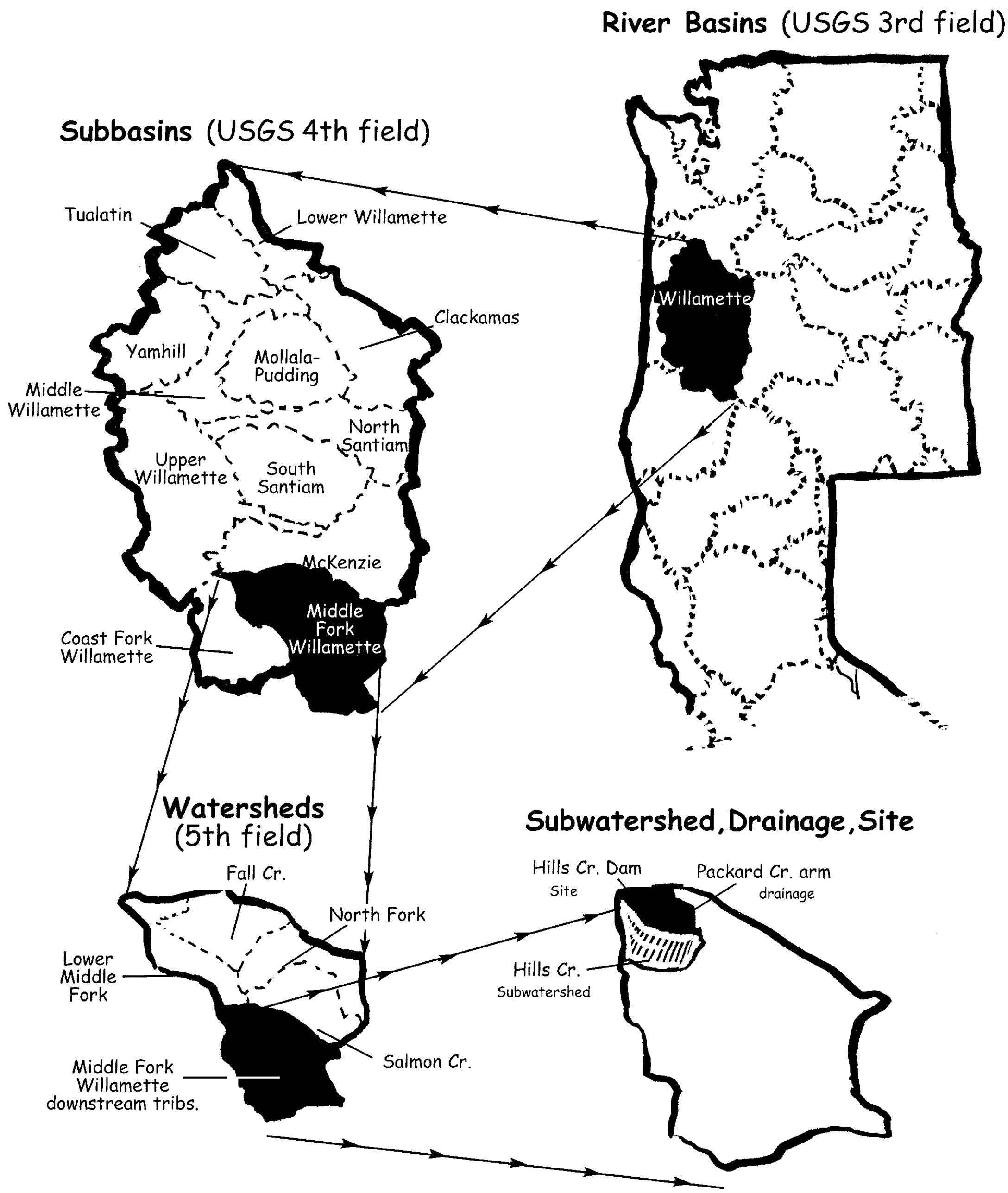


Figure 2. Suggested terminology for watershed descriptive terms based on USGS hydrologic "fields." These fields correspond to the following terms: river basin (3rd field), sub-basin (4th field), and watershed (5th field). In the figure, the Willamette River Basin is divided into sub-basins including the Middle Fork Willamette, which is divided into watersheds including the Middle Fork Willamette downstream tributaries. This watershed then includes a subwatershed, drainage, and site, as seen in the lower right of the figure.

REGIONAL PATTERNS IN WATERSHED CONDITIONS

Large-Scale Processes

The geology, climate, and ***disturbance*** regimes of an area influence the shape and condition of a watershed. The geology, climate, and vegetation of the area determines the type and distribution of soils within the watershed, which influences the amount of erosion and the character of sediments in the stream channels. Also, geologic uplifting from deep within the earth can influence the slope and orientation of the bedrock material. Earthquakes can cause large blocks of the earth's surface to shift, creating distinctive fault lines.

The prevailing local climate acts upon this geologic setting to determine the quantity and timing of ***precipitation*** that falls into the watershed, which in turn influences the vegetation patterns. Latitude, ***elevation***, and aspect (directional position) are important because they influence the timing and quantity of the solar energy that a watershed receives, and influence vegetation patterns within the watershed.

In addition to the climatic patterns that shape the landscape, watersheds are subject to periodic disturbances that can have a significant influence on stream channel conditions. Natural disturbances may be large-scale events like flood or fire that impact the entire watershed, or can be very localized, such as a pocket of trees that are blown down into the stream channel. Watersheds will typically undergo short periods of catastrophic change—for example, a large storm that produces huge floods and widespread landslides—followed by intervening periods of relative stability. Both large- and small-scale natural disturbances are an integral part of the watershed's evolution, and the aquatic community has adapted to this disturbance regime. For example, floods can create new pools, and landslides can act to deliver large trees and spawning gravels to stream channels, both of which are important for forming fish habitat.

Human activities can modify the natural disturbance regimes by changing the timing and intensity of these natural processes. For example, urbanization and roads increase ***impervious surfaces*** and change the routing of water (Figure 3). These conditions can increase ***flood peaks*** and landslide frequency above the range that would be expected in undeveloped conditions. Conversely, dams and other water impoundments can reduce flood peaks and interrupt sediment supply, impacting the aquatic system by limiting the creation of side-channels or delivery of spawning gravels.

See Start-Up and Identification of Watershed Issues component for details on how to determine the ecoregion(s) in your watershed.

All of these factors work together over time to form consistent patterns over geographic areas with similar characteristics. Large areas of land that have similar characteristics are referred to as ecoregions. The State of Oregon is divided into ecoregions that have been identified through the analysis of the patterns and composition of ***biotic*** and ***abiotic*** phenomena that reflect differences in ecosystem quality and integrity. These phenomena include climate, geology, physiography, vegetation, soils, land use, wildlife, and ***hydrology***. Each ecoregion has characteristic disturbance regimes that shape the form and function of watersheds in the region. This assessment manual uses Level III and Level IV ecoregions to help characterize patterns within a watershed (Figure 4.)

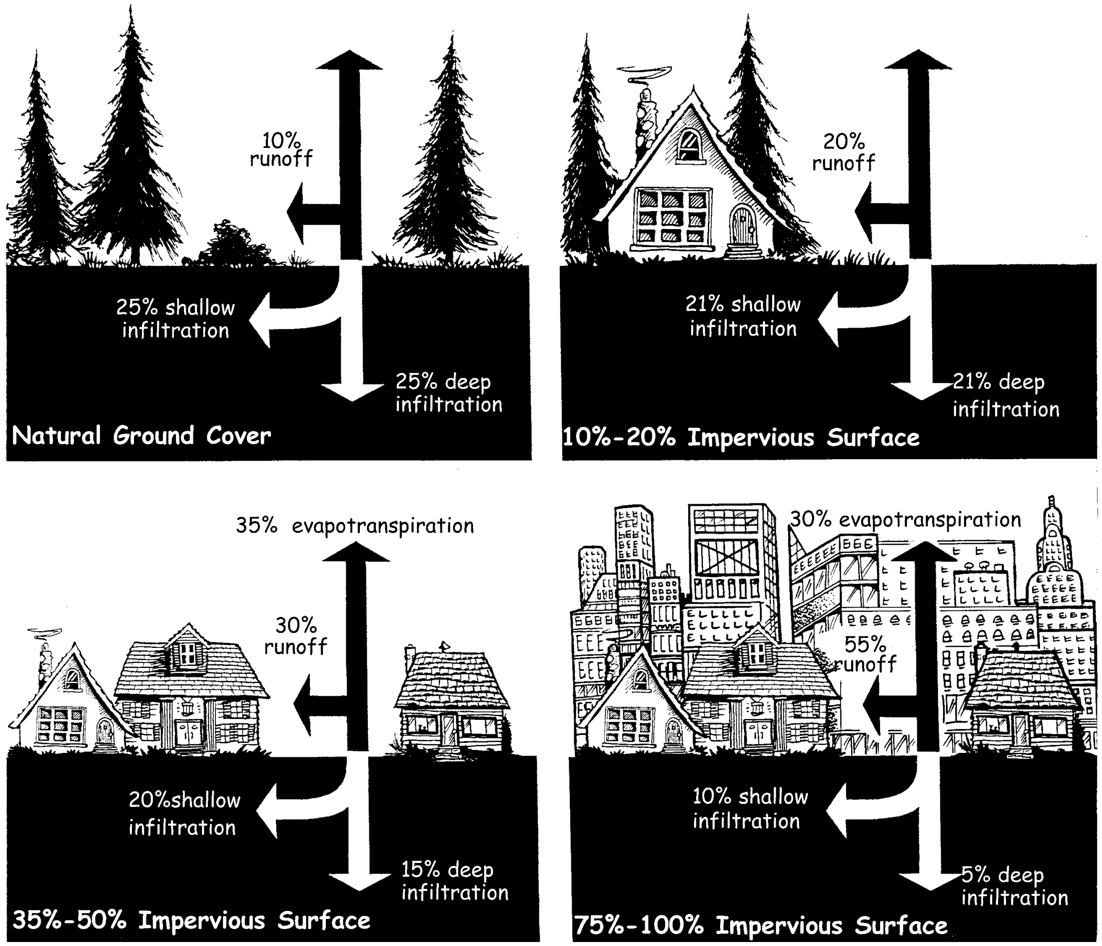


Figure 3. Human activities such as urbanization and road development can modify the routing of water. An increase in impervious surfaces causes a decrease in infiltration and an increase in runoff.

Stream Network

See Channel Habitat Type component for instructions on identifying CHTs.

The processes that operate in a particular watershed work on a number of different levels. On a large scale, the geologic and climatic conditions shape gross watershed characteristics such as basin size and ***stream density***. On a finer scale, geologic conditions and biologic inputs combine to influence localized characteristics such as the number of pools in a section of stream. This makes the stream channel network a focal point of many watershed processes occurring between ridge-tops. Common patterns in these formative processes have produced groups of streams that display similar physical characteristics (Figure 5). These stream groups provide aquatic habitat conditions that respond in predictable patterns to natural and human-caused modifications. These groupings of stream types are called ***Channel Habitat Types*** (CHTs). This channel stratification system

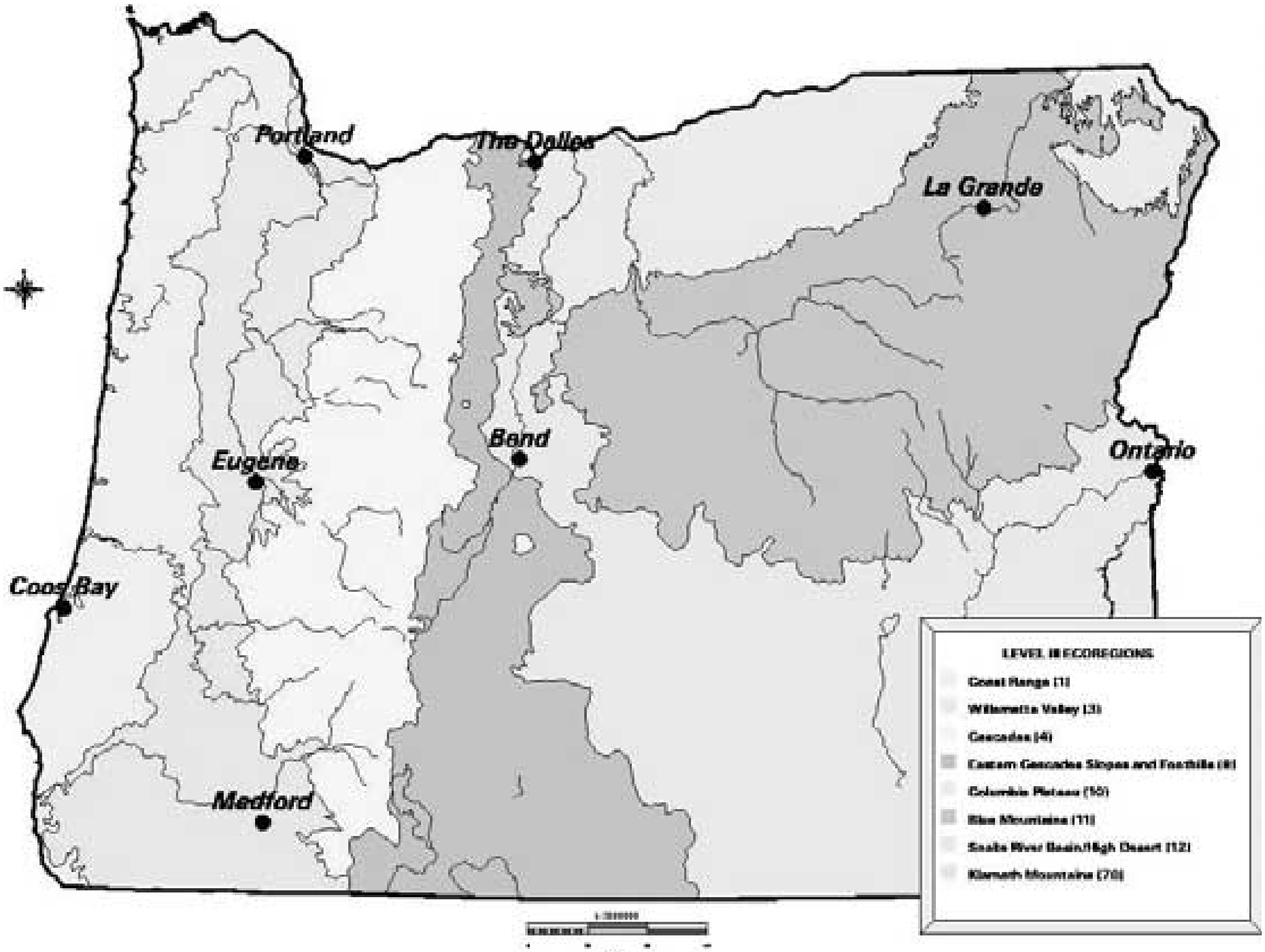


Figure 4. This assessment manual uses Level III (shown in figure) and IV ecoregions to characterize patterns within a watershed.

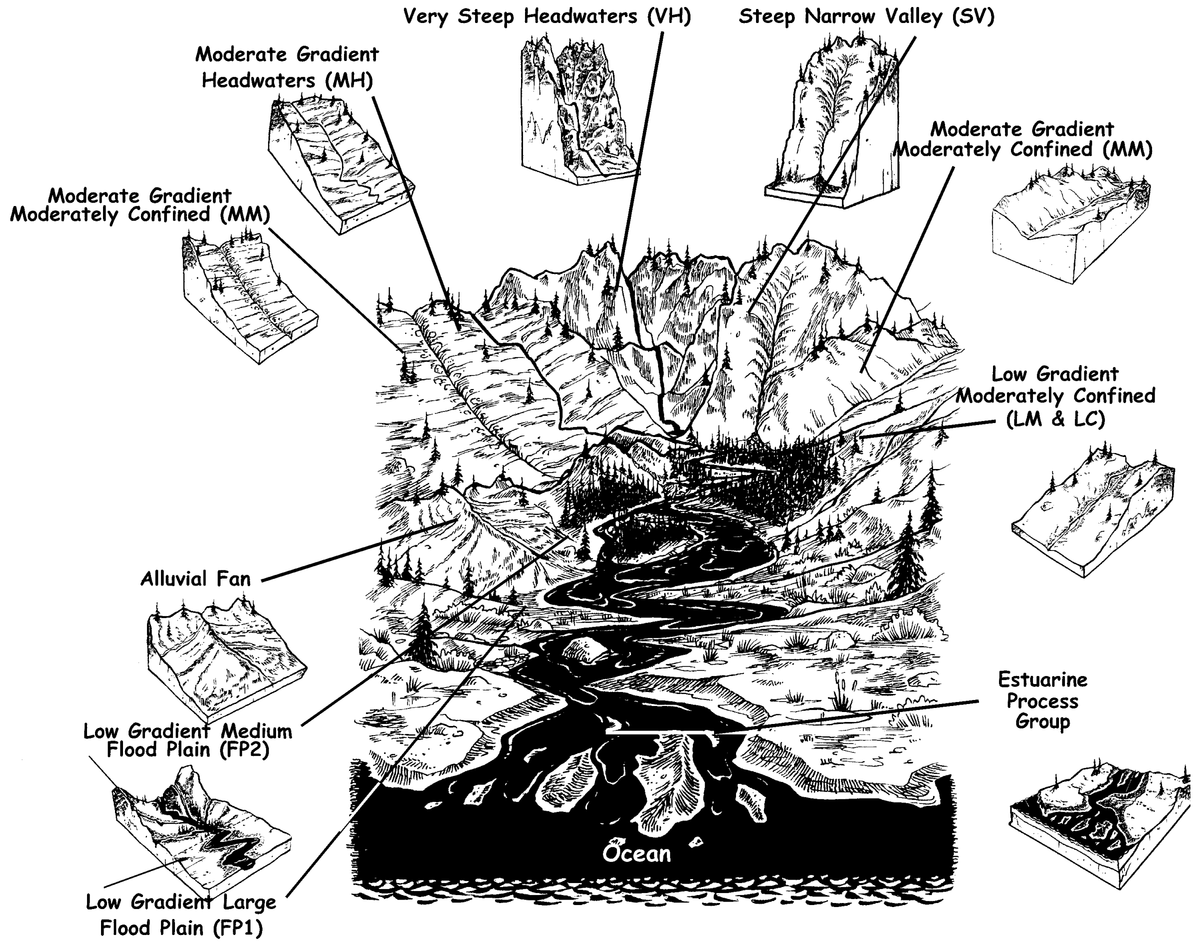


Figure 5. Typical distribution of CHTs in a mountainous watershed.

provides a framework and mechanism for evaluating (1) basin-wide stream channel conditions, (2) the influences of land management activities on specific stream reaches, and (3) potential restoration opportunities.

See Historical Conditions and Channel Modification components to map human impacts to the stream channels.

The Historical Conditions Assessment component provides a methodology for obtaining and interpreting historical material to identify where potential impacts may have occurred, and to describe what the watershed may have looked like before human activities. The Channel Modification Assessment component systematically determines how the channels in the watershed have been modified by various human uses. Often, it is hard to separate impacts resulting from current, ongoing land and water management activities from historical or ***legacy activities***. For that reason, knowledge of past use can provide a context to help us understand the current condition of a watershed.

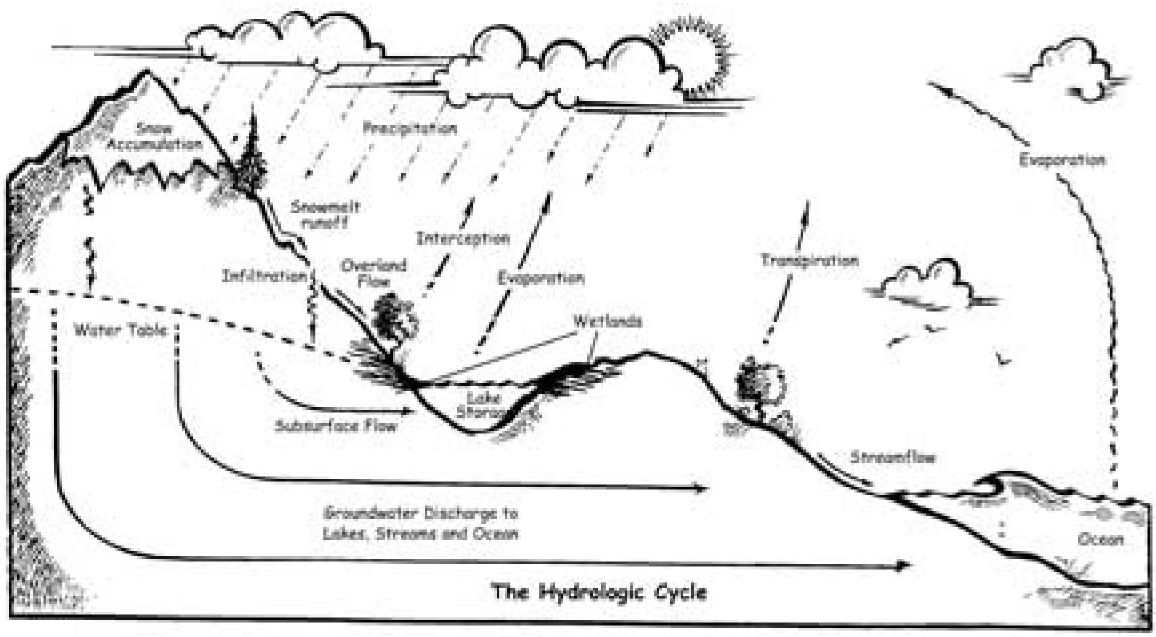


Figure 6. The hydrologic cycle describes the circulation of water around the earth, from ocean to atmosphere to the earth's surface and back to the ocean again.

WATER DYNAMICS

Anyone who has experienced hardship associated with a drought or seen the havoc caused by floods or landslides knows that the distribution and movement of water in an area can be highly variable. Likewise, what we do in a watershed can affect the amount and quality of water that is available. This section covers the basic concepts and terms necessary for understanding the hydrology of a watershed and how we can affect the movement of water.

The Hydrologic Cycle

The ***hydrologic cycle*** (Figure 6) describes the circulation of water around the earth, from ocean to atmosphere to the earth's surface and back to the ocean again. Oceans, covering 70% of the earth's surface, play a large role in the movement of water through this cycle. Solar energy evaporates water from the ocean, wind carries the water over the land surface, and water is precipitated by gravity back to earth. Rain is the most common form of precipitation, but snow, hail, dew, fog drip, and frost all can bring water into a watershed.

Precipitation that reaches the surface of the earth moves through three different pathways. Water can:

1. Be intercepted by vegetation and evaporated or transpired back to the atmosphere.
2. Move downslope on the surface or through soil to a stream system, eventually making its way back to the ocean.
3. Be stored in snowpack, groundwater, ponds, or wetlands for a variable period of time.

Heat from the sun can evaporate water from any point in the cycle, from the surface of vegetation, ground, or water bodies. The rate of evaporation in a watershed is dependent on the water surface area exposed to the air, air temperature, humidity, and wind. The average annual evaporation from shallow lakes in Oregon ranges from 20 inches on the coast to 46 inches in the south-central region of the state. ***Transpiration*** is the loss of water to the atmosphere through living plants. The two processes of evaporation and transpiration are referred to as ***evapotranspiration*** (ET). The difference between rainfall and runoff in a watershed can largely be explained by ET. The annual amount of water leaving a ***drainage basin*** as runoff varies, from less than 10% of yearly precipitation in hot desert climates to greater than 90% in the Cascade Mountains. The amount of water intercepted, evaporated, and transpired in a watershed is dependent on the type and the extent of vegetative cover in a watershed. Land uses that alter the vegetative cover of a watershed can affect the water available for runoff.

When water evaporates, it enters the atmosphere as water vapor that eventually condenses to form drops of water (if the temperature is above 32°F) or ice crystals (if below 32°F). When the drops of water or ice crystals have grown large enough or when the wind moves them through the air, they fall to the earth. Upon reaching the earth, water will tend to move downslope, under the influence of gravity. ***Precipitation intensity***, the rate at which water is delivered to the earth's surface, is usually less than ***infiltration***, the rate at which water enters the soil. Thus, most of the precipitation infiltrates into the soil and little, if any, ***surface runoff*** or overland flow occurs. In the case where the precipitation intensity exceeds the soil infiltration rate, surface runoff occurs. Additionally, there are a few watershed conditions under which surface runoff will occur, including precipitation on very steep slopes, in watersheds with thin soils over bedrock, and in disturbed watersheds (particularly those with a large area of impervious surfaces). Land uses in a watershed can have a significant impact on infiltration rates. Decreases in infiltration rates result in water moving more quickly to streams, causing ***peak flows*** to occur earlier and to be larger in magnitude. Decreases in infiltration also reduce water storage and result in lower ***low flows***.

Water that enters the soil infiltrates vertically to the groundwater table. From there, water moves either toward the river channel or percolates and becomes groundwater. Water that enters the river channel becomes surface water, called streamflow or ***discharge***. Streamflow is conveyed by gravity through the stream channel to connect with progressively larger channels, eventually flowing into the ocean. The length of stream channels with actively flowing water depends on the volume of water moving through the system. During the dry season, there are typically fewer actively flowing channels than during wetter periods.

Groundwater can be recharged from the nearby stream channel (a losing reach) or can provide flow to the channel (a ***gaining reach***), depending on the relative energy (***hydraulic gradient***) and the ability to transmit flow. The direction of flow between connected surface- and groundwaters depends on the hydraulic gradient and the ability of the soils to transmit flow.

Water can be stored in seasonal snowpack, as groundwater storage, or in surface-water storage such as ponds, wetlands, lakes, and reservoirs. Spring runoff is derived from melting snowpacks, whereas summer baseflows represent groundwater discharge to the stream during dry or low-flow periods. Water stored in ponds, marshes, wetlands, and lakes are often of special interest because these areas represent unique features in the watershed and may be used in special ways by plants, animals, and humans. Land uses in a watershed can have a significant impact on the amount of stored water.

Conditions that reduce the infiltration rate can also lead to a reduction in the amount of water held in groundwater storage.

Hydrologic Data: Collection and Use

The USGS has been primarily responsible for establishing a network of streamflow ***gaging stations*** that record discharge for many streams and rivers throughout the country. The records from these stations are published annually in *Water Resources Data* reports for each state. These records include the mean values for the daily, monthly, and annual flows; annual instantaneous peak flows (largest annual flow); annual minimum flows, etc. USGS streamflow data can also be obtained via the Internet. Hydrologic information can be summarized and displayed in many ways. For instance, the plot of streamflow over time is called a ***hydrograph***. Some typical annual hydrographs based on mean monthly flow values from different ecoregions are illustrated in Figure 7. The quantity of water flowing through the channel of a stream or river can vary by several orders of magnitude throughout the year as well as from year to year.

The shape of the hydrograph provides an identifying characteristic of a watershed. In watersheds where peak flows are generated primarily from rainstorms, the annual hydrograph curve tends to have one period of higher flows occurring during the storm season (most often fall/winter). Similarly, watersheds where snowmelt produces peak flows have an annual hydrograph with one high-flow period occurring in the snowmelt months (April to June). Both fall and winter events and ***spring snowmelt*** events produce peak flows in many watersheds. The annual hydrograph for these watersheds will have two periods of higher flows (Figure 7).

Hydrographs can also represent periods shorter than a year; storm hydrographs are often constructed to illustrate the changes in flow over the course of a storm, typically 3 to 5 days. During a storm event, water is collected by the watershed and is routed downstream past the gaging station. Since it takes time for the water to move from the upper end of the watershed to the gage point, there is a delay or lag before the peak flow occurs at the gage. If the duration of the storm is long and the watershed is small, the maximum flow will be dependent on the rate that the rainstorm supplies water. After the rain stops, the streamflow will gradually diminish as the effect moves

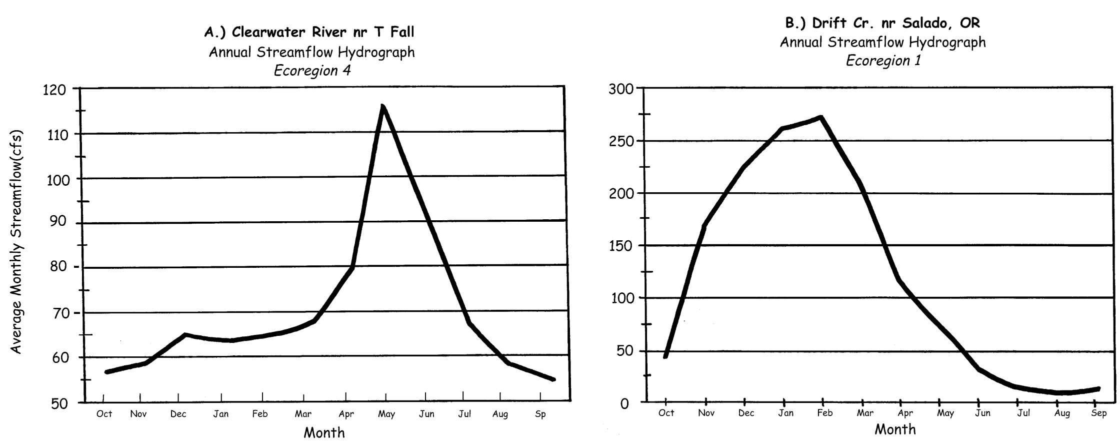


Figure 7. Typical hydrographs from different ecoregions, showing the differences between storm-driven runoff (A) and spring snowmelt (B).

down the channel and the storage decreases substantially. Watersheds with steep slopes and/or thin soils tend to move water relatively quickly, and their hydrographs will be distinctively shaped with sharply rising, spiked peaks. Such watersheds are often referred to as "flashy." Larger watersheds or watersheds with deep soils that retain water or have extensive storage will tend to have more rounded or flatter-shaped hydrographs (Figure 8).

While streams have been flowing for millions of years, humans have collected streamflow data for only a small snapshot in time. Through the use of statistics, the recent past can be used as a predictor of the near future. For example, the data can be used to determine how much water will be available in the average year. Also, the probability that an extreme event such as a flood or drought may occur can be estimated

Information on these extreme events is of special interest, because floods can change the shape of the stream channel and can impact the ***floodplain***, whereas droughts can affect the vegetation and organisms that depend on a constant supply of water or moisture. There is always a risk that some type of extreme event may occur within any given year. Analysis of the historic streamflow records provides a way to determine the probability that an event of a given magnitude will be exceeded. For example, a 100-year flood has a 1% chance of occurring in any given year; a 25-year flood has a 4% probability of occurring in any given year. Figure 9 illustrates some example ***recurrence intervals*** with probabilities.

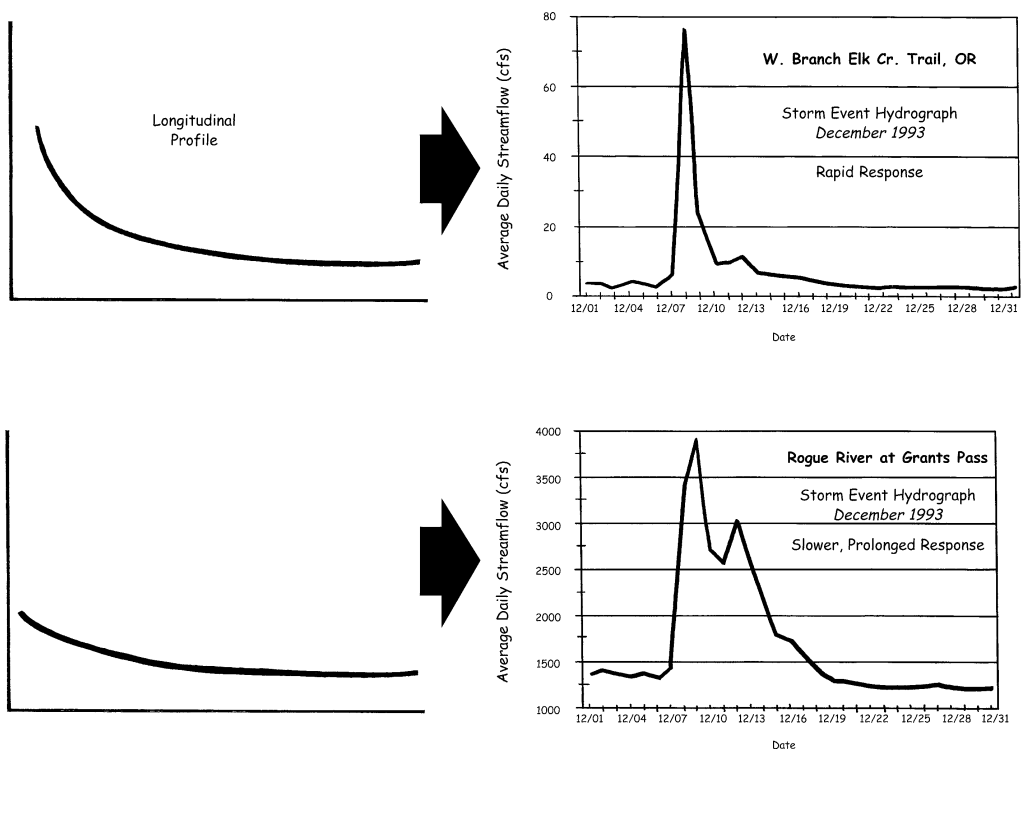


Figure 8. Hydrograph patterns showing the difference between watersheds with a steeper topography, which have a rapid runoff response (top), and watersheds with flatter topography, which have a slower, more prolonged runoff response (bottom).

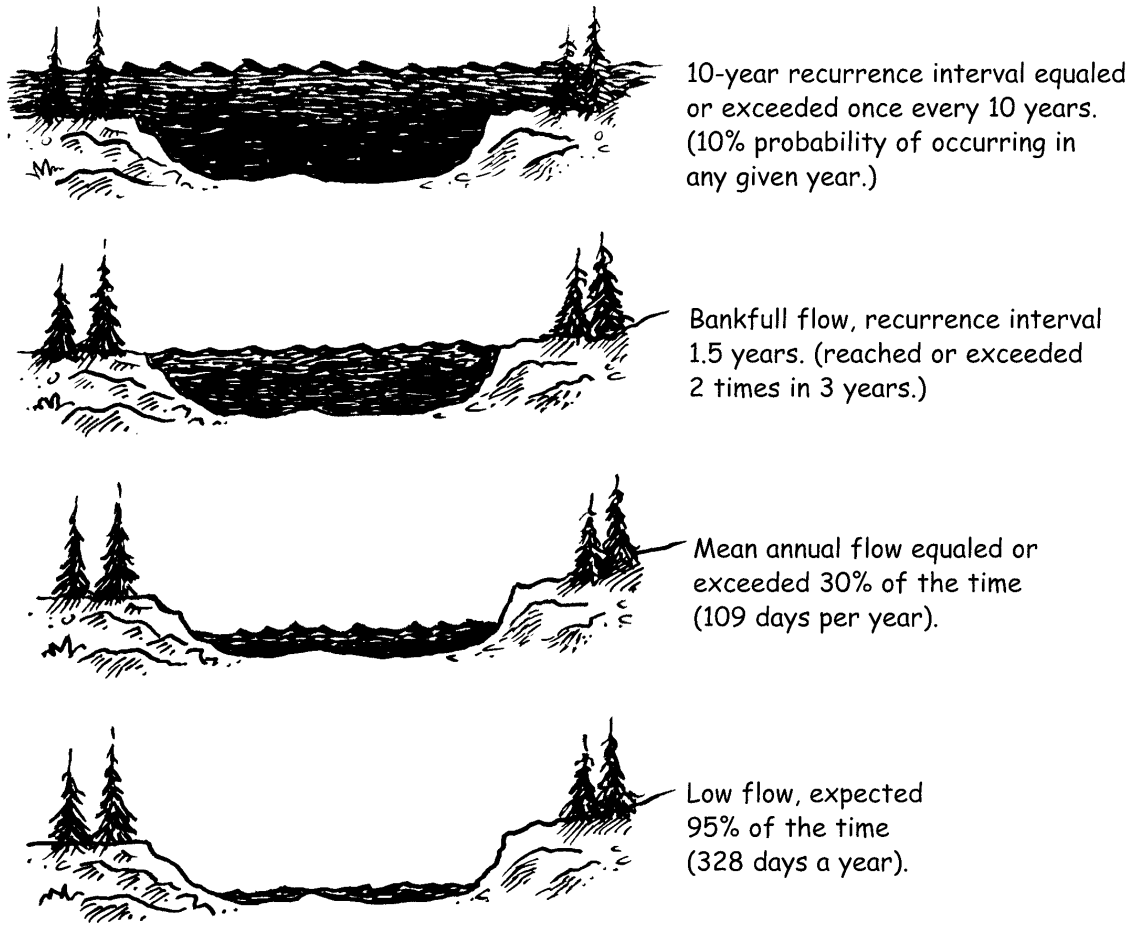


Figure 9. A recurrence interval is the average length of time between two events (rain, flooding) of the same size or larger. Recurrence intervals are associated with a probability, as illustrated in the figure for streamflow.

Land uses in a watershed can have a significant impact on the frequency of floods. For example, impounding water in a reservoir can reduce the frequency and magnitude of floods in the portion of the river below the dam; reservoir operations must be clearly taken into account in a hydrologic assessment.

Understanding long-term climate and streamflow data can help the user realize the variability of the watershed's response to climatic conditions. The Hydrology and Water Use Assessment component provides direction on how to obtain and use this information specific to your watershed.

See Hydrology and Water Use component for how to obtain climate and streamflow data.

Land use and vegetation cover in upland areas can have distinct impacts on the watershed. Large-scale vegetation change can directly influence the flow regime. Reduced vegetation will reduce the amount of transpiration that takes place but can result in higher evaporation rates. Vegetation removal can also increase snow retention in high-elevation forests. The melting of these accumulations can affect the timing of the winter flow pattern, especially in ***rain-on-snow*** areas. The Hydrology and Water Use component provides an evaluation methodology to determine the extent of these effects.

Urbanization increases the area of impervious surfaces on upland areas so water runs off and is not absorbed by soil. This situation can result in increased peak flows, which alter aquatic habitat, and reduced water storage, which causes in reduced summer low flows. Upland agriculture can route water to the stream more efficiently due to ditch and tile drains. This also decreases absorption of water into the groundwater storage system and can result in reduced summer low flows.

Historical and current fire suppression activities have altered the vegetation communities and allowed dead wood material to accumulate to dangerous levels in unmanaged forests. Fire exclusion practices have allowed juniper to become established in former meadow areas. In the absence of periodic fires, sage becomes established; mature sagebrush then offers juniper a protected environment in which to establish. In order to restore the meadow environment, periodic disturbance by fire or other means is needed. In upslope forests this same kind of disturbance, along with retention of larger trees, will be required to re-establish the ponderosa pine/grass (open savannah) plant community.

In areas where dead wood material has accumulated, there is an increased risk of hotter, more severe fires. Hot fires remove all ground cover, expose bare soils, and can create "***hydrophobic soils***," which increase overland flows and runoff. These conditions can have a severe impact on riparian conditions and channel stability. This is a concern in some east-side ecoregions (identified in the Ecoregions appendix).

Consumptive Uses of Water

The use of water and its energy are very essential to the needs of modern society. Obviously, when water is removed or flows are restricted, the function of the watershed is affected. When groundwater is used excessively for irrigation, the flow in adjacent streams or stream reaches can be reduced, resulting in increased stream temperatures. Thus, even irrigation withdrawals that reduce groundwater discharge can also influence in-stream flows. An important part of the assessment process is to identify the locations and amounts of consumptive water uses, and then assess the effect on the watershed and the ecosystem. The Hydrology and Water Use component provides a methodology to make this assessment.

See Hydrology and Water Use component for how to assess consumptive water use.

SOIL EROSION AND SEDIMENT IN STREAMS

Sediment in streams comes from the erosion of upland areas, lateral movement of stream channels (i.e., ***meandering***), and ***downcutting*** of streambeds. The Sediment Sources Assessment component evaluates sources of fine sediments and coarse sediments. Fine particles deposited on the streambed may blanket spawning gravels and reduce survival of fish eggs incubating in the gravel. Fine sediment may cover the exposed rock surfaces preferred by aquatic insects, reducing the food supply to fish. Suspended sediments cause turbidity (clouding of the water), which prevents fish from feeding. Large deposits of coarse sediments can overwhelm the channel capacity, resulting in pool-filling, burial of spawning gravels, and, in some cases, complete burial of the channel, resulting in subsurface streamflows.

The hardness of the underlying rock and its fracturing as the land is uplifted over long periods of time determine the rate of erosion. These geological processes also influence the pattern and density of streams in a watershed. Hill slopes in the central Coast Range erode quickly because of the high rainfall, soft rock, and rapid uplifting of the land by forces deep in the earth. These processes create steep slopes and a high stream density in coastal watersheds. In contrast, central Oregon watersheds usually erode more slowly due to low rainfall, hard underlying rock, and relatively slow uplifting of the land. In these portions of central Oregon, slopes are gentle and streams are sparse across the landscape.

Human activities occur within the backdrop of natural forces that control erosion in a watershed. Understanding the differences between natural and human-induced erosion is important in developing a watershed restoration plan. We have little control over natural erosion rates; in fact, it would be undesirable to decrease the natural erosion rates in a watershed, because aquatic organisms have locally evolved to the natural conditions. Because we can influence only human-induced erosion, it is important to understand how erosion processes are altered by management activities, whether the accelerated erosion is significant compared to natural rates, and where these changes are occurring in the watershed.

The Sediment Sources Assessment component contains methods for identifying various sources of erosion from the following eight potential sediment sources:

1. Road instability
2. Slope instability (not related to roads)
3. Rural road runoff
4. Urban runoff
5. Surface erosion from crop land
6. Surface erosion from range land
7. Surface erosion from burned land
8. Other discrete sources

In addition to identifying potential sediment sources, the sediment assessment helps determine which portions of the watershed have a higher potential for accelerated erosion due to human activities, and segregates human from natural sources of erosion.

It is important to recognize that much eroding soil will deposit on a hill slope before it reaches the stream. This is good news, since there are a number of things that can be done to fix a site that is eroding before the sediment enters the streams. For example, water draining from a rutted road surface can be diverted onto a well-drained slope where the sediment will be filtered out, and the clean water can flow beneath the ground's surface to the stream.

The distinction between erosion and sediment in the stream can become blurred when eroded soil is deposited in or near the stream. A good example of this is a beaver dam, which traps soil particles flowing in the stream. Beaver dams can be so effective at trapping sediment that a large deposit of sediment into a stream can be unnoticeable downstream of the beaver dam. Where dams are stable for a long time and do not wash out during floods, beaver activity can locally raise the elevation of a valley bottom. In such cases, the soil is trapped in place for centuries or longer. Of course, if the beaver dam complexes are temporary and wash out each winter, their overall influence on sediment is minimal.

Another important consideration is that erosion and sedimentation primarily occur in pulses during infrequent events. Typically, an intense rainfall event or flood that happens only once every decade will trigger a chain of events causing large amounts of soil to move rapidly downhill and into streams. An example of this is the February 1996 flood in the Willamette River basin. Over 80% of the annual sediment production for the Willamette River occurred during a few days in February when the flood took place. If the sediment conditions of a stream were examined only during "average" conditions, the sediment yield would probably be greatly underestimated.

There are a number of mechanisms that move soil downhill and into stream channels. The next sections discuss these erosion processes.

Raindrop Splash

Raindrop splash occurs when a raindrop hits a bare soil surface, creates a small crater, and splatters soil grains in all directions. On sloping ground, these detached soil particles have a tendency to land downhill and can be moved further downhill by water that flows over the soil surface. Individually, soil movement caused by the collision of a raindrop is insignificant, but when multiplied by many millions of raindrops the results become noticeable.

Raindrop splash is not common in most of Oregon under natural conditions. Vegetation and organic material at the soil surface absorbs the energy of a raindrop and the soil remains intact. However, if machinery, intense grazing, or high-intensity fire removes this protective material, raindrop splash can occur. Raindrop splash is most noticeable where the soil is not very ***cohesive***, such as soils derived from granitic rock or volcanic ash, or those high in sand or silt.

Ravel

Some soils become less cohesive as they dry. On steeper slopes, gravity can exceed the forces that hold the soil together and particles move downhill. ***Raveling*** is noticeable along steep surfaces immediately uphill of roads. Frost heaves often make conditions worse by reducing the forces that normally hold the soil together. Bare road cuts can produce a sizeable amount of raveled soil, which collects in the road ditch. If this ravel is not removed, this raveled soil can move down the road ditch and into streams during heavy rainfall or when the snow is melting. Ravel is also common on steep, bare stream banks. Here, the detached soil particles have a direct pathway into the stream.

Surface Rilling

Water flowing over the surface of the soil can carry off surface soil in a process called soil ***rilling***. Natural soil rilling does not occur much in Oregon. The ability of the soil to absorb water is usually greater than the rainfall intensity, so no water flows over the soil surface. However, surface rilling does occur where the ability of the soil to absorb water has been reduced, such as road surfaces, intensely grazed areas, plowed steep slopes, or areas recently burned by hot fires. Rainfall collects on the compacted or burned surface and, as it moves downhill, cuts small rills where the soil is softer. Damaged soils can recover their ability to absorb rain. Vegetative cover, frost heave, and soil organisms typically increase soil permeability over time.

Shallow and Deep-Seated Landslides

Shallow landslides can be a common feature on very steep slopes, especially after high-intensity rainfall. These shallow landslides are most common in small depressions on the hillside (Figure 10). Gravity delivers soil to these depressions over time and the soil remains in place until something increases the forces that move the soil downhill. Large amounts of water moving through a depression cause the area to be less stable. High-intensity rainfall or runoff water from roads channeled into the depression can trigger these landslides. A piece of steep hill slope can also become less stable if it is overloaded by soil that is sidecast during construction of a road. On extremely steep slopes, it has been shown that even the roots of trees can hold the soil in place during high-intensity rainfall. After timber harvest on steep slopes, however, the soil becomes vulnerable when roots of the harvested trees rot before the root mass of the new stand of trees has developed.

Shallow landslides typically consist of a failure point on the slope and have little effect on streams unless they end up in a channel. When shallow landslides move into a channel they can trigger ***debris flows***—a rapid movement of soil down a steep channel (Figure 10). The mass of moving material and water usually grows as it moves downhill. Vegetation, logs, boulders, and soil in the path of the debris flow are often incorporated. The debris flow stops once it reaches a lower-gradient stream channel. The effects of a debris flow can be beneficial as well as detrimental to fisheries habitat when viewed over the long term. Large wood and boulders caught up in the debris slide can increase the amount of pools and areas of low-velocity water that fish use for refuge.

Deep-seated landslides often originate from shallow depressions, but can also involve a broader area of a hillslope (Figure 10). The mechanisms for triggering deep-seated landslides are similar to those causing shallow slides, though they result in a thicker mass of sediment movement. Other causes for deep-seated landslides include oversteepening of slopes with road cuts, erosion of the base of slopes leading to oversteepening, and large volumes of subsurface water discharge along impermeable soil/rock units. Often, the failure plane of a deep-seated failure is below the rooting depth of trees, so that trees and other vegetation have less ability to hold soil in place. Types of deep-seated landslides include slumps, block failures, and wedge failures. In some cases, deep-seated

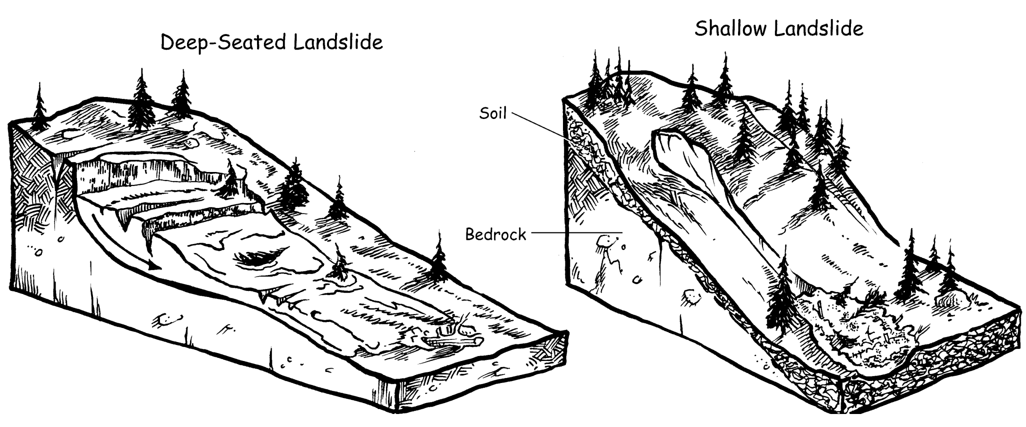


Figure 10. Deep-seated landslides often originate from shallow depressions, but can also involve a broader area of a hillslope. When shallow landslides move into a channel they can trigger *debris flows*—a rapid movement of soil down a steep channel.

landslides can dam and divert flow in streams, because of the large volume of sediment delivered.

Soil Creep and Earth Flows

Soil creep occurs as gravity moves the soil mantle downhill toward streams at rates too small to observe. Soil creep occurs on all sloping areas but is more noticeable in steep terrain. Earth flows are like soil creep except they occur at a faster rate where water saturates the soil and rock mantle. Trees on the surface of an earth flow often become tilted as the soil they are rooted in moves downhill (Figure 11). Creeping soil and earth flows can ultimately constrict stream channels. The stream erodes the soil away, usually during high flows.

Soil creep and earth flows are natural phenomena, although some human activities can accelerate their movement. For example, overloading a slope with sidecast or undercutting a slope during road construction can increase soil movement or cause earth flows. Once an earth flow becomes accelerated, there is little that can be done to fix the problem.

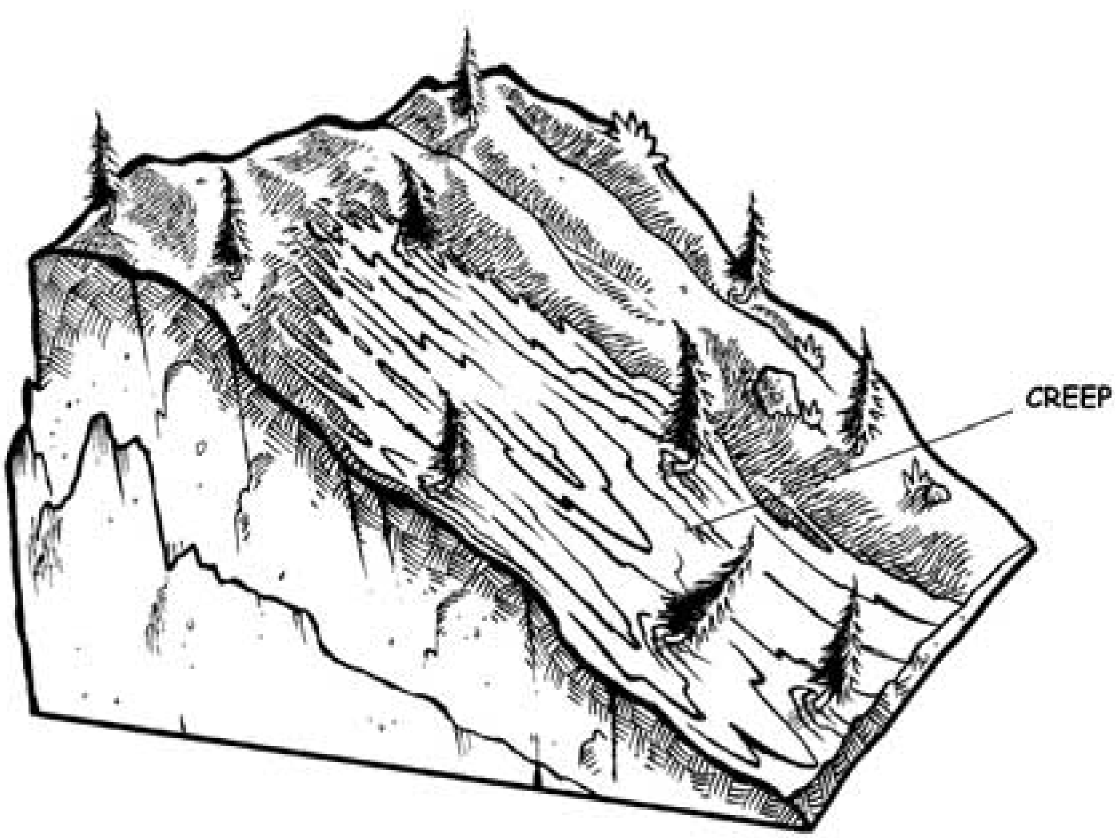


Figure 11. Soil creep and earth flows occur as gravity moves soil downhill toward streams. Trees on the surface of an earth flow often become tilted as the soil they are rooted in moves downhill.

Road-Related Erosion

The road network is another potentially significant erosion feature. Improperly placed roads can divert sediment-laden water to streams. Poor drainage of roads can lead to gullying and channeling of the road surface. Improper maintenance of inboard road ditches can cause saturation of the roadbed, leading to ***mass wasting***.

Road washouts also can occur when a road adjacent to the stream is undercut and a portion of the road drops into the stream, or at stream crossings during a high flow where there was either an undersized or plugged culvert or bridge. In steeper terrain, road washouts can create shallow landslides on unstable fill or cut-slopes failures. Appropriate sizing of culverts and bridges at stream crossings, locating roads away from streams, designing roads properly, and correctly disposing of soil during road construction on steeper slopes can prevent most road washouts.

Channel Erosion

The appearance of a channel reflects site-specific, relatively short-term processes, such as flow energy, and resistive forces set in the broader landscape factors of geology and climate. The complex interactions among these factors ensure that stream channels are seldom in a steady state. One of the most obvious results of this dynamic situation is channel erosion. It is a natural process resulting from the stream power being greater than the resistive forces. Considerable damage can be done to a stream and the fish habitat it provides by drastically changing the relationship between flow energy and resistive forces such as sediment deposits. Channel erosion and meandering help create gravel deposits, deep pools, and areas of low water velocity that are critical to fish habitat.

Channel erosion often occurs when in-stream sediment supplies are low and flows are high. The excess stream energy is directed at the channel bed or bank. As this process continues, the channel will start to form a meander pattern. During drought periods when floods are infrequent or sediment supply is unusually high, a stream typically experiences a net increase in sediment stored within its channel. Much of the stream energy is spent reworking sediment deposits rather than eroding banks. In addition to these site-specific, seasonal influences, the role of channel erosion is dictated by the channel type, which is in turn a result of the landscape factors of geology and climate. For example, lower-gradient streams show a much greater response to both natural and human-caused variations in flood frequency and sediment supply.

The stream channel shape and configuration reflect the balance between erosive forces and sediment deposition. Channel shape also provides a useful way to characterize various portions of the watershed. The Channel Habitat Type Classification component of the manual describes how to classify channels within a watershed to help understand how each portion of the stream network interacts with the entire watershed. In addition, classification of channels allows some modest predictive capabilities about how channels react to changes within the watershed.

See Channel Habitat Type Classification component.

Due to the complexity of the many interactions that influence channel erosion, it is beyond the scope of this document to present assessment methodologies for channel erosion. In basins where obvious and widespread erosion is occurring, a geomorphologist or hydrologist should be consulted.

VEGETATION

Human activities can alter the vegetative patterns in a watershed through timber harvest, forest management practices, fire suppression, agriculture, grazing, and conversion to urban areas. These changes can potentially impact water temperatures, sediment delivery to streams, and the amount and timing of runoff. To evaluate these potential impacts, it is important to understand the functions of vegetation in a watershed, and how alteration of vegetation can ultimately influence fish habitat and water quality.

See Historical Conditions component and Ecoregions appendix for assessment of fire history and other disturbances.

Vegetation patterns and characteristics within a watershed generally change over time. Fires are a primary process of vegetative disturbance that has the potential to cause widespread tree death and the initiation of new forests. The frequency of ***stand-replacing fires***, referred to as fire cycles, varies in Oregon from west to east due to decreases in precipitation, and from north to south because of increasing temperature and occurrence of lightning. Fire regimes are also strongly affected by topography; e.g., south-facing slopes burn more frequently than wide valley floors. Fires can be detrimental to a watershed when ground cover is removed, bare soil is exposed, the soil is damaged or sterilized, or large downed wood in the channel is destroyed, affecting channel stability. Typically, a catastrophic event such as a fire removes or sets back the established vegetative growth and a new cycle of recovery begins. Insects and disease also affect this cycle. When dry, dead material derived from trees killed by insects or disease accumulates, the risk of fire increases and eventually most areas burn. The typical history of fires and other disturbances, and their effects on vegetation in the watershed, are discussed in the Ecoregions appendix and evaluated on a local basis in the Historical Conditions component.

Role of Upland Vegetation

Vegetation functions to slow runoff and reduce soil compaction, allowing better percolation of rainfall into soils and groundwater, which creates better water storage for summer baseflows. In addition, the patterns, sizes, and composition of the vegetation affect many wildlife species. Finally, vegetative composition and density can reduce or prevent soil erosion. Leaves and branches intercept the falling rain and reduce the effect of raindrop splash. Vegetative litter from dead leaves and branches builds up an organic surface that provides protection of the soil layer. Root systems help to keep soil material from moving downslope. When landslides do occur they often bring large wood into the channel, which has an important influence on channel condition and fish habitat. The effects of vegetation removal on soil erosion are discussed in the Sediment Sources component.

See Sediment Sources component for discussion of the effects of vegetative removal on soil erosion.

In some areas of Oregon, ***upland vegetation*** may influence snow accumulation, and the timing of snowmelt and runoff. In areas of the western Cascades, snowmelt in open areas may be accelerated during the relatively warm and windy winter storms that come from the southwest. In eastern Oregon, patterns of vegetation may change the process of

See Hydrology and Water Use component for discussion of how vegetation removal affects hydrology.

snow accumulation and melt, potentially changing the timing and amount of runoff in the late spring and summer. Removal of landscape vegetation can also increase water yield and discharge during the normal low-flow period, although the effect is short-term. The effects of vegetation removal on the hydrology of the watershed are evaluated in the Hydrology and Water Use Assessment component.

Role of Riparian Vegetation

The green areas along streams and rivers are ***riparian areas***; the characteristic plant communities that occur there are referred to as ***riparian vegetation***. Riparian areas generally have higher levels of soil moisture than adjacent upland areas, and usually are well-vegetated. A wide variety of hydrologic, geomorphic, and biotic processes determine the character of the ***riparian zone***.

Riparian vegetation influences fish habitat and water quality in a number of ways. Riparian vegetation may act as a filter in some areas, keeping sediment and pollutants out of streams. The roots of riparian vegetation stabilize stream banks by reducing erosion and preventing stream channels from downcutting. Streamside vegetation provides habitat for insects, some of which fall in the water and provide a food source for fish. In addition, vegetative litter is an important source of nutrients to the stream. During high stream flows, riparian vegetation may slow and dissipate the energy of floodwaters, preventing erosion (Figure 12). Although all of these are important functions of riparian vegetation, they are difficult to quantify and are beyond the scope of this assessment process. This assessment focuses only on the functions of the riparian areas in providing a source of large wood to the stream, and in providing shade for temperature` control. Riparian areas that are

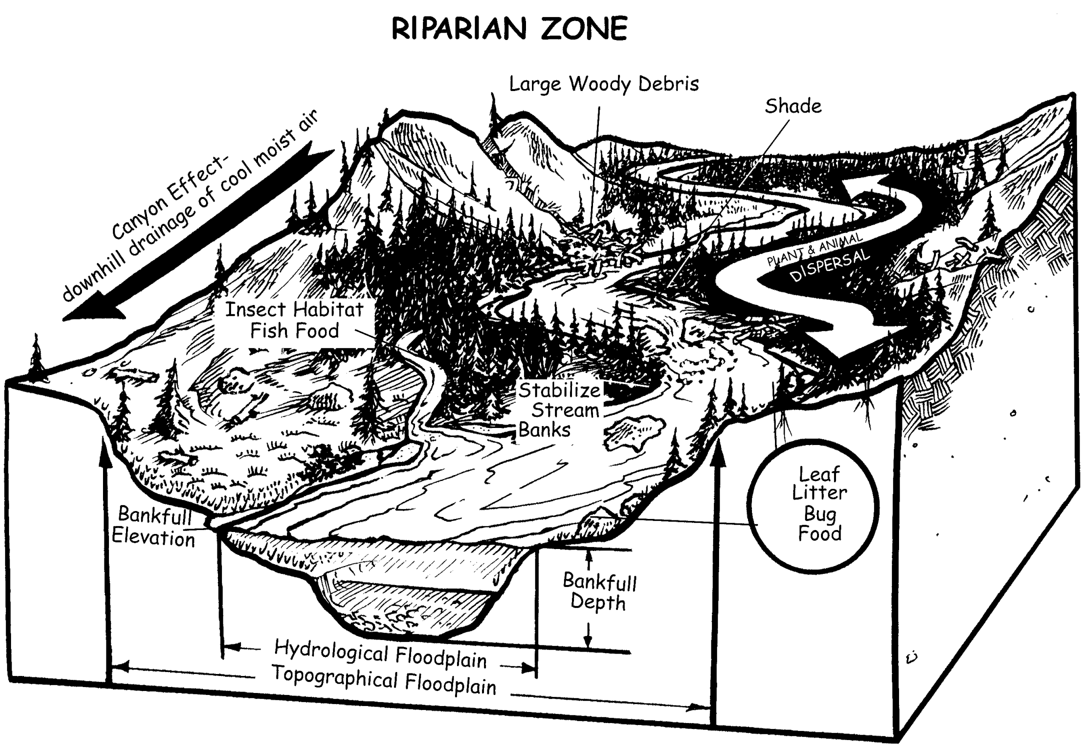


Figure 12. The riparian zone provides a number of functions, as illustrated.

functioning to provide these two key inputs will also generally provide the other functions and processes attributed to riparian areas.

Large Wood Recruitment

Riparian areas are an important source of large woody debris (LWD) that enters, or is ***recruited*** to, the stream channel. LWD includes tree boles, root wads, and large branches, and is recruited to the stream by bank erosion, mortality (disease or fire), or ***wind throw***. As mentioned above, trees from both the riparian and upland areas may also be carried into the stream by landslides (Figure 13).

In the stream channel, LWD diverts and obstructs flow, thereby increasing ***channel complexity*** (i.e., the large wood creates pools and riffles that provide areas of different velocity and depth). This complexity provides cover from predators, creates rearing areas, and develops refuge areas for fish during high stream flows. LWD also creates storage sites for sediment in all sizes of streams. In small headwater streams, wood controls sediment movement downstream. In larger streams, accumulation of sediment behind LWD often provides spawning gravels. LWD plays an important role in stream nutrient dynamics by retaining leaf litter and needles, making these energy supplies available for consumption by aquatic insects that ultimately serve as food for fish.

See Ecoregions appendix and Riparian/Wetlands component regarding the role of LWD.

The importance of riparian zones for providing LWD varies by ecoregion. The Ecoregions appendix provides a description of potential riparian vegetation and the role of LWD in different areas of the state. The Riparian/Wetlands Assessment component provides a methodology to assess and evaluate the vegetation associated with riparian zones.

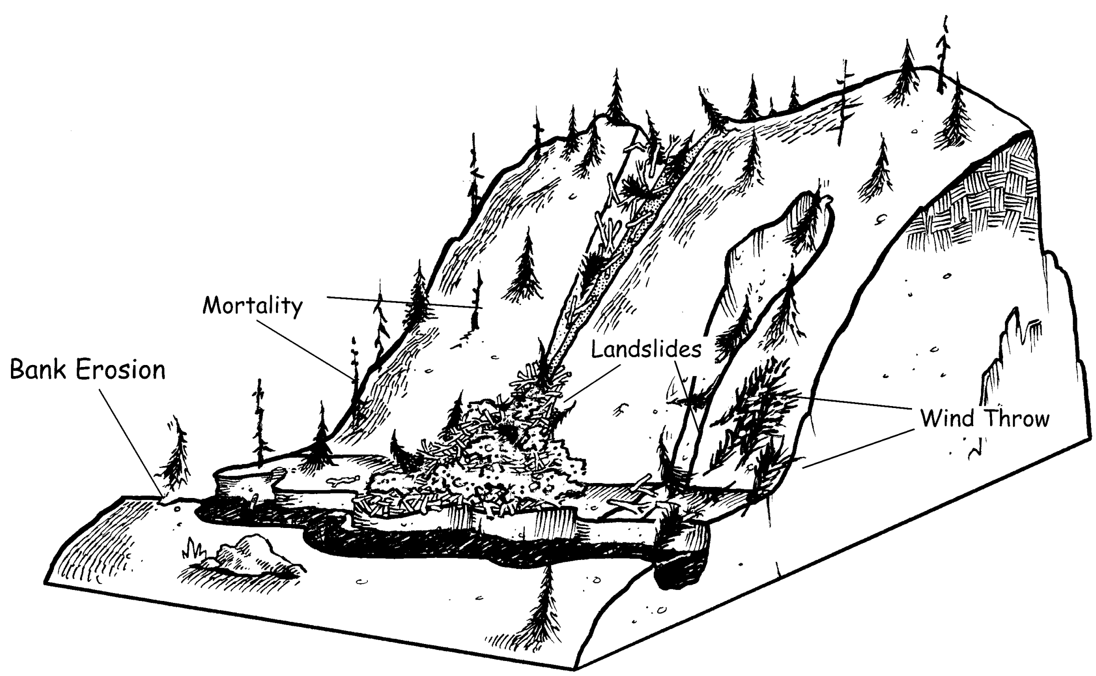


Figure 13. Large woody debris is recruited to the stream by bank erosion, mortality (disease or fire), or wind throw.

Riparian Shade

Although other processes besides shading affect heating and cooling of water (such as groundwater inflows), shading can have the biggest affect because it counteracts the most important source of stream heating during the summer—solar radiation. Riparian enhancement efforts that provide shade have a high potential to contribute to temperature moderation as well as provide direct benefits to fish and wildlife habitat.

Shade provided by riparian vegetation affects stream temperature by reducing the inputs of solar radiation to the water surface. Although the vegetation itself will radiate heat to the stream, the increase in water temperature due to radiation from this source is very small compared with heating from direct solar radiation. Radiation from vegetation is important, however, because it decreases fluctuation of water temperatures on a daily (or diurnal) basis (Figure 14) in forested streams compared with streams that have no ***canopy cover***. The slope and aspect of a site also affect the amount of radiation received. In some areas (e.g., deep canyons) the topography of the land can also provide significant shade.

Role of Ambient Air Temperature

In most streams evaporation of moisture is a primary mechanism of stream cooling; the heat is used to turn water into vapor. Turbulent streams (e.g., high-gradient streams with cascades, etc.) will cool faster than slow streams with smooth surface conditions, due to the higher evaporation rate. Inputs

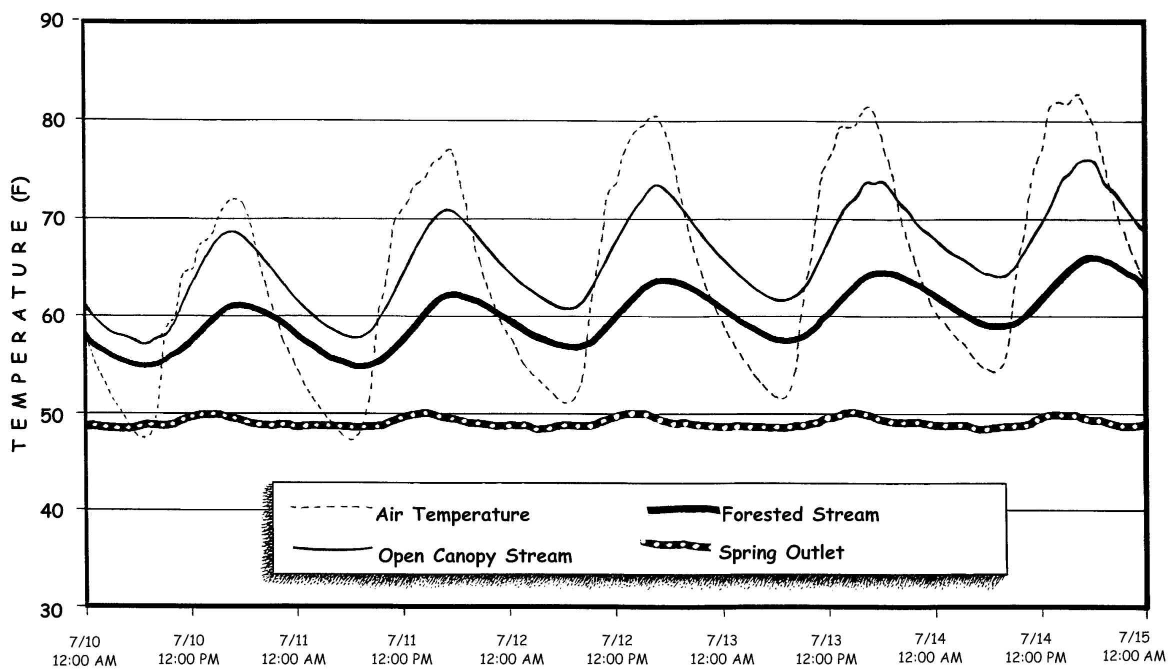


Figure 14. Radiation from vegetation decreases fluctuation of water temperatures on a daily basis in forested streams compared with streams that have no canopy cover. Inputs of cool groundwater are also a significant source of stream cooling in some areas.

of cool groundwater are also a significant source of stream cooling in some areas (Figure 14). Likewise, inputs from hot springs can raise stream temperatures.

Stream temperatures are cooler than the ambient air temperature because of the higher ***specific heat*** of the water, and the cooling processes associated with evaporation and the inflow of groundwater. The daily patterns in stream temperature follow the daily change in air temperature. Typically, the maximum daily temperature occurs in the late afternoon and the minimum occurs late at night or early morning (Figure 14).

In many streams in Oregon, late-summer streamflows are lowest when the net heat gain is the greatest, resulting in the warmest water temperatures of the year. This phenomenon reflects the fact that the maximum water temperature is a result of both the net heat received and the amount of water that is heated. Consequently, the maximum annual stream temperatures may be higher in low-flow or drought years even though the stream receives the same level of heating each year.

Summary

All of the physical processes described above play a role in the temperature of water. However, vegetative density in riparian zones is typically the most important process that can be changed by management activities. The Riparian/Wetlands Assessment component provides a methodology to determine the current condition of the site vegetation, and to predict the effect of increasing or decreasing shade levels. The Ecoregions appendix provides a description of potential shade associated with riparian vegetation in different areas of the state. The Water Quality Assessment component identifies where existing high stream temperatures have been identified.

WETLANDS

Wetlands can be present in the riparian zone, or they can occur in upslope areas with no obvious surface connection to a stream channel. Wetlands provide a variety of important functions, including water quality improvement, ***flood attenuation*** and desynchronization, groundwater recharge and discharge, and fish and wildlife habitat. These functions are described in the following subsections.

Water Quality Improvement

Wetlands aid in water quality improvement by trapping sediment, and contaminants that may be attached to the sediments. Dense wetland vegetation tends to slow the rate of movement of water, which allows sediments to settle out. Although deposition of sediments is beneficial to downstream resources, excessive sedimentation may have negative impacts on the wetland itself. When a wetland is subjected to ongoing sediment deposition, the bottom elevation of the wetland will change; over time, this change could lead to wetland loss.

Vegetation within wetlands also can assimilate certain nutrients and some toxins, thereby protecting downstream resources. The anaerobic environment of many wetland soils breaks down nitrogen compounds and keeps many compounds in a nonreactive form. The ability of a wetland to provide this function is limited: At a certain point, toxins can build up to lethal levels in the wetland community and decrease the wetland's capacity to metabolize the nutrients entering from upstream sources. In addition, plant die-back and decay can re-release nutrients or toxins back into the system, although many toxins are actually converted to less harmful forms or bound in sediments.

Flood Attenuation and Desynchronization

Wetlands can help alleviate downstream flooding by storing, intercepting, or delaying surface runoff. Wetlands within the floodplain of a river can hold water that has overtopped river banks.

Floodwater desynchronization occurs when wetlands higher in the watershed temporarily store water, reducing peak flows. The most effective wetlands at providing desynchronization are generally located in the middle elevations of the watershed; these wetland locations are far enough away from the receiving water to create delay, but are low enough in the watershed to collect significant amounts of water.

Groundwater Recharge and Discharge

Wetlands are intimately associated with groundwater, and some wetlands can function to recharge underlying ***aquifers***. Wetlands are sources of groundwater discharge that may help extend streamflows into the drier summer months. In eastern Oregon, restoring wet meadows in stream headwaters has extended the seasonal duration of streamflow.

Fish and Wildlife Habitat

Wetlands provide habitat and food for a wide variety of aquatic and terrestrial plant and animal species. Many species rely on wetlands for all or a portion of their life cycle. In addition to directly providing habitat, wetlands can indirectly support fish through some of the functions, discussed previously, that protect water quality and channel stability. ***Estuarine*** wetlands provide important feeding and holding areas for outmigrating salmon smolts.

AQUATIC RESOURCES

The sections above briefly describe fundamental processes operating in a watershed. The watershed assessment characterizes these processes because they influence fisheries and water quality in the watershed and set the stage for assessment of aquatic resources. Fisheries and water quality are important aquatic resources that are evaluated as a fundamental expression of healthy watersheds. The relationship between these resources and statewide regulatory issues is discussed in more detail in the Start-Up and Identification of Watershed Issues assessment components.

WATER QUALITY

A combination of the natural watershed processes and the effect of human activities determines water quality at a particular site on a stream or river. Water quality is described in terms of the beneficial uses of water and the level of quality needed to support those uses. Measures of water quality—the criteria or indicators—provide the connection between the beneficial uses of water and the natural and human sources of watershed inputs. The following paragraphs briefly discuss the relationships illustrated in Figure 15.

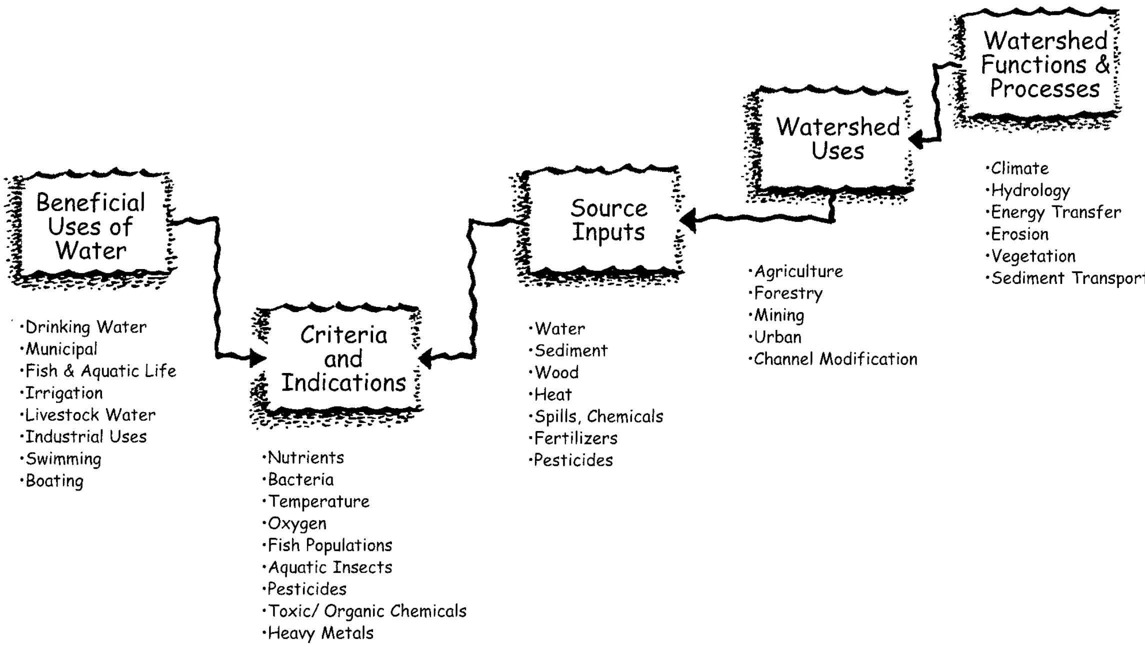


Figure15. Measures of water quality—the criteria or indicators—provide the connection between the beneficial uses of water and the natural and human sources of watershed inputs. These relationships provide the context for water quality and fisheries assessments.

Beneficial Uses of Water

The streams and rivers in the diverse landscapes of Oregon support different uses of water. To focus the water quality assessment, it is necessary to identify the beneficial uses of water that are important in the watershed as well as those that are specifically identified in the Oregon water quality standards. Beneficial uses determine which water quality criteria apply. For example, assessment for drinking water primarily focuses on the presence of pathogens that can cause disease or chemicals that can contribute to long-term health effects such as cancer risk. Assessment for water that supports fish populations focuses on elements of the stream system such as temperature, dissolved oxygen, metals, and chemical contaminants.

Criteria and Indicators

Water quality criteria provide a warning system when activities in a watershed are limiting beneficial uses. Water quality criteria are specifically established in the State Water Quality Standards by major river basin. Indicators refer to values used in the analysis when the state standards do not specify a numerical criteria. The list of criteria and indicators in Figure 15 illustrates the relationship between beneficial uses of water and the potential sources that may alter the quality of the receiving water. Water quality concerns can be grouped into several major categories for analysis—nutrients, bacteria, temperature, dissolved oxygen, and toxics. Water quality status can be evaluated indirectly by examining the health of the aquatic community using aquatic invertebrates and fish populations.

Nutrients

Nutrients refer to chemicals that stimulate growth of algae and aquatic plants in water. In fast-moving streams, algae grow attached to the ***substrate*** and are called "periphyton." Algae and aquatic plants are a necessary part of the stream ecosystem and act as the primary producers in a stream—processing the sun's energy into food that is used by aquatic insects and crustaceans. These invertebrates in turn provide food for stream fish. Excess algae and aquatic plant growth, however, becomes a problem in slow-moving streams and rivers, and in still waters such as ponds and lakes. The excessive growth can result in low or no dissolved oxygen and interfere with recreation, and certain algae can produce chemicals that are toxic to livestock and wildlife. Phosphorus and nitrogen are the major growth-limiting nutrients in water, and are therefore the focus of a water quality evaluation.

Bacteria

Bacteria in the coliform group are used as indicators to test the sanitary quality of water for drinking, swimming, and shellfish culture. Bacteria in the coliform group are found in wastes associated with warm-blooded animals, including humans, domestic animals, and other mammals and birds; these bacteria are indicators of contamination of surface waters by sewage, feedlots, grazing, and urban runoff. The State of Oregon specifies the use of *Escherichia coli* (*E. coli*) as the bacterial indicator for water contact recreation, such as swimming, and fecal coliform bacteria as the indicator in marine and estuarine waters used for shellfish growing. *E. coli* is a more specific test for organisms that occur in warm-blooded animals. The fecal coliform procedure tests positive for some bacteria that occur naturally in the environment, but has generally been accepted as a good screening tool.

Fecal coliform bacteria enter streams from many sources associated with human and animal wastes in urban and agricultural watersheds. In range lands, bacterial contamination occurs primarily from direct deposition of fecal material in streams. Good vegetative cover on the upslope areas and dense riparian vegetation impedes contaminated runoff from reaching streams. Once coliform bacteria enter streams, the majority settle to the bottom and are attached to sediment particles. The stream sediments can act as a reservoir for fecal coliform bacteria; bacteria are resuspended when bottom sediments are disturbed through increased turbulence or animal movement.

Temperature and Dissolved Oxygen

Cool temperatures and high dissolved oxygen are necessary features of streams that support ***salmonid*** fish and the associated aquatic community. Suitable temperature ranges have been evaluated for all life history stages of salmonids—adult migration, spawning, egg incubation, embryo development, juvenile rearing, and juvenile migration. The biological rationale for temperature criteria are based on laboratory and field studies. Laboratory studies evaluate egg development rate and juvenile survival under constant temperatures. Field studies evaluate the effect of water temperature on adult and juvenile migration behavior and adult spawning behavior. Oregon water quality standards are established to protect fish populations based on sublethal effects to fish, such as susceptibility to disease, inability to spawn, reduced survival rate of eggs, reduced growth and survival rate of juveniles, increased competition for limited habitat and food, and reduced ability to compete with other species. A general numerical standard of 64° Fahrenheit (7-day moving average of maximum temperatures) was established in Oregon on the basis of preventing these sublethal effects. Several documents (Boyd and Sturdevant 1997, Oregon Department of Environmental

Quality 1995) have been published by state agencies to help understand the technical basis for the standard, and what managers and land owners can do to meet the standard. High dissolved oxygen is a basic physiological requirement of cold-water fishes. Critical dissolved oxygen levels for various ***life stages*** have been evaluated in laboratory and field studies. The early larval stages of fish are wholly dependent on the transfer of oxygen within the ***redd***, the salmonid gravel nest. When oxygen is below saturation, salmonid embryos are smaller than usual and hatching is either delayed or is premature. Salmonid juveniles survive in dissolved oxygen less than saturation, but growth, food conversion efficiency, and swimming performance are adversely affected. Water quality criteria are established to provide for the natural fluctuations below saturation while assuring sufficient dissolved oxygen to protect aquatic life. The concentration of dissolved oxygen is a function of many factors: water temperature, surface and intragravel water interchange, water velocity, substrate permeability, and the oxygen demand of organic material. The content of oxygen in water is directly related to water temperature and barometric pressure, and therefore, temperature and pressure (estimated through elevation) must be measured at the same time.

Toxic Contaminants

Toxic contaminants refer to chemicals introduced by human activities that may be deleterious to people or aquatic organisms. Organic compounds are man-made chemicals that are used for a variety of industrial purposes and as pesticides and herbicides. Metals often occur naturally, but when introduced into the environment or concentrated during mining or industrial processes, they can reach a toxic level. Toxicity covers a range of responses in aquatic organisms, from lethal to sublethal effects. Water quality criteria based on lethal effects are determined by exposing aquatic organisms to the chemical in a laboratory and determining at what concentration 50% of the organisms die. Tests for setting sublethal criteria follow an organism through its life cycle and evaluate the effects on growth and reproduction. These standard toxicity tests are the basis for the majority of water quality criteria recommended by US Environmental Protection Agency (EPA). The State of Oregon has adopted criteria recommended by EPA and listed in a document called the EPA "Goldbook."

Because of the wide variety of organic chemicals, it is not feasible to list the criteria for each chemical in a screening assessment. Establishing the "safe" level for these chemicals is the subject of continuing debate among scientists and there is often little agreement. Therefore, for the screening assessment, the suggested approach is to record the number of times an organic chemical exceeds the detection limits. If a number of these exceedences are recorded, then a water quality specialist or toxicologist should be consulted.

Metals mining, such as gold and silver mines, are located in mineralized zones that may contain other elements such as cadmium, zinc, copper, lead, mercury, and arsenic. These metals can reach groundwater in dissolved form, or in surface waters as dissolved or particulate material. Criteria for metals are expressed as acute and chronic values. Toxicity for most metals is based on the hardness of the receiving water, and therefore the criteria are expressed as a function of hardness.

FISHERIES RESOURCES

Because modifications to watershed process tend to "roll downhill" and influence the stream channel network, it is important to understand the patterns of fish use and the habitat requirements of fish in the watershed. The *Biennial Report on the Status of Wild Fish in Oregon* (Hooten et al. 1995) contains information on over 40 native fish species occurring in Oregon. The salmonids are the most widespread group of fish in the state and best-recognized as an indicator of watershed health. These are a class of fish that include salmon, trout, and ***char***. This assessment process focuses on evaluating salmonid populations and habitat conditions. In areas where there are sensitive nonsalmonid fish species, this approach may be adapted to evaluate the specific needs of those species.

Salmonids have a wide variety of life history patterns (Figure 16). They may be ***anadromous***—spending some portion of their life history in the ocean and returning to freshwater streams to spawn. They may be ***resident*** and spend their entire lives in the stream network. Or they may move between large river systems or reservoirs and the stream network where they were born.

Chinook, coho, steelhead, and cutthroat trout are the most common anadromous salmonids occurring in Oregon. Anadromous chum salmon and kokanee/sockeye salmon also occur in Oregon, but have more limited distributions. Redband (rainbow) trout and interior cutthroat trout are the most common resident salmonids; bull trout also occur in Oregon but have a limited distribution. The life history patterns and distribution in the stream network of the most common salmonids are summarized in Table 1 and described in the following paragraphs (Figure 17). These descriptions are general in nature; it is not uncommon for fish species to have life history patterns adapted to the watershed of origin. For this reason the Fish and Fish Habitat Assessment component asks users to describe the known life history patterns of fish occurring in their watershed. The *Biennial Report on the Status of Wild Fish in Oregon* provides some watershed-specific information and contains more detailed information on the life history patterns of nonsalmonid fish species that may occur in your watershed.

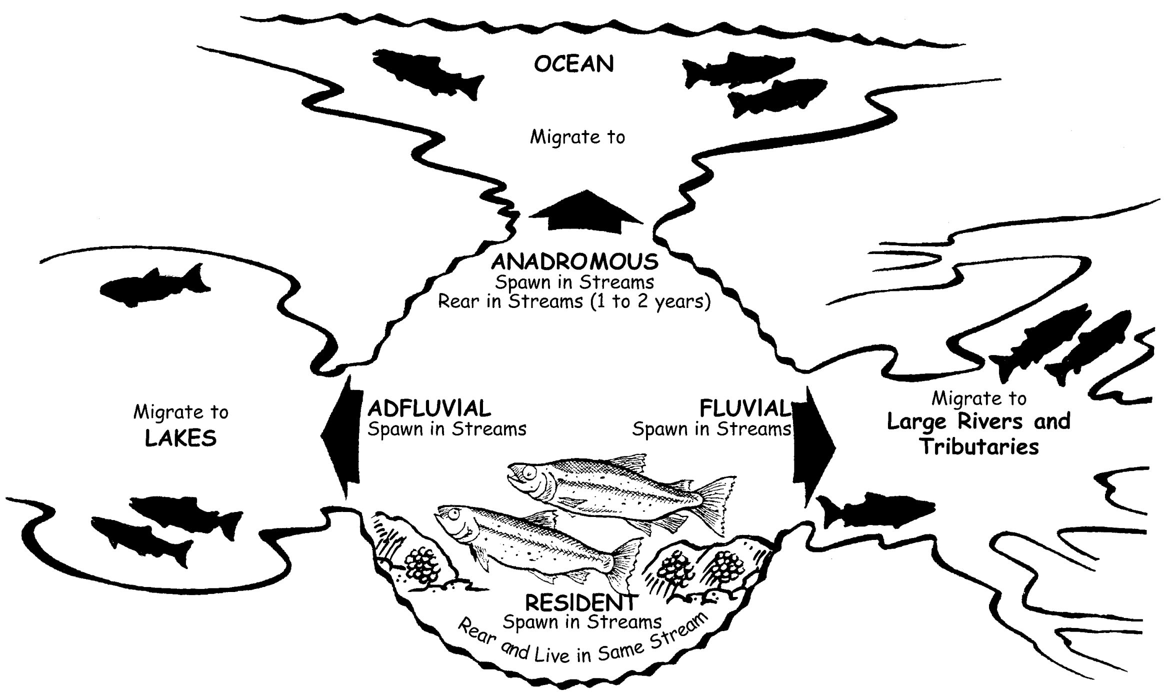


Figure 16. Salmon and trout have three distinct life history patterns: (1) "anadromous," spending some portion of their life history in the ocean and returning to freshwater streams to spawn; (2) "resident," spending their entire lives in the stream network; or (3) fluvial or adfluvial, moving between large river systems or reservoirs and the stream network where they were born.

Table 1. Generalized life history patterns of anadromous salmon, steelhead, and trout in the Pacific Northwest.[1]

Species	Adult Return	Spawning Location	Eggs in Gravel[2]	Young in Stream	Freshwater Habitat	Young Migrate Downstream	Time in Estuary	Time in Ocean	Adult Weight (average)
COHO	Oct-Jan	coastal streams, shallow tributaries	Oct-May	1+yrs	tributaries, main-stem, slack water	Mar-Jul (2nd yr)	few days	2 yrs	5-20 lb (8)
CHUM	Sept-Jan	coastal rivers and streams lower reaches	Sep-Mar	days-weeks	little time in fresh water	shortly after leaving gravel	4-14 days	2.5-3 yrs	8-12 lb (10)
CHINOOK		main-stem large and small rivers			main-stem-large and small rivers		days-months	2-5 yrs	
spring	Jan-Jul		Jul-Jan	1+yrs		Mar-Jul (2nd yr)			10-20 lb (15)
summer	Jun-Aug		Sep-Nov	1+yrs		spring (2nd yr)			10-30 lb (14)
fall	Aug-Mar		Sep-Mar	3-7 months		Apr-Jun (2nd yr)			10-40 lb
STEELHEAD[3]		tributaries, streams, & rivers			tributaries		less than a month	1-4 yrs	
winter	Nov-Jun	Nov-Jun	Feb-Jul	1-3 yrs		Mar-Jun (2nd-5th yr)			5-28 l b(8)
spring	Feb-Jun	Feb-Jun	Dec-May	1-2 yrs		spring & summer (3rd-4th yr)			5-20 lb
summer (Col. R.)	Jun-Oct	Jun-Oct	Feb-Jun	1-3 yrs		Mar-Jun (3rd-5th yr)			5-30 lb (8)
summer (coastal)	Apr-Nov	Apr-Nov	Feb-Jul	1-2 yrs		Mar-Jun (of 2nd-5th yr)			5-30 lb (8)
Inland Columbia STEELHEAD/ REDBAND	Jun-Oct	tributaries	spring	1-3 yrs or resident		1-3rd yr	less than a month	1-4 yrs	
Oregon Basin REDBAND	resident spring		spring	resident		resident	na	na	
Coastal-Sea Run CUTTHROAT	Jul-Dec	tiny tributaries of coastal streams	Dec-Jul	1-3 yrs (2 avg.)	tributaries	Mar-Jun (2nd-4th yr)	less than a month	0.5-1 yrs	0.5-4 lb (1)
Lahontan CUTTHROAT	resident		spring	resident	tributaries, lakes	resident	na	na	
Westslope CUTTHROAT	resident Mar-Jul	small tributaries	Apr-Aug	resident	tributaries	resident	na	na	
BULL TROUT	Jul-Oct	cold headwaters, spring-fed streams	Sep-Apr	1-3 yrs (2 avg.)	prefer water < 15°C	spring, summer, fall (1st-3rd yr)	na	na	0.5-20 lb (varies with form)

1 Life history patterns vary— fish in each watershed may have unique timing and patterns of spawning, growth, and migration. As part of the fish assessment you will update this chart.

2 The eggs of most salmonids take 3-5 months to hatch at the preferred water temperature of 50-55ºF; steelhead eggs can hatch in 2 months.

3 Steelhead, unlike salmon and coastal cutthroat trout, may not die after spawning. They can migrate back out to sea and return in later years to spawn again.

From: StreamNet Web page (www.streamnet.org) – fact sheets

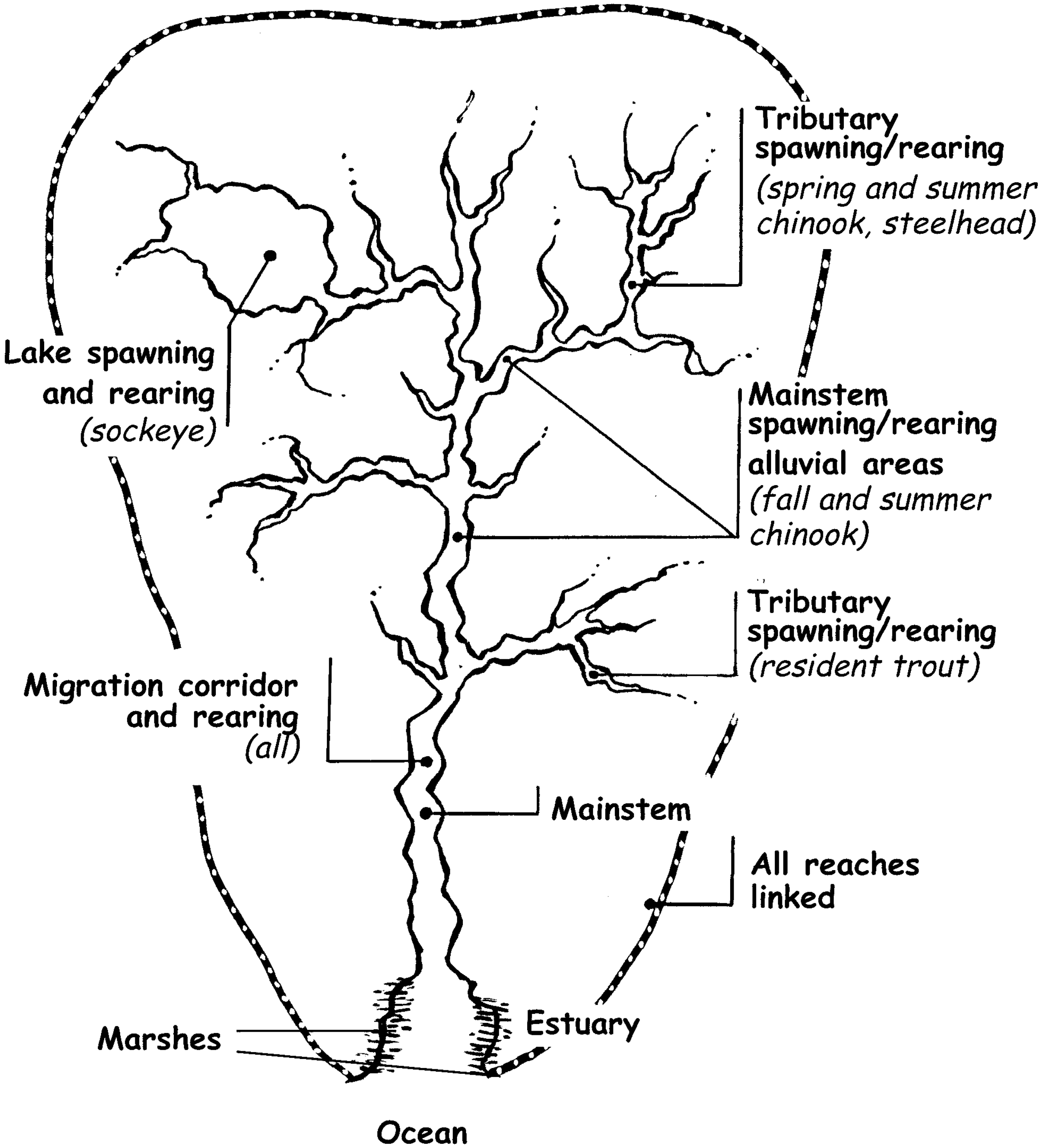


Figure 17. Salmonid distribution in a watershed varies by species and life history stage.

Chinook (king) salmon exhibit a wide range of life history diversity, with variations in the date, size, and age at ocean entry; in adult migration season; in spawning habitat selection; and in age and size at maturity. Chinook have two adult migration seasons, fall or spring, which refers to the period when they return to the watershed. Fall chinook return from the ocean in late August through December and spawn in the late fall and winter. Spring chinook return from the ocean in the spring and adults spend the summer in deep pools until the fall spawning period. Chinook salmon prefer to spawn in large main channels and low-gradient (less than 3%) tributaries. Spring chinook are typically good jumpers and can leap significant barriers in streams that would be impassable to fall chinook. Generally, juvenile chinook of coastal stocks rear in coastal streams from 3 to 6 months and rear in estuaries from 1 week to 5 months. Nearly all coastal chinook stocks enter the ocean during their first summer or fall. Some coastal and Columbia River spring chinook spend one summer and one winter in fresh water. Chinook adults range from 2 to over 70 pounds, with the average size ranging from 10 to 40 pounds.

Coho (silver) salmon usually spawn from November to February. Coho prefer to spawn and rear in small, low-gradient (less than 3%) tributary streams. Adults are good jumpers and often ascend higher-gradient reaches to access spawning areas in the upper portions of a watershed. Adult coho may spend several weeks to several months in fresh water before spawning, depending on the distance they have to migrate to their spawning areas. Juveniles normally spend one summer and one winter in fresh water. They migrate to the ocean in the spring, 1 year after ***emergence***. Most adults mature at 3 years of age, but some males mature as jacks or precocious males. Coho adults rarely exceed 15 pounds.

Steelhead/Rainbow/Redband: The rainbow trout species consists of multiple subspecies that are closely related fish that exhibit differences in life history patterns, distribution, and/or body form. Currently, three subspecies of rainbow trout are recognized in Oregon: (1) coastal steelhead/rainbow trout, (2) inland Columbia Basin redband/steelhead trout, and (3) Oregon Basin redband trout.

> **Coastal steelhead** are seagoing rainbow trout that occur west of the Cascade Mountains and have a wide variety of fresh- and saltwater rearing and adult migration strategies. Juvenile steelhead may rear 1 to 4 years in fresh water before migrating to saltwater. Steelhead may reside in saltwater 1 to 3 years. Adult steelhead that enter fresh water between May and October are called "summer-run" fish. These fish hold several months in fresh water prior to spawning. Adults that enter between November and April are called "winter-run" fish. These fish are more sexually mature when they go upstream and they stay in fresh water for a shorter time before spawning. Steelhead return to saltwater after spawning. Resident rainbow trout remain in the same stream network throughout their entire life. Rainbow trout typically spawn in the winter or spring. Both rainbow and steelhead spawn more than once.
>
> **Inland Columbia Basin redband/steelhead** occur in the Columbia Basin east of the Cascade Mountains. This subspecies includes anadromous steelhead and resident redband trout, both of which can occur in the same stream system. There are also isolated redband trout populations in streams that are above barriers to anadromous fish. Juvenile steelhead before returning to fresh water to spawn. Most inland steelhead are summer-run fish, entering fresh water between March and October and holding for several months prior to spawning. Only four populations of winter-run steelhead are found in Oregon; these populations occur in Fifteenmile Creek and adjacent creeks.
>
> **Oregon Basin redband trout** occur in the following basins: Klamath, Summer Lake, Abert Lake, Fort Rock Valley, Christmas Valley, Fossil Lake, Silver Lake, and Malheur. Populations in each of these basins are completely isolated by natural geological features, except for the Klamath Basin. These trout are adapted to thrive in the often warm and alkali waters of the Great Basin streams where they occur. Historically, these redband trout populations had ***adfluvial*** life histories, which means they migrated between the spawning areas in streams to rearing areas in lakes and marshes. The diking, channeling, irrigation

diversions, and draining of marshlands that have occurred extensively in these basins has resulted in the loss of rearing habitat and functional migration corridors.

Cutthroat trout have three subspecies occurring in Oregon: (1) coastal cutthroat trout, which occur west of the Cascade Mountains; (2) Lahontan cutthroat trout, occurring in southeastern Oregon, and (3) westslope cutthroat trout, which occur in the John Day Basin.

Coastal cutthroat trout have variable life history patterns. Some migrate to the ocean while others remain in the same area of a stream all of their lives. They spawn in the spring or fall and the juveniles emerge by June or July. Cutthroat trout tend to spawn in very small tributaries. Sea-run cutthroat trout rarely exceed a length of 20 inches or a weight of 4 pounds.

Lahontan cutthroat trout occupy remnant streams in the basin of historical Lake Lahontan. These fish have evolved a tolerance to high alkaline conditions. Lahontan cutthroat tend to be small-sized and occupy small streams that usually have no other fish species present.

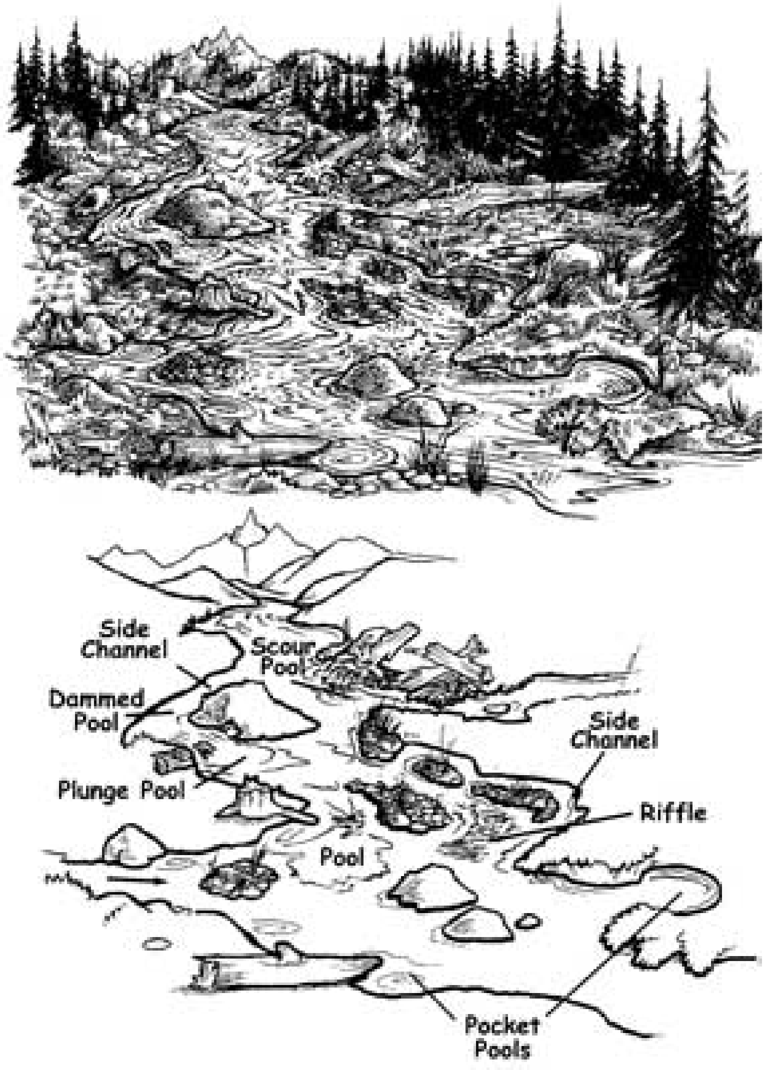
Westslope cutthroat trout only occur in the John Day Basin in Oregon. These populations all have a resident life history and remain in the same stream system their entire lives. Westslope cutthroat are specialized to feed on insects and other invertebrates, while the other cutthroat subspecies occurring in Oregon prefer to feed on other fish.

Bull trout are a char closely related to trout. Researchers believe the bull trout populations in Oregon became established during the last glacial period, which helps explain why they need cold water to successfully reproduce. Bull trout in Oregon have three distinct life history patterns: They may be (1) adfluvial fish that migrate between lakes or reservoirs and spawn in streams, (2) ***fluvial fish*** that migrate to large rivers and spawn in small tributaries, or (3) resident fish that remain in the same stream network for their entire lives. The migratory forms of bull trout move long distances to reach their spawning tributaries. Typically, bull trout occur farther upstream in the watershed than other salmonids. Bull trout grow slowly, do not mature until age 5 or older and will live for 12 or more years. They typically spawn in the fall as water temperatures are decreasing, and can spawn annually or in alternate years. Bull trout are predatory on other fish and can grow to 30 pounds where adequate food is available.

There are many elements of in-stream fish habitat that affect the production of salmonids during the freshwater phases of their life history (Figure 18). Physical habitat features include depth and water velocity ranges (usually grouped by channel units), cover, spawning gravels, and temperature ranges. The Oregon Department of Fish and Wildlife has compiled extensive amounts of stream habitat data from over 5,000 miles of stream surveys and has developed a series of ***benchmark*** values for key physical habitat conditions. The Fish and Fish Habitat Assessment component uses these benchmark values as a comparison in order to evaluate the current condition of fish habitat in the watershed.

See Fish and Fish Habitat component for habitat evaluation process.

It is clear from the descriptions of the life histories that the anadromous trout and salmon occurring in Oregon watersheds migrate long distances upstream and downstream during their life cycles.



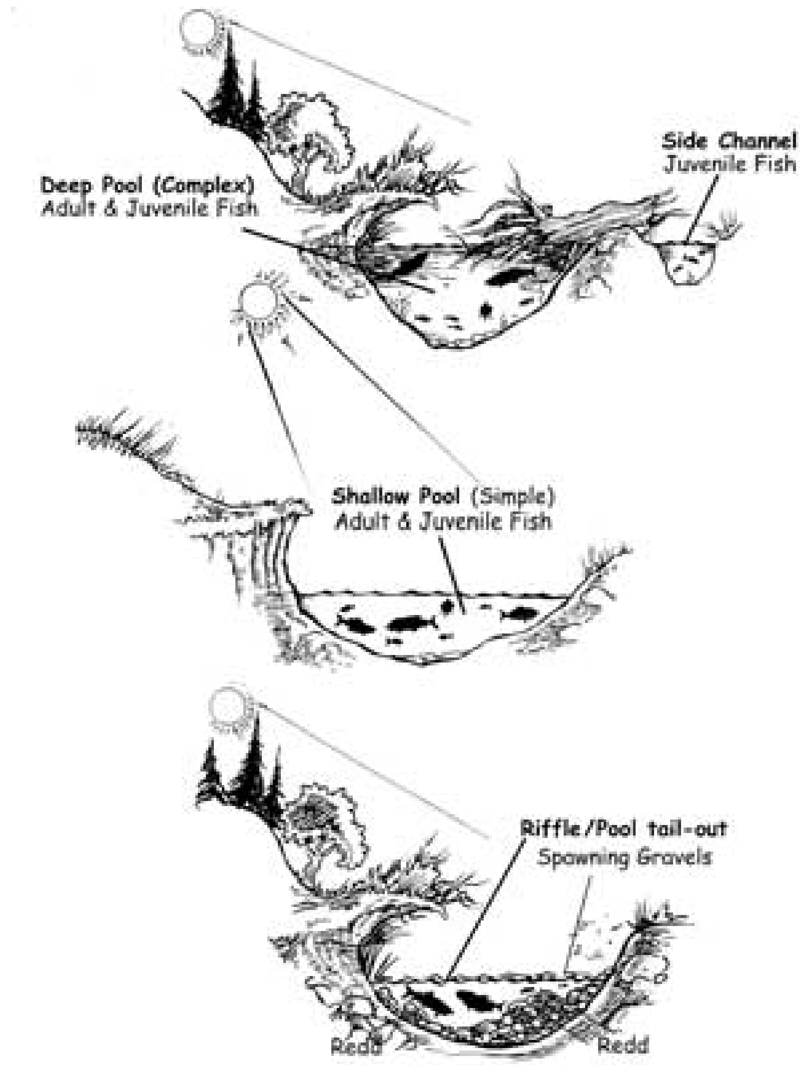


Figure 18. Elements of in-stream fish habitat that affect salmonid production in fresh water include depth and water velocity, cover, spawning gravels, and temperature ranges.

These conditions are dependent on such physical characteristics as pools and side channels, substrate, and riparian vegetation.

Resident trout will also move up and downstream to seek food, shelter, and spawning. Culverts under roads can block fish passage through a number of factors, including jumps, no resting pools, insufficient depth, excessive water velocity, or a combination of these factors (Figure 19). The migration barrier portion of the Fish and Fish Habitat Assessment provides a protocol for mapping potential barriers, and identifying if an existing crossing is a barrier.

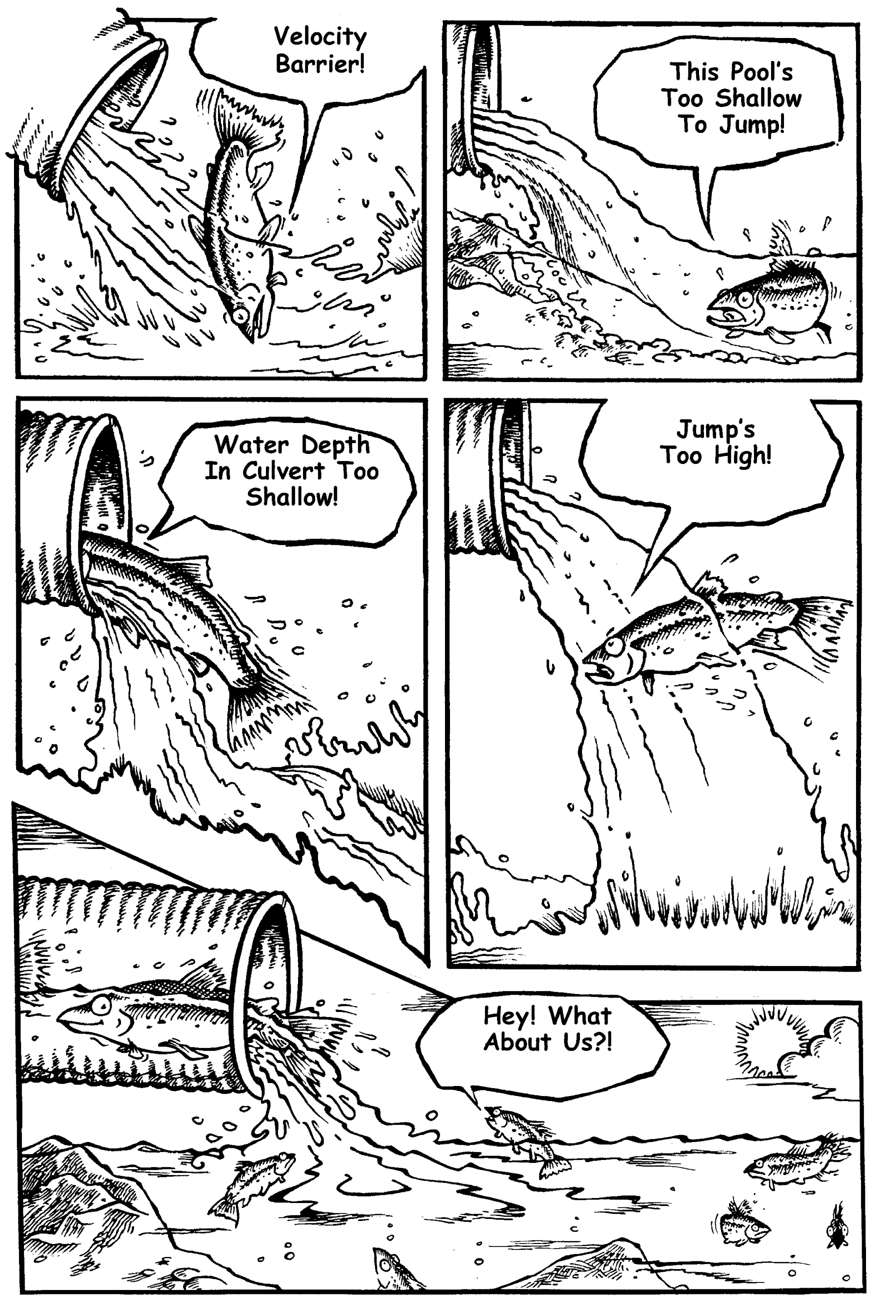


Figure 19. Culverts under roads can block fish passage through a number of factors, including excessive water velocity, insufficient depth, excessively high jumps, or a combination of these factors.

POTENTIAL LAND MANAGEMENT EFFECTS

General

Potential impacts to streams from human activities are based on the nature of the disturbance and the responses of the watershed to the disturbance. Human activities can create disturbances that alter how watershed processes function in predictable patterns. This watershed assessment manual recognizes that it is the manner in which land management activities are conducted combined with the local sensitivity or resilience of the landscape that ultimately determine the type and severity of potential effects. However land use activities can be used to screen for potential impacts. Table 2 summarizes the types of disturbances that can be created by specific land use activities and lists how the watershed may respond to these disturbances in terms of fish habitat or water quality conditions. The References section lists a number of comprehensive discussions on this topic.

Cumulative Effects

Cumulative effects can be defined as the changes to the environment caused by the interaction of natural ecosystem processes with the effects of land use and other human activities distributed through time and over the landscape. According to this definition, individual actions that by themselves are relatively minor may impact resources when combined with other modifications that have occurred in the watershed. The current habitat condition at any location in a stream is a function of the watershed activities that currently occur upslope and upstream, added to the effect of historical activities. For example, in a typical managed forest, historical streamside timber harvest combined with ***stream cleaning***, ***splash damming***, and use of streams as transportation corridors have resulted in a legacy of low LWD frequency. Downstream in an agricultural area, streams were often channelized and riparian forests were removed. These historical changes combined with present-day expansion of suburban areas, for example, result in altered channel conditions throughout the watershed. Cumulative effects are detected in the assessment process by describing and identifying the location of historical activities, by assessing the current riparian and habitat conditions (which reflect past and present actions), and by combining the outcome of assessment sections into one Watershed Condition Evaluation.

The impact on the watershed from multiple activities depends on where and when they occur. This assessment addresses the location of impacts through a mapping process that links the impacts to specific Channel Habitat Types. This process also addresses the timing of watershed modifications by identifying historical activities that may have long-term channel impacts (e.g., splash dams and channelization), and those which have current and future impacts (e.g., limited wood recruitment from riparian zones). The Channel Habitat Type Classification component identifies stream reaches that are most susceptible to impacts and are the most responsive to enhancement efforts based on physical characteristics. These sensitive reaches can then become a focal point for follow-up studies, monitoring efforts, or protection and enhancement efforts.

Table 2. Summary of potential stream impacts from human activities.

Human Activity	Potential Disturbances	Potential Habitat/Watershed Process Responses
Timber harvest	• removal of riparian zone canopy cover • soil disturbance, increased erosion of fine sediments • alteration of total basin vegetation cover	• increased summer water temperatures • reduced woody debris recruitment potential • decrease in interstitial spaces and pools (spawning and rearing habitat) • alteration of timing and magnitude of peak flows (hydrology) • change in timing and characteristics of landslides
Transportation (road development, rail, bridges, etc.)	• surface erosion, increased fine-sediment inputs • destabilization of upslope areas increased coarse- and fine-sediment inputs • blockage of migratory corridors (culverts) • loss of riparian vegetation • chemical spills, toxics, nutrient runoff	• decrease in interstitial spaces and pools (spawning and rearing habitat) • major channel disruption & catastrophic loss of habitat with major events • loss of migratory population component • increased summer water temperatures • reduced woody debris recruitment potential • chemical contamination • changes in peak flows
Agriculture/livestock grazing	• bank damage • soil compaction • in-channel stream bed disruption • removal of bank vegetation • changes in vegetation species & distribution	• decreased bank stability & direct inputs of fine sediments • reduced water infiltration, changes in peak flows, reduced baseflows • loss or disruption of summer rearing habitat • loss of cover, increased summer water temperatures & formation of anchor ice • increased stream nutrients
Agriculture/crops	• soil compaction • surface erosion, increased fine-sediment inputs • removal of bank vegetation • chemical, nutrient runoff	• decreased bank stability & direct inputs of fine sediments • reduced water infiltration, changes in peak flows, reduced baseflows • loss of cover, increased summer water temperatures & formation of anchor ice • increased stream nutrients, contamination
Mining	• streambed disturbance • fine-sediment inputs • chemical runoff or seepage to groundwater	• loss or disruption of spawning & summer rearing habitat • creation of chemical barriers &/or direct fish mortality, groundwater contamination
Dams (hydroelectric development, water supply, irrigation diversions)	• blockage of migratory corridors • changes in temperature, sediment delivery, flow regime due to dam regulation • increased temperatures, fine sediments, chemicals and nutrients with wastewater returns • channel dewatering	• loss of migratory/anadromous population component • overall decrease in habitat condition • direct mortality loss of one or more year-classes, reduction of redds, loss of available habitat • loss of anadromous prey base/nutrients • loss or disruption of spawning & summer rearing habitat

`

Table 2. (continued).

Human Activity	Potential Disturbances	Potential Habitat/Watershed Process Responses
Urbanization, channelization, diking, levees, recreation, & other	• reduction / removal of riparian vegetation • direct streambed modification • dewatering • stormwater runoff, reduced infiltration to soils	• increased summer water temperatures & formation of anchor ice • habitat simplification • reduced channel stability, channel incision • chemical, nutrient, bacterial inputs • increased magnitude and frequency of peak flows • reduced baseflows
UTILIZATION/HARVEST		
Fishing harvest	• direct mortality	• reduced recruitment & loss of nutrients to the stream
SPECIES INTERACTIONS		
Exotic species introductions, hatchery production	• competition • hybridization • predation • disease • water pollution	• displacement from most favorable habitats • sterile or less fit hybrids • direct mortality • weakness • nutrient, dissolved oxygen, and chemical contamination
HISTORICAL HUMAN USES (modifications that may not be apparent without historical research)		
Splash damming & log drives, yarding up stream channels, channel dredging, harvest of stream-bank trees, agriculture	• channel scour • streambed damage • removal of riparian vegetation • bank destabilization	• long-term loss or disruption of spawning & summer rearing habitat • increased summer water temperatures & formation of anchor ice • reduced woody debris recruitment potential • decrease in interstitial spaces and pools (spawning and rearing habitat)
Water withdrawals/ channel dewatering	• dry channel	• migration barriers, loss of one or more year-classes of fish
Stream cleaning to remove wood	• reduced sediment retention • increased channel scour • reduced channel complexity	• loss or disruption of spawning, summer & winter rearing habitat
Placer (hydraulic) mining or gravel quarries	• streambed disturbance • substrate removal	• loss or disruption of spawning & summer rearing habitat
Beaver eradication	• dam deterioration, removal • loss of pond/wetland areas	• loss of rearing habitat • alteration of water retention/floodplain function • temperature increases
Tailings deposits	• fine-sediment inputs • toxic contaminants	• loss or disruption of spawning & summer rearing habitat • creation of chemical barriers &/or direct fish mortality

See Watershed Condition Evaluation component regarding how to combine and use the information gathered in the assessment process.

The use of watershed resources often causes conflicts and even the irreplaceable loss of important resources. A key objective of this assessment is to understand how the watershed functions, including identification of factors that limit fish populations and contribute to water quality concerns. The Watershed Condition Evaluation component will use the information gathered in the assessment to help watershed councils prioritize actions to protect and restore fish habitat and water quality.

REFERENCES

Beckman, H.O., and N.C. Brady. 1969. The Nature and Properties of Soils, Seventh Edition. The Macmillan Co., New York.

Behnke, R.J. 1992. Native Trout of Western North America. American Fisheries Society Monograph 6. Bethesda, MD.

Bell, M. 1986. Fisheries Handbook of Engineering Requirements and Biological Criteria. US Army Corps of Engineers. Washington, DC.

Boyd, M., and D. Sturdevant. 1997. The Scientific Basis for Oregon's Stream Temperature Standards: Common Questions and Straight Answers. Oregon Department of Environmental Quality, unpublished agency document, Portland, Oregon.

Bruce, J.P., and R.H. Clark. 1966. Introduction to Hydrometeorology. Pergamon Press, Oxford.

Buchanan, D.V., M.L. Hanson, and R.M. Hooten. 1997. Status of Oregon's Bull Trout. Oregon Department of Fish and Wildlife, Salem, Oregon.

Evans, W.A., and B. Johnston. 1980. Fish Migration and Fish Passage: A Practical Guide to Solving Fish Passage Problems. US Forest Service, EM-7100-2, Washington, DC.

Hooten, B., S. Jacobs, et al. 1995. Biennial Report on the Status of Wild Fish in Oregon. Oregon Department of Fish and Wildlife, Salem, Oregon.

Jumikis, A. 1966. Thermal Soil Mechanics. Rutgers University Press. New Brunswick, NJ.

Leopold, L.B. 1994. A View of the River. Harvard University Press, Cambridge, MA.

Logan, R S. and R.A. Fletcher. 1996. Forest Ecosystem Stewardship. MSU Publications, Bozeman, MT.

Linsley, R.K., M. Kohler, and J. Pauhus. 1975. Hydrology for Engineers. McGraw-Hill, New York.

Meehan, W.R. (ed.). 1991. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication. Bethesda, MD.

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

Omernik, J., 1994. Ecoregions: a spatial framework for environmental management. Chapter 5 in W.S. Davis and T.P. Simon, eds. Biological assessment and criteria: tools for water resource planning and decision making, Lewis Publishers, Boca Raton, FL.

Oregon Department of Environmental Quality. 1995. 1991-1994 Water Quality Standards Review. Oregon Department of Environmental Quality, Portland, Oregon.

OSU Draft Document. 1998. Watershed Stewardship: A Learning Guide. Oregon State University, Corvallis.

Pearcy, B. 1992. Ocean Ecology of North Pacific Salmonids. University of Washington Press, Seattle.

Regional Interagency Executive Committee. Ecosystem Analysis at the Watershed Scale—Federal Guide for Watershed Analysis. Version 2.2. August 1995.

Satterlund, D.R. 1972. Wildland Watershed Management. John Wiley & Sons, New York.

Trotter, P.C. 1987. Cutthroat Native Trout of the West. Colorado Associated University Press.

Yates, S. 1988. Adopting A Stream: A Northwest Handbook. Adopt-A-Stream Foundation.

US Geological Survey. 1974. Map: Hydrological Unit Map for State of Oregon. US Department of the Interior, Washington, DC.

Vannote, R., G. Minshall, K. Cummins, J. Sedell, and C. Cushing. 1980. The River Continuum Concept. Canadian Journal of Fish Aquatic Science, Vol. 37.

GLOSSARY

abiotic: Something that is not living (for example, rock).

adfluvial: Migrating between spawning areas in streams and rearing areas in lakes or reservoirs.

anadromous: Fish that move from the sea to fresh water for reproduction.

aquifer: A body of rock that can collect groundwater, and can yield water to wells and springs. A groundwater reservoir.

benchmark: An initial context for evaluating stream habitat quality. Derived from reference conditions, analysis of regional survey data, and published information.

biotic: Something that is living, or pertaining to living things.

canopy cover: The overhanging vegetation over a given area.

channel complexity: A term used in describing fish habitat. A complex channel contains a mixture of habitat types that provide areas with different velocity and depth for use by different fish life stages. A simple channel contains fairly uniform flow and few habitat types.

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, ***channel pattern***, and ***confinement***. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

char: A close relative to trout, another salmonid. Bull trout are a species of char.

cohesive: When describing soil, tendency of soil particles to stick together. Examples of soils with poor cohesion include soils from volcanic ash, and those high in sand or silt.

connectivity: The physical connection between tributaries and the river, between surface water and groundwater, and between wetlands and these water sources.

debris flow: A type of landslide that is a mixture of soil, water, logs, and boulders which travels quickly down a steep channel.

discharge: Outflow; the flow of a stream, canal, or aquifer.

disturbance: Events that can affect watersheds or stream channels, such as floods, fires, or landslides. They may vary in severity from small-scale to catastrophic, and can affect entire watersheds or only local areas.

drainage basin: A geographic and hydrologic subunit of a watershed.

downcutting: When a stream channel deepens over time.

ecoregion: Land areas with fairly similar geology, flora and fauna, and landscape characteristics that reflect a certain ecosystem type.

elevation: The vertical reference of a site location above mean sea level, measured in feet or meters.

emergence: For salmonids, the time of year when fry swim up from gravels in their nesting site and begin to swim in the stream.

estuarine: pertaining to, or in, an estuary.

evapotranspiration (ET): The amount of water leaving to the atmosphere through both evaporation and transpiration.

fish life stage: See life stage.

flood attenuation: When flood levels are lowered by water storage in wetlands.

flood peak: The highest amount of flow that occurs during a given flood event.

floodplain: The flat area adjoining a river channel constructed by the river in the present climate, and overflowed at times of high river flow.

fluvial fish: Fish that rear in larger rivers and spawn in smaller river tributaries.

gaining reach: Reach where groundwater is flowing into the stream channel to become surface water.

gaging station: A selected section of a stream channel equipped with a gage, recorder, or other facilities for measuring stream discharge.

hydraulic gradient (hydraulic head): Water level from a given point upstream to a given point downstream; or the height of the water surface above a subsurface point. Used in analysis of both ground- and surface-water flow, and is an expression of the relative energy between two points.

hydrograph: A graph of runoff rate, inflow rate, or discharge rate, past a specific point over time.

hydrologic cycle: The circulation of water around the earth, from ocean to atmosphere and back to ocean again.

hydrology: The science of the behavior of water from the atmosphere into the soil.

Hydrologic Unit Codes (HUCs): US Geological Survey designations that correspond to specific watersheds, and are expressed in a hierarchical scale.

hydrophobic soils: Soils that do not easily soak up water, and thus increase the rate of surface runoff.

impervious surface: Surface (such as pavement) that does not allow, or greatly decreases, the amount of infiltration of precipitation into the ground.

infiltration: The rate of movement of water from the atmosphere into the soil.

large woody debris (LWD): Logs, stumps, or root wads in the stream channel, or nearby. These function to create pools and cover for fish, and to trap and sort stream gravels.

legacy activities: Past land use practices that have contributed to current watershed and stream channel conditions.

life stage (fish life stage): A part of a fish's life cycle, with identifiable habitat requirements associated with it; for example, summer rearing, spawning, and juvenile outmigration to ocean waters.

low flows: The minimum rate of flow for a given period of time.

mass wasting: (also soil mass movement): Downslope transport of soil and rocks due to gravitational stress.

meandering: When a stream channel moves laterally across its valley.

peak flow: The maximum instantaneous rate of flow during a storm or other period of time.

precipitation: The liquid equivalent (inches) of rainfall, snow, sleet, or hail collected by storage gages.

precipitation intensity: The rate at which water is delivered to the earth's surface.

raindrop splash: Erosion created when a raindrop hits a bare soil surface. Not common in most of Oregon.

rain-on-snow (event): When snowpacks are melted by warm rains, causing peak flow events. Rain-on-snow events usually occur within the transient snow zone.

raveling: Erosion caused by gravity, especially during rain, frost, and drying periods. Often seen on steep slopes immediately uphill of roads.

recurrence interval(s) (return interval): Determined from historical records. The average length of time between two events (rain, flooding) of the same size or larger. Recurrence intervals are associated with a probability. (For example, a 25-year flood would have a 4% probability of happening in any given year.)

recruited large woody debris: A professional term assessing the amount or size of large trees in a riparian area that could potentially fall in (recruit) to the stream channel. Mechanisms for recruitment include small landslides, bank undercutting, wind throw during storms, individual trees dying of age or disease, and transport from upstream reaches.

redd: The salmonid gravel nest.

resident fish: Nonmigratory fish that remain in the same stream network their entire lives.

rilling (surface rilling): Erosion caused by water carrying off particles of surface soil.

riparian area(s): Areas bordering streams and rivers.

riparian zone(s): An administratively defined distance from the water's edge that can include riparian plant communities and upland plant communities. Alternatively, an area surrounding a stream, in which ecosystem processes are within the influence of stream processes.

riparian vegetation: Vegetation growing on or near the banks of a stream or other body of water in soils that are wet during some portion of the growing season. Includes areas in and near wetlands, floodplains, and valley bottoms (from Meehan 1991).

salmonid: Fish of the family *Salmonidae*, including salmon, trout, char, whitefish, ciscoes, and grayling. Generally, the term refers mostly to salmon, trout, and char.

sediments, fine and coarse: Fragments of rock, soil, and organic material transported and deposited into streambeds by wind, water, or gravity.

soil creep: When gravity moves the soil mantle downhill at rates too small to observe.

specific heat (of water): The amount of heat required to make a 1° change in water or air temperatures.

splash damming: Historical practice where a small dam was built across a stream to impound water and logs. The dam was then removed (usually with explosives) to release the impounded logs and water, causing scour downstream.

spring snowmelt: The time when the seasonal snowpack melts out.

stand-replacing fire: A fire of enough severity, at a local level, to kill all the mature trees.

stream cleaning: The removal of large wood or fine organic matter (i.e., branches, twigs, leaves, etc.) from stream channels. Historically, this practice was used to remove debris jams that were thought to block fish passage, or to remove fine organic matter that was thought to cause water quality problems such as reducing aquatic oxygen levels. Because stream cleaning was found to damage fish habitat, it is currently not a common practice.

stream density (drainage density): Total length of natural stream channels in a given area, expressed as miles of stream channel per square mile of area.

substrate: Mineral or organic material that forms the bed of a stream.

surface runoff: Water that runs across the top of the land without infiltrating the soil.

transpiration: Loss of water to the atmosphere from living plants.

upland vegetation: Vegetation typical for a given region, growing on drier upland soils. The same plant species may grow in both riparian and upland zones.

wind throw (also blowdown): The uprooting and felling of trees by strong gusts of wind.

Component I
Start-Up and Identification of Watershed Issues

Table of Contents

Component I
Start-Up and Identification of Watershed Issues

THE ASSESSMENT START-UP PROCESS

Overview

Watershed assessments can be used to meet a wide variety of goals. An assessment can function as a catalyst to establishing a community-based watershed group. Or it can provide an already-established group with a structured compilation of available watershed data, along with a review of the existing watershed conditions.

The initial step of the watershed assessment process is identifying the assessment team and gathering basic watershed information. These tasks are described in the steps below. After putting together a team and gathering information, the key to a smooth and successful assessment is establishing effective communications between the community, the assessment team, and technical support specialists, and ensuring that each group understands the goals of the process. The project manager or coordinator plays an important role in establishing and facilitating these communications. Important to the assessment is involvement, from the start, of property owners and other stakeholders in the watershed. The property owners should understand the goals of the process and be engaged in the process at the beginning. In addition, property owners often have detailed local knowledge, which can provide valuable insights to understanding watershed condition. Ultimately, stakeholders need to have ownership in the assessment process in order to develop support for identified enhancement and protection opportunities.

Stakeholders (including property owners, local residents, agency and industry representatives) should understand that watersheds are complicated, and that they will need to invest time either completing the assessment or reviewing and understanding the assessment findings.

The project manager leads this Start-Up and Identification of Watershed Issues component, oversees completion of each assessment component, and facilitates communications between the assessment team, the community, and local landowners. The first task of the project manager is to identify how the assessment components will be completed. The team may consist of staff or volunteers who have the skills and time to complete one or more assessment components. The project manager needs to track the progress of the watershed assessment team to ensure the assessment components are completed in a timely manner. The project manager will also be responsible for gathering and compiling basic maps and data, which are needed throughout the entire assessment.

Informing landowners in the watershed about the proposed watershed assessment, and building their understanding and support for the process, will help ensure that the assessment findings will be utilized. The project manager needs to notify the community that the assessment is taking place and provide opportunities for community involvement and input. Notices can be posted in prominent locations; landowners in the watershed, as well as local agency representatives, should be mailed notices. Community meetings designed to obtain input and identify issues will engage interested parties in the process; the information gathered can be used to help focus the assessment. During the Watershed Condition Evaluation phase at the end of the assessment, the start-up issues can be revisited to determine if these issues were adequately evaluated or if new issues were identified.

Necessary Skills

The project manager should have good organizational and communication skills. Meeting facilitation skills will help focus community meetings and build support for the assessment process.

Final Products of the Start-Up Component

The products of this component will be used in subsequent portions of the assessment. The following items need to be collected or developed:

- Base Map
- **Ecoregion**[1] locations and descriptions
- Refined Land Use Map: Map showing location of key land uses in the watershed
- Recent **stereo aerial photographs** covering the entire assessment area
- Issues Identification Form (Form SU-1)

Step 1: Identify Project Manager

The project manager will be responsible for assigning tasks, contacting stakeholders, and tracking and coordinating the completion of the assessment components. The project manager may also help with data acquisition and facilitate data transfer between the people working on individual components.

Step 2: Coordinate Community Input

There are a number of potential methods to solicit input from the local community for the purpose of building support for the project. The following tasks are recommended, although you may find it useful to structure them differently, depending on your knowledge of the community and your goals:

1. The project manager and assessment team should meet with the watershed council and technical advisors to review the list of potential issues. After this meeting, the watershed council should identify an appropriate forum for involving local property owners, local and community leaders, community action groups, and other stakeholders in the watershed in reviewing the list of issues. It is important that all parties understand that a watershed assessment cannot address all potential community concerns or issues.

2. Hold a series of informal meetings with community groups on their own ground. For example, presentations could be made at regularly scheduled meetings of the local Soil and Water Conservation District, small communities, industry associations, and interest groups.

Making the various entities comfortable with the process will take considerable time. A reasonable expectation is that the initial process of identifying issues and interacting with the community will

[1] Terms that appear in bold italic throughout this text are defined in a Glossary at the end of this component.

take several months. A number of data-gathering efforts, such as obtaining historical accounts and agency data records, can occur concurrently with the issue identification process.

Step 3: Identify Assessment Team

Completing an assessment is a big commitment in time and resources. We expect that it will take between 4 to 8 months to complete an assessment, depending on the watershed and the commitment of the assessment team. It would be very difficult for a single person to compile an entire watershed assessment in a timely manner. Hence, a team of people will usually be involved in completing the process. This watershed assessment process is designed for people who do not necessarily have specialized technical training. Each component lists specific skills which are either required or would be helpful in completing that component. You may be able to find staff on the watershed council, volunteers, students, consultants, or some mix of people who have the skills and can commit the time to completing one or more assessment components. The project manager needs to assign responsibility for specific components based on the person's skills, interests, and availability. Each potential team member should review the appropriate section of the manual to be certain they feel qualified to complete that portion of the assessment.

Step 4: Compile Initial Materials

Decide on Watershed

There are 1,063 5th field watersheds in the State of Oregon, with an average size of 58,218 acres. A geographic area of approximately 50,000 to 100,000 acres is an appropriate size to complete a watershed assessment. Watersheds of this size can usually be mapped at 1:24,000 scale (1 inch equals 2,000 feet) on standard plotter paper, and the scale provides adequate resolution for data display.

Obtain USGS Maps

A complete set of US Geological Survey (USGS) 7.5-minute topographic maps (also at 1:24,000 scale) for the entire watershed will be useful for initial orientation in the watershed, and for completing some assessment components. (See Contact Information sidebar for how to obtain copies of USGS and other maps.) The USGS also publishes a key to topographic map symbols, which will be useful for interpreting maps in some of the components. (Also see How to Interpret a Topographic Map sidebar.) In order to decide which maps are needed, you will need to locate an index map to identify names of map sheets (quads) covering your watershed. This information is usually available where you purchase maps. In addition, other maps used in the assessment will orient off of the USGS quad maps, so a list of quads covering the watershed will be useful for obtaining other background information.

CONTACT INFORMATION FOR MAP ACQUISITION

Topographic maps ($4 to $5/map)

- Nature of the Northwest Store, Oregon Building, Portland (503) 872-2750
- USGS Map Sales, Box 25286, Federal Center Building 810, Denver, CO 80225; (800) 872-6277
- Oregon State University, Valley Library http://www.orst.edu/dept/library/
- Local outdoor stores or bookstores

ODF stream classification maps

- ODF Fish Presence Coordinator (503) 945-7483. Cost $1.50/quad sheet + $2.35 shipping (up to 12 maps)

Obtain ODF Stream Classification Maps

These black-and-white maps produced by the Oregon Department of Forestry (ODF) are extremely useful and are available at a lower cost than USGS maps. You will need at least one complete set for the entire watershed, although you may want to order several sets. The ODF stream classification maps were developed from USGS quad maps, and have an enhanced stream network. The stream classification maps also show breaks between "large," "medium," and "small" streams; and upstream limit of fish use. The accuracy of fish distribution and stream size information on these maps varies across regions and watersheds. The analyst performing the Fish and Fish Habitat Assessment component will update the information on these maps. There is a current effort to digitize these maps into **Geographic Information System (GIS)** format, and digital versions should be available sometime in 1999.

Obtain Recent Stereo Aerial Photographs

Recent stereo aerial photographs covering the entire assessment area are essential for the Riparian/Wetlands Assessment component, and are useful for completing the Channel Habitat Type Classification and Sediment Sources assessment components, as well as others. Stereo aerial photographs allow the analyst to view the area of interest three-dimensionally. A scale of 1:12,000 is preferable, although smaller scales may suffice. Color or color-infrared photographs are preferred.

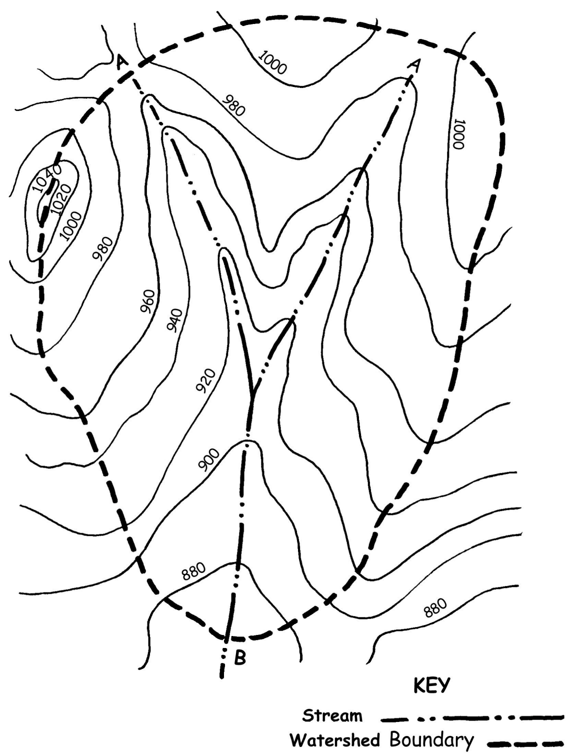
If stereo aerial photographs are not available **orthophotos** may be of some use. Orthophotos are aerial photos that have been corrected to remove displacement. Orthophotos are scale-correct but can only be viewed two-dimensionally.

HOW TO INTERPRET A TOPOGRAPHIC MAP*

Each contour line on a topographic map represents a vertical distance above a reference point such as sea level. All points along a contour line are at the same elevation. The difference between two adjacent contours is called the contour interval. It represents the vertical distance you would need to climb or descend from one contour elevation to the next.

The horizontal distance between contours is determined by the steepness of the landscape. On relatively flat ground, two 20-foot contours can be far apart horizontally. On a steep cliff, two 20-foot contours might be directly above and below each other. In both cases the vertical distance between contour lines is still 20 feet.

Water always flows downhill perpendicularly to the contour lines. As you go upstream, successively higher and higher contour lines first parallel then cross the stream. This is because the floor of a river valley rises as you go upstream. Likewise, the valley slopes upward on each side of the stream. A general rule is that topographic lines always point upstream. With that in mind, it is not difficult to make out drainage patterns and the direction of flow on the landscape. In the figure, the direction of streamflow is from Point A to Point B



* Adapted from the *Oregon Freshwater Assessment Methodology* (Roth et al. 1996).

The owner of the aerial photos for your watershed may not wish to loan out photos; however, you may be allowed to photocopy the set. Photocopies made using a high-quality machine (approximately $1/copy; cheaper sometimes for a large order) work well, and is a lower-cost alternative than buying your own set. Several possible sources for aerial photographs are listed in the Aerial Photos sidebar.

AERIAL PHOTOS

Training in Interpretation
Aerial photos are used for the Riparian/Wetlands Assessment component, and are very useful for the Sediment Sources and Channel Habitat Type Classification assessment components.

Examples of information gained from aerial photos include overall land use, riparian area width and species composition, evidence of historic changes, assistance in determining types of stream channels, identification of sediment sources, and evaluation of road networks. For someone without training in aerial photo interpretation and in working with stereo images, making sense of a series of aerial photos can be a daunting task. One approach is to find someone with experience reading aerial photos; perhaps an employee of a large landowner or a resource agency staff member may be able to help. That person may be willing to perform the aerial photo tasks, or to provide orientation and coaching to the person doing the interpretation. Consulting the Oregon State University (OSU) Extension Forester for your county may also help identify others who could provide expertise.

If training in aerial photo interpretation is desired, resources are available. The OSU College of Forestry periodically offers a short course on *Mapping from Aerial Photographs*. Contact the College of Forestry Conference Assistance Office at (541) 737-2329 (www.cof.orst.edu/cof or conference@cof.orst.edu).

Useful textbook resources include:
Paine, D.P, 1981. Aerial Photography and Image Interpretation for Resource Management. John Wiley and Sons, New York. 571 pp.

Avery, T.E. and G.L. Berlin, 1992. Fundamentals of Remote Sensing and Airphoto Interpretation, 5th edition. Macmillan Publishing Co., New York. 472 pp.

Sources for Aerial Photos
- Oregon Department of Forestry
- Natural Resource Conservation Service (NRCS)
- Local Soil and Water Conservation District
- University of Oregon Map and Aerial Photography Library, 165 Condon Hall, Eugene, OR 97403-1251; (541) 346-4565; http://libweb.uoregon.edu/~map/
- Local US Forest Service district or Bureau of Land Management district
- Oregon State University, Valley Library http://www.orst.edu/dept/library/
- Other possible agencies include: US Army Corps of Engineers, USGS, Oregon Department of Transportation, Bonneville Power Administration (if watershed located near major transmission lines), and county government

Commercial sources for photos in Oregon:
- WAC Corporation, 520 Conger Street, Eugene, OR 97402-9817; (800) 845-8088
- Spencer B. Gross, Inc., 13545 NW Science Park Drive, Portland, OR 97229; (503) 646-1733

Other possible sources of photos:
- Large forest landowners

Step 5: Create the Base Map

After materials are compiled, your first big task is to create a base map for the assessment. If the watershed council has GIS support, the State Service Center for GIS (SSCGIS) can provide base maps of watersheds that include the stream network, watershed boundaries, subwatershed boundaries, estuary boundaries, roads, legal boundaries, and locations of major cities and towns. These maps are available to download off the SSCGIS World Wide Web site or the center can be contracted to provide initial GIS map products. (See sidebar, Some GIS Mapping Options, for more information.)

SOME GIS MAPPING OPTIONS

Free Data

You can obtain baseline information from the State Service Center for GIS (SSCGIS) Web site at www.SSCGIS.state.or.us. This information includes major roads, waterbodies, public land survey (Township, Range and Section lines), watershed boundaries, generalized zoning, land ownership, city limits, urban growth boundaries, and 1990 census information on population. Available data includes fish distribution, 303(d) listed streams, and watershed council boundaries. This information is available for the entire state and can be downloaded directly from the Web site. You will need some type of GIS browser to import and view the data, and must be able to cookie-cut the data to your watershed (data is in county or state-wide format). Local governments often have a wealth of digital information that they are willing to share with other groups. Contact the State of Oregon GIS Data Administrator for contacts with local government GIS groups in your watershed. The local governments may have technical resources to help you.

Additional data may be available for the area where the assessment is taking place. Contact the State of Oregon GIS Data Administrator for more information:

(503) 373-7461 or (503) 378-2166
data@SSCGIS.state.or.us
http://www.SSCGIS.state.or.us

Professional GIS Services

There are several methods of obtaining quality GIS services. Several consultants work with watershed councils and provide GIS support for a fee. A list of these consultants can be obtained from the Governor's Watershed Enhancement Board (503-378-3589).

The SSCGIS has provided base information to several watershed councils at the request of the Governor's Watershed Enhancement Board. Base maps of major roads, streams, waterbodies, ownership, generalized zoning, and the USGS quad maps of topography can be obtained for $1,500 per 5th field watershed. Additional GIS services are available. Contact the SSCGIS at (503) 378-4163 for additional information and price quotes.

Coordination of Digital Data

The state would like to coordinate the update of base information and the additional data collected during the assessment process. This digital data could then be used for regional or multiple basin assessments. Whatever the process you use to develop your base information, please contact the SSCGIS to make sure your results are incorporated into the Oregon Digital Map Library.

Numerous sources of GIS data are available, and deciding what data to use can be confusing. In addition, the usability of the data depends on the scale at which the data was collected and compiled, and the format and presentation of the data. Sorting through maps to determine the metadata (data about data) used to create them can be an overwhelming task. Then it takes a solid understanding of the mapping process and professional judgement to determine if the data accurately portrays conditions. GIS support requires professional expertise, which in itself can be time-consuming and expensive. For these reasons, this assessment process does not require GIS support to be completed. However GIS support can expedite creation of the base map, and allows for better-quality final maps and more options for summarizing results. We have described in the following subsections a process for developing your own base maps without GIS support.

Choose the Best Watershed Map

The ODF stream classification maps are the most informative maps and are usually the best-suited for use as base maps. The initial base map is made by cutting and pasting together the paper quad maps to produce a single map of the entire assessment area. Many photocopy shops have large-format copy machines that can reproduce several copies of this map for use in subwatershed delineation.

Identify Subwatersheds

You will need to partition the large watersheds into subwatersheds of roughly equal size to provide a framework for organizing and summarizing the data. There is currently no standard delineation of 6th field **Hydrologic Unit Codes** (HUCs) (subwatersheds), although in some portions of the state 6th field HUCs are mapped, and these established subwatersheds may be adequate for the assessment. If 6th field watersheds have not been mapped, the project manager, in consultation with the assessment team, will be responsible for deciding how to partition the watershed. Usually watersheds can be divided up into 6 to 12 subwatersheds depending on the overall geomorphology and land use patterns.

Delineation can be based on a combination of factors, including major changes in topography, land use, and stream size. (See Delineating Watersheds and Subwatersheds sidebar for mapping instructions.) Where some subwatersheds are dominated by different land uses, certain individuals or groups within the councils may take responsibility for specific uses (agriculture, forestry, a suburban stream) with which they are familiar, while still working to ensure consistency of analysis within the watershed. It may also be possible and desirable to separate out a tributary or sub-basin that has been highly impacted (greater than, say, 50%) by development. Subwatershed boundaries can be identified by following the major topographic features dividing drainage areas (tributaries). It may take several attempts to decide on an appropriate delineation for subwatershed boundaries. Subwatersheds should be named for the major tributary within the subwatershed so that references to the subwatersheds will be consistent through all assessment components. Once the subwatersheds have been identified and agreed upon, they should be delineated on all of the base maps. Because subwatersheds are so fundamental to watershed characterization and assessment, the watershed technical team should review and approve the proposed division of subwatersheds.

Delineate Ecoregions

The Level III and IV ecoregions of Oregon and Washington are mapped in the Ecoregion appendix of this manual. Locate your watershed on the map and identify the ecoregion(s) that occur in your watershed. If more than one ecoregion occurs in your watershed, draw the divisions between ecoregions on the map. Find the appropriate ecoregion descriptions in the Ecoregion appendix. These descriptions contain information useful for most components of the assessment. Make copies of the pertinent description for each member of the assessment team.

Finalize Base Map

You should now have a paper map at 1:24,000 scale produced either by GIS or cutting and taping. The map should show the watershed partitioned into named subwatersheds of roughly equal size, the stream network, stream names along with watershed boundaries, estuary boundaries, section boundaries, present ecoregions, major roads, and the locations of cities and towns. Additional copies of this map can now be produced (either plotted from GIS or copied on a large-format copy machine) on paper or Mylar and given to the assessment team members to start their assessments. Paper maps can be laminated so that information can be added with a fine-tipped marker and erased if a correction is needed.

DELINEATING WATERSHEDS AND SUBWATERSHEDS*

The head of a watershed is the point where land slopes away into another watershed. Generally, this occurs at hill tops, ridge lines, or saddles. If you were to join all of the high points around a stream, you would have the watershed boundary. The following example shows how to locate and connect all of the high points around a watershed on a topographic map.

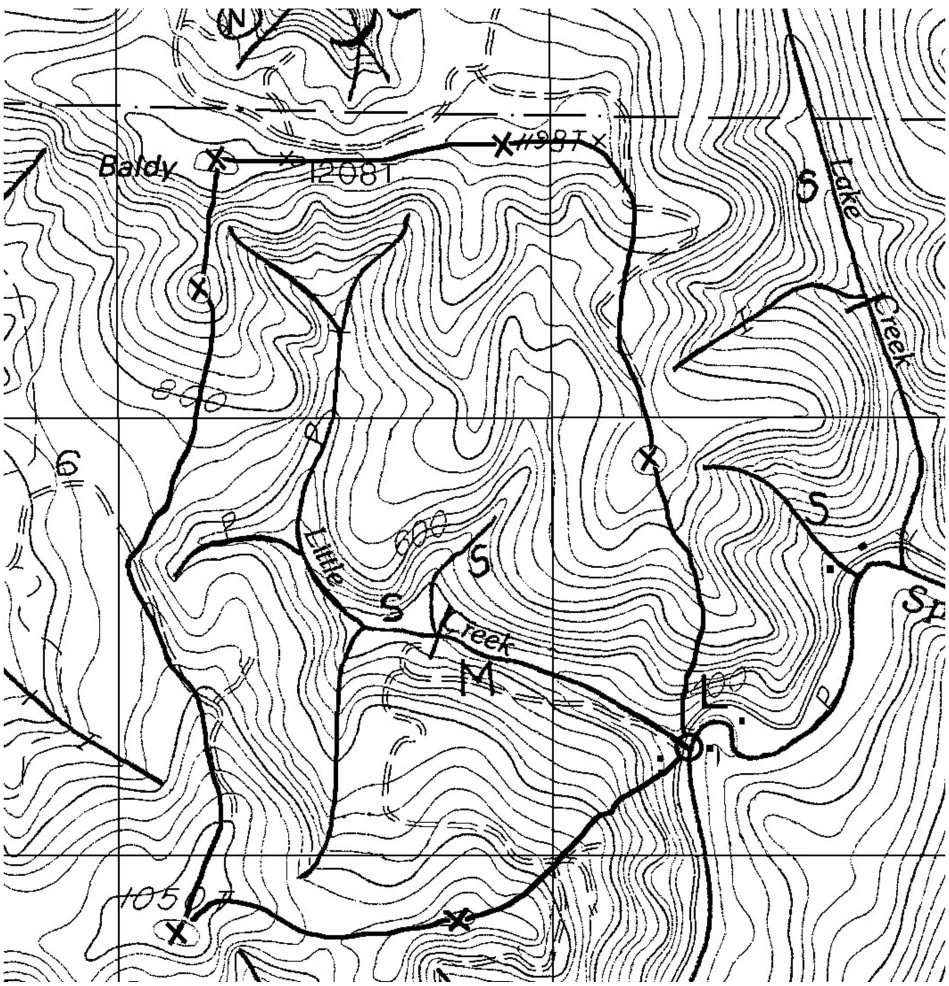
1. Draw a circle at the outlet or lowest point of the stream or tributary in question.

2. Put small x's on the high points along both sides of the stream, working your way upstream.

3. Starting at the circle, draw a line connecting the x's. This line should always cross the contours at right angles (i.e., it should be perpendicular to each contour line it crosses).

4. Continue the line until it circles the stream watershed.

The boundary will appear as a solid line around the stream or tributary. Generally, surface-water runoff from rain falling anywhere in this boundary flows into the subwatershed stream.



*Adapted from the *Oregon Freshwater Assessment Methodology* (Roth et al. 1996).

Step 6: Refine the Land Use Map

The Refined Land Use Map will be used in assessment components to identify the types and areas of potential land use impacts. Land use maps are available at 1:24,000 from the SSCGIS. In addition, users should request an ownership map to help with validation of the land uses within the mapped categories. The land use map provided by the SSCGIS is based on zoning designations and is produced at a larger scale than other maps used in the assessment. This means users will need to make some additions to create the Refined Land Use Map for use in the assessments.

For the assessment process the watershed land uses are placed into the four categories: (1) forestry, (2) agriculture, (3) rangeland, and (4) urban. Typically, stakeholders will have specific understanding of land uses in the watershed. The actual land uses should be validated using ownership maps, local knowledge, aerial photo validation, or field visits.

In this step, you inspect the land use map provided by the SSCGIS and identify the different land uses present in your watershed and in each of its subwatersheds. The land use map acquired from the SSCGIS is based on local zoning designations. These designations may not accurately represent the actual land uses in the watershed. First you need to validate the boundaries around the mapped land uses using aerial photographs or orthophoto quadrangle maps. Orient yourself to a landmark visible on both the photo or map (road and streams are often good points of reference). Visually compare the boundaries of observed land uses (i.e., fields, forests) to the mapped land uses. On the land use map, mark the corrected land use boundaries. Using this corrected, Refined Land Use Map, determine the area (acres or square miles) of forestry, agriculture, range land, and/or urban land uses in each subwatershed. The areas in each land use can either be estimated using GIS or calculated using either the rectangular grid method or a **planimeter** (see the How to Measure Watershed Area sidebar). The project manager should make an effort to ensure that the Refined Land Use Map represents the actual land uses as accurately as possible and make sure the stakeholders in the watershed agree with the maps at this stage.

HOW TO MEASURE WATERSHED AREA

Grid Method

The grid method entails constructing a rectangular grid and counting squares, estimating partial squares. Usually it is easiest to trace the basin outline onto a sheet of graph paper, and count the squares on that grid. Converting the number of squares to an area value depends on the scale of the map you are using. If you are using a USGS quad map, the scale is 1 inch equals 2,000 feet or 1 square inch equals 0.143 square miles (Dunne and Leopold 1978).

How many squares inches did you count in your drainage basin?

Multiply this number by 0.143 and the result is the area in square miles.

To convert to acres: 1 square mile = 640 acres.

Planimeter Method

A planimeter is a small device with a hinged mechanical arm. One end of the arm is fixed to a weighted base while the other end has an attached magnifying lens with a pointer. You trace around the area to be measured with the pointer. The planimeter readout registers the area being measured.

Planimeters cost between several hundred to a thousand dollars depending on the degree of sophistication. They are available from forestry or engineering supply companies.

Step 7: Acquisition and Compilation of Other Data

Table 1 lists basic data needs and identifies which assessment components utilize specific data products. The project manager may want to order additional data materials for other assessment components to facilitate the process. Directions for acquiring materials for a specific assessment component can be found in that component.

IDENTIFICATION OF WATERSHED ISSUES

Critical watershed issues should be identified early in the process to help focus the watershed assessment. Although all elements of the watershed characterization and assessment generally apply to a watershed, this step will help the council in understanding how the assessment products fit into current state and federal regulatory direction. In addition, early identification of important watershed issues may help direct where time will be spent.

Table 1. List of basic background materials needed for a watershed assessment.

	Historical Conditions	CHT	Hydrology & Water Use	Riparian/ Wetlands	Sediment Sources	Channel Modifi-cation	Water Quality	Fish & Fish Habitat
Watershed base map	√	√	√	√	√	√	√	√
Land use map			√	√			√	
USGS topo maps		√			√	√		
Aerial photographs		√	√	√	√	√		
Orthophoto quads			√		√	√		
Ecoregion summary			√	√	√			
Oregon Department of Fish and Wildlife and other physical stream habitat surveys		√		√				√*
CHT map		√		√		√		√
Historic condition summary table						√		√
Mean annual precipitation map			√*					
NRCS county soil surveys			√	√*				
USGS stream gage data			√*					
Division of State Lands wetland inventory maps				√*				
National Wetland Inventory maps				√*				

* Indicates that directions for obtaining this information are included in this component.

The issues to be addressed in a watershed assessment typically arise from local efforts to address concerns that often begin at federal and state levels. Listing of fish populations under the federal Endangered Species Act, for example, immediately focuses attention on evaluating habitat quality or hatchery production in the watershed. Water quality limited stream segments, listed under authority of the federal Clean Water Act, require that watershed management plans (or Total Maximum Daily Loads [TMDLs]) be developed at the state or local level. (See "Section 303[d] Requirements" in Appendix I-A.) These national- and state-level issues need to be integrated with local concerns expressed by watershed councils, communities, and other stakeholders in the watershed. Issue identification will be an iterative process, but can be initiated using a rational approach that answers the following critical questions. This Issue Identification component provides guidance on how to step through this process.

Critical Questions

1. What resource-condition issues that affect local decision making in the watershed arise from state and federal laws?

2. What are the potential effects of land management activities that affect these issues?

3. Are there additional aquatic resource issues that have been identified at the local level?

4. How does one use this set of issues in conducting a watershed assessment?

Identify Typical Issues Associated with Land Use

Regulatory listings and land use categories are a good way to organize potential watershed issues at the outset of the assessment. Table 2 identifies how to determine the regulatory status of fish and water quality conditions in your watershed. Appendix I-A provides more detailed background information on state and federal programs regulating water quality and fisheries. The Refined Land Use Map created during the start-up provides a means of spatially locating potential issues in the watershed. The list of typical issues associated with land uses (Table 3) provides a starting point for identifying the specific issues applicable in the watershed. This table is intended to help identify the typical major concerns with the land use related to fish habitat and water quality. The list is used to initiate discussion within the assessment team and the watershed council, and to focus the objectives and scope of the watershed assessment.

There are significant distinctions between the type of alteration for the same issue listed in the table resulting from different land uses. For example, most land use activities have the potential to alter basin hydrology with resulting effects on aquatic resources. In forestry, the primary consideration is with the potential for increase in peak flows due to rain-on-snow events and the alteration of runoff patterns associated with the road network. In crop-land and range-land areas, activities can reduce infiltration of runoff into the soil, increasing high flows and reducing summer baseflows. These distinctions will be addressed in the Hydrology and Water Use Assessment component. At this point in the process it is merely necessary to flag the issue of "flow alteration."

The project manager should initially identify the regulatory issues and the potential issues related to land management. Then during the community coordination phase of the start-up, the project manager should plan a meeting involving watershed council members and property owners in the watershed to discuss the list of potential issues and identify any other issues. The project manager can then complete Form SU-1: Issues Identification form. Table 4 provides an example of a completed Issues Identification form.

The completed Issues Identification form is used to base discussions between the assessment team and the water council regarding approaches for addressing potential issues in the watershed. As illustrated in Table 4, conditions that warrant a regulatory status in Item 1 may conflict with landowner perceptions or local information (i.e., temperature). The information compiled in Items 1 to 3 is used for Item 4, identifying the relevance to the watershed assessment process. For example, a detailed temperature analysis and monitoring are recommended because there is potential conflict over whether temperature is an issue.

Table 2. Identifying regulatory issues in your watershed.

Regulatory Program	How to Determine Watershed Status
Federal and state endangered species	The Oregon Natural Heritage Program (ONHP) provides standard data on endangered species and communities. This listing includes all species with state and/or federal listing status. To request data, write or fax to the address or number below, stating your data needs. Include the following information: Name, address, and phone number of user or organization Type of data needed Specific locations of data needed, if appropriate Explanation of how the information will be used Fees are charged to cover the cost of providing data services. The minimum charge is $30. Charges are based at the rate of $50 per hour of staff time required, plus a $0.50 per record printout fee, and a $20 computer access fee. A fee estimate can be given prior to initiating a search. Send data requests to: Oregon Natural Heritage Program 821 SE 14th Avenue Portland, OR 97214-2531 (503) 731-3070 ext. 335 or 338; fax (503) 230-9639 The ONHP publication *Rare, Threatened and Endangered Plants and Animals of Oregon* (March 1998, 92 pp.) has tables listing the status of species of concern in the state by counties. This listing will be adequate for an initial identification of key species. The principal tables from this document are available online at: http://www.heritage.tnc.org/nhp/us/or/index.html#publications
303(d) water quality listings	Information on beneficial uses, water quality criteria, and 303(d) listings are available on the Oregon Department of Environmental Quality (ODEQ) Internet site or by contacting the local office of ODEQ. The information can be obtained by following the hypertext links starting with the ODEQ Internet home page. ODEQ Home page: http://www.DEQ.state.or.us Web links: DEQ Home Page ⇒ Water Quality Program ⇒ 303(d) List *Section 303(d) List:* This list shows parameters, the basis, and supporting data. Query the list for the specific stream segments and download this information. *More 303(d) Information (optional):* The 303(d) List site contains additional information about water quality limited streams and TMDLs, including information on listing criteria, TMDL schedules, priorities, 303(d) database, fact sheets, guidance, and examples of TMDLs. **Phone Numbers** (800) 452-4011 ODEQ Public Information (503) 229-5279 Water Quality Division

Table 3. Typical issues organized by major land use activity.

Land Use Category	Habitat-Related Issues	Water Quality Issues
Forestry	Channel modification Pool quantity and quality Large wood abundance Shade and canopy Substrate quality Flow alteration Passage barriers	Temperature Turbidity Fine sediments Pesticides and herbicides
Crop-land grazing	Channel modification Pool quantity and quality Large wood abundance Shade and canopy Substrate quality Flow alteration	Temperature Dissolved oxygen Turbidity Fine sediments Suspended sediments Nutrients, bacteria Pesticides and herbicides
Feedlots and dairies	Channel modification	Suspended Sediments Nutrients Bacteria
Urban areas	Flow alteration Channel modification Pool quantity and quality Large wood abundance Shade and canopy Substrate quality Passage barriers	Temperature Dissolved oxygen Turbidity Suspended sediments Fine sediments Nutrients Organic and inorganic toxics
Mining	Channel modification Pool quantity and quality Substrate quality	Turbidity Suspended sediments Fine sediments Heavy metals
Dams and irrigation works	Flow alteration Channel modification Pool quantity and quality Substrate quality Passage barriers	Temperature Dissolved oxygen Fine sediments
Road networks	Flow alteration Channel modification Pool quantity and quality Substrate quality Passage barriers	Turbidity Suspended sediments Fine sediments

Table 4. Example of a completed Issues Identification Form (Form SU-1).

Location—Oregon Coast Watershed	
1. Identify aquatic resource issues based on state and federal laws.	Endangered Species Act Coho salmon – threatened Steelhead trout – candidate Chum salmon – state sensitive listing
	Clean Water Act – 303 (d) List Habitat modification Sediment Temperature – summer
2. Identify potential issues related to land management.	Land Use Designation 95 % – Forest lands 05 % – Mixed agriculture and rural residential
	Potential Issues Channel modification Pool quantity and quality Large wood frequency and recruitment potential Shade and canopy Substrate quality Flow alteration
3. Check these potential issues with the watershed council and local community.	Example Outcomes • Abandoned mines in headwaters. • Watershed assessment on federal lands indicated temperature violations. • Landowners believe that temperature is not a problem. • Landslides have frequently closed the county road at the bottom of the drainage.
4. Revise list of issues and identify relevance to watershed assessment process.	Focus Issues • Coho juveniles require habitat with deep pools and overhead cover supplied by large woody debris (LWD). • Investigate LWD potential and existing shade. • Since temperature may be an issue, plan on detailed analysis of continuous records (7-day averages); potential for summer monitoring. • Look for records on heavy metals. • Screen for forest harvest effects on peak flows. • Investigate landslides along lower road. Recruit agency specialist or hire technical consultant.

REFERENCES

Dunne, T. and L.B. Leopold. 1978. Water and Environmental Planning. W.H. Freeman and Co., New York.

Roth, E., R. Olsen, P. Snow, and R. Sumner. 1996. Oregon Freshwater Assessment Methodology. Second edition. Oregon Division of State Lands, Salem.

GLOSSARY

ecoregion: Land areas with fairly similar geology, flora and fauna, and landscape characteristics that reflect a certain ecosystem type.

Geographic Information System (GIS): A computer system designed for storage, manipulation, and presentation of geographical information such as topography, elevation, geology, etc.

Hydrologic Unit Codes (HUCs): US Geological Survey designations that correspond to specific watersheds, and are expressed in a hierarchical scale.

orthophoto: A combined aerial photograph and planimetric (no indications of contour) map without image displacements and distortions.

planimeter: An instrument for measuring the area of a plane (2-dimensional) figure by tracing its boundary line.

stereo aerial photo: Pairs of photos taken from the air that can be viewed through a stereoscope to reveal three-dimensional features of the landscape.

Appendix I-A
Background on State and Federal Regulatory Issues

APPENDIX I-A: BACKGROUND ON STATE AND FEDERAL REGULATORY ISSUES

The Oregon watershed assessment is targeted at "aquatic resource issues." Fish and water quality are the primary drivers for watershed assessment and restoration in Oregon. The assessment process focuses on evaluating watershed processes that influence the ability of the watershed to produce clean water and support fish populations. This appendix summarizes the regulatory policies that direct aquatic resource protection at the state and federal level. Numerous other laws regulate land management activities, such as the National Environmental Policy Act or local planning and zoning regulations, which are not discussed here. These other laws will influence what restoration actions can be taken and how they are conducted.

Fisheries

Federal Endangered Species Act

The Endangered Species Act (ESA) of 1973 provides for listing of native animal and plant species as endangered and provided means for their protection.[1] The US Fish and Wildlife Service (USFWS; responsible for inland fish, wildlife, and plants) and the National Marine Fisheries Service (NMFS; responsible for marine and anadromous fish and marine mammals) are the designated federal agencies responsible for administering the law. The key components of the ESA include the following:

1. Defining categories of "endangered" and "threatened," and listing populations.

2. Requiring all federal agencies to undertake programs for the conservation of endangered and threatened species.

3. Prohibiting these agencies from authorizing, funding, or carrying out any action that would jeopardize a listed species or destroy or modify its "critical habitat."

Before proceeding on any action that may affect endangered species, federal agencies must "consult" with the NMFS or USFWS. Consultation is a formal process that evaluates the effects of the action and determines if the activity needs to be modified to reduce the potential effect on the organism. In addition, the ESA applies broad "taking" prohibitions to all threatened or endangered animal species. In Oregon, there are 25 species of fish, 8 species of birds, 5 species of mammals, and 14 species of plants listed or proposed for listing under the ESA at the time of this writing.

Oregon State Endangered Species Programs

The Oregon Endangered Species Act of 1987 (ORS 496.172) gave the Oregon Department of Agriculture (ODA) responsibility and jurisdiction over threatened and endangered plants. The Oregon Department of Fish and Wildlife (ODFW) has responsibility for threatened and endangered fish and wildlife. Both of these agencies have entered into cooperative (Section 6) agreements with the USFWS to continue research and conservation programs for animal and plant species under the

[1] The ESA defines endangered as any species (except insects) "in danger of extinction throughout all or a significant portion of it range," and as threatened any likely to become endangered "within the foreseeable future throughout all or a significant portion of its range."

federal ESA. The Oregon Natural Heritage Program (ONHP) has a similar agreement with the USFWS for invertebrates.

The ODFW maintains a list of threatened and endangered species; currently 35 species of fish and wildlife are on the list. The Oregon act requires state agencies to develop programs for the management and protection of endangered species, and requires agencies to comply with guidelines adopted by the Oregon Fish and Wildlife Commission for threatened species. The Oregon Fish and Wildlife Commission has provided criteria for listing and delisting species, and for protecting listed species.

The Oregon Fish and Wildlife Commission has also adopted a rule requiring the department to develop and maintain a state list of sensitive species for vertebrates. Sensitive species constitute naturally reproducing native vertebrates that are likely to become threatened or endangered throughout all or a significant portion of their range in Oregon. The sensitive species list, which is divided into four categories (see sidebar), is for the express purpose of encouraging actions that will prevent further decline in species' populations and/or habitats, thus avoiding the need for listing.

OREGON STATE SENSITIVE SPECIES CATEGORIES

Critical (SC)—Species for which listing as threatened or endangered is pending; or those for which listing as threatened or endangered may be appropriate if immediate conservation actions are not taken.

Vulnerable (SV)—Species for which listing as threatened or endangered is not believed to be imminent and can be avoided through continued or expanded use of adequate protective measures and monitoring.

Peripheral or Naturally Rare (SP)—Peripheral species are those whose Oregon populations are on the edge of their range. Naturally rare species are those which had low population numbers historically in Oregon because of naturally limiting factors. Maintaining the status quo for the habitats and populations of these species is a minimum requirement.

Undetermined Status (SU)—Animals in this category are species for which status is unclear. They may be susceptible to population decline of sufficient magnitude that they could qualify for endangered, threatened, critical, or vulnerable status, but scientific study will be required before a judgement can be made.

Water Quality Laws and Programs

Federal Clean Water Act

The 1972 Federal Clean Water Act (CWA) as amended gives the state responsibility for setting water quality standards and developing water quality management programs which ensure that the goals of the CWA are met. Recent judicial actions have focused attention on listing of impaired waters under Section 303(d) of the CWA. States in the Pacific Northwest, including Oregon, have significantly increased the number of stream segments that are designated as water quality limited under the provisions of the act. Listing of the stream segment as water quality limited requires the state to prepare a Total Maximum Daily Load (TMDLs) plan or a water quality management plan that will function as a TMDL plan for nonpoint sources (e.g., forestry, agriculture, grazing, and untreated urban stormwater runoff). Information collected during a watershed assessment can be used to assist the state in evaluating the status for listing and in developing the management plans required under the act. In addition, Section 404 of this law regulates the discharge of fill material into wetlands and other "Waters of the United States."

Oregon Department of Environmental Quality

In Oregon, the Department of Environmental Quality (ODEQ) has the responsibility for developing standards that protect beneficial uses such as drinking water, cold-water fisheries, salmonid spawning, industrial water supply, recreation, and agriculture. The state must monitor water quality and review available data and information to determine if the standards are being met. Section 303(d) of the CWA requires the state to develop a list of waterbodies that do not meet standards, and to submit an updated list to the US Environmental Protection Agency (EPA) every 2 years. The list provides a way for Oregonians to identify problems and develop and implement watershed recovery plans to protect beneficial uses while achieving federal and state water quality standards. There are 1,067 streams and rivers, 32 lakes, and 1,168 stream segments on the 1998 303(d) list, which covers 13,892 miles of streams in Oregon.

The 303(d) list is a useful source for identifying water quality issues that are important in the watershed. The list identifies the parameter, the basis for the listing, and information that supported the listing. The watershed assessment can be useful in part to evaluate the basis for listing, evaluate the adequacy of supporting data, and establish a monitoring plan to fill data gaps. The programs described below and in the sidebars on pages 5 and 6 have been developed to provide solutions to these issues.

Relationship of Watershed Assessment to TMDL Requirements

Watershed assessment can be an important tool in completing the planning and assessment elements for TMDL plans required under the CWA. State agencies have developed watershed management plans to respond to these requirements for nonpoint source watersheds. Several of these initiatives led to watershed planning documents which have similar names, but may differ in their content and standing in fulfilling the requirements of the CWA. It is useful to review the intended purpose of these programs, then identify the potential role that watershed assessment can play in resolving these issues.

Section 303(d) Requirements

Section 303(d) of the 1972 federal CWA requires states to develop a list of waterbodies that cannot meet water quality standards without application of additional pollution controls. These waters are referred to as “water quality limited” and must be periodically identified in each state. In Oregon, this responsibility rests with the ODEQ. Water quality limited waters requiring the application of a TMDL plan are identified in the 303(d) list. This list, developed by the ODEQ, is subject to public review and must be approved by EPA.

The 303(d) list is really a subset of the larger list of water quality limited waters. These waters are defined **not** by whether they meet the standards, but by whether treatments above and beyond “best available technology” and normally applied “best management practices” are required to protect beneficial uses. In other words, a waterbody will retain its water quality limited status so long as the attainment of water quality standards requires a heightened level of treatment or watershed management, even if standards are currently being met or a TMDL plan is being implemented. Those waters that (1) don’t meet standards and (2) haven’t yet received TMDL plans or equivalents are placed on the 303(d) list. The other water quality limited waterbodies will still be identified in ODEQ’s regular Water Quality Status Assessment (305[b]) report.

A full TMDL development process determines the pollutants causing water quality impairments, identifies maximum permissible loading capacities for the waterbody in question, and then, for each relevant pollutant, assigns load allocations to each of the different sources, point (e.g., sewage treatment plants, industrial facilities) and nonpoint, in the watershed. Different TMDL development processes will be used in different situations depending on the types of sources involved. More complex and lengthy processes are required where the contributions of both point sources and nonpoint sources make the situation complex. Where only nonpoint sources are involved, the TMDL development process will generally be less complex, although a thorough understanding of the watershed and its water quality are necessary in either case.

Water Quality Management Area Plans

In 1993, the state legislature approved Senate Bill (SB) 1010, which requires the Oregon Department of Agriculture (ODA) to help reduce water pollution from agricultural sources and improve overall watershed conditions in various areas throughout the state. SB 1010 directs ODA to work with farmers and ranchers to develop overall agricultural water quality management area plans for watersheds that are required by state or federal law to have such plans in place.

Landowners who conduct agricultural activities within areas delineated by ODA where an agricultural water quality management area plan is in place are required to perform activities in conformance with the plan. The goal of a plan is to improve the overall health of the watershed; specific practices will not be prescribed to landowners as long as the goal is being met. However, landowners contributing to water quality problems who do not take voluntary steps to address problems may be subject to specific compliance orders and/or enforcement action. Other regulatory and nonregulatory programs are explained in the following sidebars.

OTHER WATER QUALITY PROGRAMS

Comprehensive Land Use Plans

These plans, required for all areas of Oregon by state law, address the protection and management of a number of natural resource values, including water resources. Developed by cities and counties in accordance with statewide goals and guidelines, these plans are based on detailed inventories and are implemented through enforceable local ordinances which govern the location and execution of many land use and land management activities. Under these plans, local governments must develop storm water treatment plans.

Oregon Forest Practices Act (FPA)

The forestry practices resulting from this program have been conditionally approved by EPA as the "best management practices" (BMPs) for water quality protection on state and private forest lands within the boundary of the Coastal Nonpoint Source Control Program. Water quality protections in federal forest practices must meet or exceed the effectiveness of the FPA practices. The Oregon Department of Forestry has already served as the lead agency for TMDL development on state and private forest lands in several basins.

Public Land Management Plans

Between them, the US Forest Service and Bureau of Land Management manage over 50% of Oregon's land area, and federal lands in national parks, federal wildlife refuges, and military reservations are another 5% or 6%. These federal lands are a large majority of the area in many rural watersheds. Federal laws require detailed management plans for these lands, and the law also requires that the plans be consistent with the Clean Water Act and with state environmental protection programs.

NONREGULATORY STATE FISHERIES AND WATERSHED PLANS

Oregon Plan for Salmon and Watersheds (Oregon Plan)

The Oregon Plan originated in 1995 as an effort to address declining populations of coastal coho salmon. The plan has been expanded to include nonlisted coho populations and declining steelhead populations. The goal of the plan is to restore fish populations to productive and sustainable levels that will provide environmental, cultural, and economic benefits. While the Plan focuses on the needs of salmon, it is designed to conserve and restore crucial elements of natural systems that support fish, wildlife, and people. The Oregon Plan relies on four fundamental approaches to accomplish the goal of securing and protecting healthy fish habitat: (1) community-based action, (2) government coordination, (3) monitoring and accountability, and (4) making improvements over time. Watershed councils play a key role in developing watershed restoration plans and engaging landowners in restoration actions. This watershed assessment guide is being developed as a tool to assist watershed councils in conducting the assessment as a necessary first step to implementing meaningful restoration activities. The Healthy Streams Partnership described below is a component of the Oregon Plan.

Healthy Streams Partnership

The Healthy Streams Partnership was formed in an effort to find cooperative solutions to water quality problems. The partnership is made up of representatives from the agricultural community, forestry, environmental groups, local government and state agencies, and the governor's office. The partnership uses existing regulations under the departments of Agriculture, Forestry and Environmental Quality to address waterbodies that currently do not meet water quality standards. The partnership provides support to state agencies and, at the same time, ensures that landowners and other individuals will have extensive opportunity for input into decisions. Restoring Oregon's waters will meet the requirements of the federal Clean Water Act, settle lawsuits related to the act, and help ensure success of the Oregon Plan for Salmon and Watersheds to restore salmon and steelhead runs.

Governor's Watershed Enhancement Board (GWEB)

By providing grant funds, technical assistance, and information, GWEB supports the work of watershed councils and other parties and is the primary source of state funding for investment in a variety of watershed enhancement projects. GWEB is designed to work closely with the Healthy Streams Partnership and the Oregon Plan for Salmon and Watersheds.

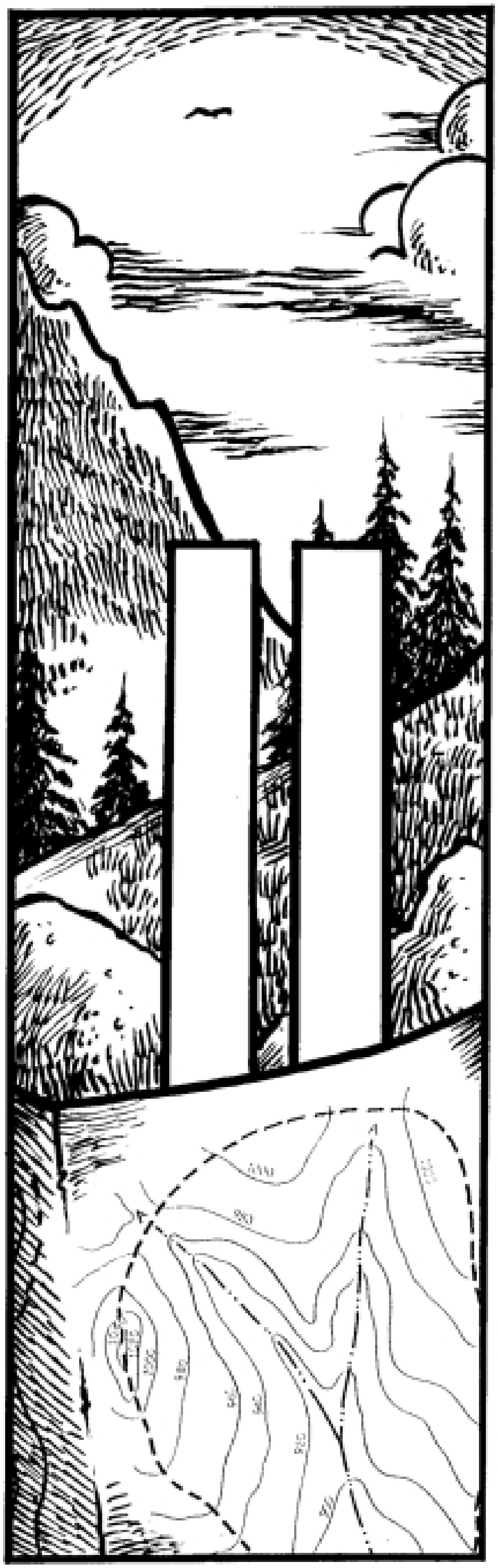
Appendix I-B
Blank Form

Form SU-1: Issue Identification Form

Watershed Name:

Participants in Issue Identification:

1. Identify aquatic resource issues based on state and federal laws.	Endangered Species Act
	Clean Water Act – 303(d) List
2. Identify potential issues related to land management.	Land Use Designations in Watershed
	Potential Issues
3. Check these potential issues with the watershed council and local community.	
4. Revise list of issues and identify relevance to watershed assessment process.	Focus Issues



Component II Historical Conditions Assessment

Table of Contents

Table of Contents (continued)

Component II
Historical Conditions Assessment

INTRODUCTION

Historical information can provide clues to the status of the watershed around the time of European exploration/settlement, and to how conditions have changed through time. A great variety and abundance of historical information exists, including museums, agency archives, literature, and oral histories. It is important to focus the search of historical materials to emphasize issues that relate to landscape conditions, aquatic/riparian habitat, fish populations, and water quality. Issues to be explored through investigation of historical information include settlement patterns, direct impacts to the stream channels, riparian vegetation patterns and change, natural and human-caused disturbance such as floods and fire, fish presence and distribution, and resource use through time.

Critical Questions

1. What were the characteristics of the watershed's resources at the time of European exploration/settlement?

2. What are the historical trends and locations of land use and other management impacts in the watershed?

3. What are the historical accounts of fish populations and distribution?

4. Where are the locations of historic floodplain, riparian area, channel, and wetland modifications, and what was the type and extent of the disturbance?

Assumptions

- Historical accounts provide clues that can be used to develop an understanding of the condition of key watershed resources before settlement.

- Some historic land use, management, and in-channel activities have changed the quality and/or quantity of aquatic habitat resources from European settlement conditions.

Materials Needed

- 7.5-minute US Geological Survey (USGS) topographic maps of the watershed (from Start-Up and Identification of Watershed Issues component)

- Project base map or Mylar overlay the size of the base map (from Start-Up and Identification of Watershed Issues component)

- Sharp pencil, colored pencils, thin permanent markers (optional: colored adhesive dots)

- USGS topographic map symbols (from Start-Up and Identification of Watershed Issues component)

- Historical data and information from many sources (see Step 1: Gather Existing Information, below)

- A map wheel (or an engineer's ruler with inches marked in 10ths so you can easily enter measurements into a calculator will work if you measure carefully)

Necessary Skills

Uncovering historical accounts and documents about a watershed requires a lot of detective work. The minimum skills necessary to produce a historical condition report include: (1) the ability and desire to search for and compile information from a variety of information sources and individuals, and (2) the ability to summarize information in a report format. The ability to use aerial photographs will help you accomplish this task, but is not required.

Final Products of the Historic Conditions Component

The final product will be a concise report on your watershed's historical conditions that includes the following seven components:

1. A descriptive historical narrative

2. Historical conditions time line

3. Historical information referenced by stream/subwatershed location

4. Historical Channel and Riparian Modification Inventory (from Form HC-1) and Map

5. A summary of historical information and trends, and conclusions on impacts on aquatic/ riparian resources

6. A comprehensive listing of the sources of information

7. Confidence Evaluation (Form HC-2)

Appendix II-A provides a suggested outline of the historical condition report. Note that the Historical Channel and Riparian Modification Inventory will be carried over to the Channel Modification Assessment component to help produce a comprehensive picture of the channel modifications that may be impacting aquatic resources. The current degree of impact from the historical channel modifications will be determined in that assessment. As a result, it is important that these tasks are coordinated; you are encouraged to read the Channel Modification Assessment component before beginning the investigation of historical conditions.

METHODS

Step 1: Gather Existing Information

Begin assembling and investigating historical information from a variety of sources. It is impossible to list all of the sources of historical information for a watershed; the following information sources are good starting points. Places to look for such information include local historical societies; city, state, and university libraries; government agencies and their archives; and so on.

- Old maps
  - explorers' sketches
  - old timber cruise maps
- Landscape photographs
- Aerial photographs
- Accounts from literature
  - local and state history books
  - newspaper accounts
  - scientific journals and other studies
  - published oral histories
- Historical archives and museums
- Oral history interviews
  - long-time watershed residents
  - resource agency personnel
- County, state, and federal agency reports/databases
  - General Land Office survey records
  - US Army Corps of Engineers snag removal records
  - fish hatchery records
  - fish catch records
  - navigability reports
  - fish counts at dams and other passage facilities
  - stream habitat surveys
  - spawning surveys
  - stream channel-obstruction reports
  - tax records

Step 2: Complete a Descriptive Historical Narrative

This section weaves together a "story" of the watershed. The historical narrative begins by describing the status of your watershed's resources from the time of the earliest recorded accounts, and traces land use changes, fish populations, and resource management of the watershed through time. It is important to use a variety of information sources to construct this history, including historical documents and interviews with agency personnel and long-time watershed residents. Begin by reviewing written literature and agency reports on a watershed, then proceed to interviews. Reviewing the written materials first will provide a context for historical information that will help you frame questions for the interview process.

There is usually a wealth of historical information available for any watershed. As a result, it is important to focus the scope of the investigation on information that provides clues on impacts to riparian/aquatic systems, including issues that have impacted water quality, fish habitat, and changes in fish abundance.

General information on landscape conditions at the time of exploration/settlement (for example, vegetation patterns, fire history, and wildlife sightings) provides a context, then can be used when interpreting land use development and management impacts through time. The description of presettlement conditions should emphasize vegetation patterns, Native American use, presence and abundance of fish and wildlife species, fish habitat, and natural disturbance patterns. The description of historical land use patterns and trends should focus on settlement patterns and resource management through time. Appendix II-B provides an example of historical information used to construct a narrative.

Step 3: Complete Historical Conditions Time Line

The historical conditions time line provides a chronological list of natural and human-caused events that have helped shape the watershed. The historical narrative will help you determine the events that should be included in the time line. Appendix II-C provides an example of a historical conditions time line.

Step 4: Organize Historical Information by Subwatershed

Describing the specific location of historical observations provides a way to interpret the location, extent, and intensity of habitat modifications through time. Historical literature (especially agency reports such as habitat surveys), resident interviews, and photographs can provide locations of floodplain, riparian, channel, and wetland habitats, as well as land use modifications.

Organize the relevant historical information by each subwatershed (or tributary stream) within the larger watershed analysis area. You can produce a table that organizes observations for a specific subwatershed within four categories: (1) vegetation/wildlife patterns, (2) patterns of settlement and agricultural practices, (3) stream channel/riparian habitat, (4) fish species and abundance, (5) water quality information, and (6) other observations. Appendix II-D provides an example of an approach for organizing the historical observations.

Step 5: Map Historical Channel and Riparian Modifications

The collected and summarized historical information is used to map and categorize historical channel and riparian vegetation modifications. The objective of the mapping is to capture historical activities that impacted the watershed's habitat, especially actions that continue to influence stream channels and riparian vegetation. Historical channel modifications include activities such as channelization and dikes, removal of large wood, splash dams, and other activities that can impact the quality of channel habitat. (See the Watershed Fundamentals component of this manual for more on activities that impact streams.) Historical activities that could impact riparian vegetation include roads and railroads along streams, agricultural practices, logging, old homesteads, and grazing.

The following steps apply to mapping historical channel and riparian modifications.

- Use the historical assessment, especially information generated about the subwatersheds, to determine the locations of documented channel and riparian impacts.

- Create a map legend with symbols (or pen colors) to represent each type of impact (large wood cleaning, areas with dikes, dam sites, logging railroads, homesteads, etc.).

- Map different types of impacts using different techniques. For example, map small features in one location (an old dam or homestead, for example) with an X or brightly colored dot; map linear features (impacts from large wood removal or roads, for example) in or along the stream channel with a colored marking pen.

- Draw each modification site or area onto the Historical Channel and Riparian Modification Map using the appropriate number from the Historical Channel and Riparian Modification Inventory (Form HC-1), which contains information about the activity. Where more than one modification activity overlaps, draw both mapping symbols. Where you are unsure of the exact beginning or end of a feature, put a question mark at the beginning and/or end of the map symbol.

- Label each historical channel and riparian modification/disturbance site with a number. Fill out the first three columns on the Historical Channel and Riparian Modification Inventory (Form HC-1) for each site.

- Sign and date the map.

Step 6: Complete Summary and Conclusions

In this section you will briefly summarize the key findings, emphasizing historical conditions at the time of exploration/settlement and change through time. The conclusions should concentrate on historical factors that have modified channel habitat and are limiting current watershed conditions, especially in floodplains, riparian areas, and wetlands.

Step 7: Document Sources of Information

It is important to document where you obtained your historical information, including interviews. Reference every statement you make and cite the source of the information at the end of the historical assessment report. Reference sources of information on channel impacts on the Historical Channel Modification Inventory form.

Step 8: Evaluate Confidence in the Assessment

You can evaluate the strength of your historical channel and riparian modification mapping by considering the resources used, whether resources reached similar conclusions, and so on. Form HC-2 provides criteria for the evaluation. If the type or quality of information used to map the fish distributions differs significantly from area to area, fill out one form for each general area. If the type or quality of information used to map historical channel and riparian modifications in the watershed differs significantly from area to area, fill out a form that evaluates each general area.

REFERENCES

Benner, P.A., and J.R. Sedell. 1997. Upper Willamette River Landscape: A Historic Perspective. Pages 23-47 in: Laenen, A. and D.A. Dunnette (eds.), River Quality: Dynamics and Restoration. Lewis Publishers, New York.

Coulton, K., P.B. Williams, and P.A. Benner. 1996. An Environmental History of the Tillamook Bay Estuary and Watershed. Tillamook Bay National Estuary Project Technical Report 09-96, Garibaldi, Oregon.

McIntosh, B.A., J.R. Sedell, J.E. Smith, R.C. Wissmar, S.E. Clarke, G.H. Reeves, and L.A. Brown. 1993. Management History of East Side Ecosystems: Changes in Fish Habitat Over 50 Years, 1935 to 1992. Pages 291-483 in: P.F. Hessburg (ed.), East Side Forest Ecosystem Health Assessment. Volume III, Assessment. US Department of Agriculture, Forest Service, Wenatchee, Washington.

Sedell, J.R. and W.S. Duval. 1985. Water Transportation and Storage of Logs. In: W.R. Meehan (ed.). Influence of forest and rangeland management on anadromous fish habitat in western North America. General Technical Report. PNW-186. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

Skovlin, J.M, J.W. Thomas. 1995. Interpreting Long-Term Trends in Blue Mountain Ecosystems from Repeat Photography. General Technical Report. PNW-GTR-315. US Department of Agriculture, Forest Service, Pacific Northwest Research Station, Portland, Oregon.

University of Oregon Map Library, http://libweb.uoregon.edu/map/ This online library has a number of historical maps and aerial photographs, including a cartobibliography of United States Geological Survey Topographic Maps of Oregon, 1889 to the present.

Appendix II-A
Outline of the Historical Conditions Report

APPENDIX II-A: OUTLINE OF THE HISTORICAL CONDITIONS REPORT

1. Descriptive historical narrative for the watershed
    A. Watershed resources at the time of exploration / settlement
        1. Vegetation
        2. Native American uses (fire, etc.)
        3. Presence and abundance of fish species
        4. Fish habitat
        5. Natural disturbance patterns (e.g., fire and floods)
    B. Historical settlement, land use, and resource management patterns and trends
        1. Settlement patterns and development: rural and urban
        2. Roads
        3. Dikes
        4. Logging practices
        5. Agriculture
        6. Urbanization
        7. Grazing
        8. Mining
        9. Water use, diversions (withdrawals, dams, etc.)
        10. Fisheries exploitation
        11. Changes in disturbance patterns (e.g., fire)
        12. Fish hatcheries and production records

2. Historical conditions time line

3. Historical information referenced by stream / subwatershed location
    A. Channel / riparian habitat
    B. Observations of fish species and abundance
    C. Water quality information
    D. Other observations

4. Map of historical channel and riparian modifications

5. Summary and conclusions
    A. Summary of presettlement historical conditions and change
    B. Conclusions about historical conditions that are currently impacting channels / riparian vegetation and other watershed resources

6. Sources of information

Appendix II-B
A Historical Conditions Narrative for a Watershed

APPENDIX II-B: A HISTORICAL CONDITIONS NARRATIVE FOR A WATERSHED

Watershed Resources at the Time of Exploration/Settlement

Vegetation: One account in 1885 stated: "The amount of green timber is small…the devastating fire of several years ago…destroyed many square miles of timber leaving a forest of dead trees…These defunct monarchs of the forest are now rapidly decaying and disappearing, and as they go…"

Fish Species and Abundance: Fishing records from the early 1900s suggest that the Yaquina Basin coho salmon run may have been in the 20,000–30,000 range, and the chinook salmon run was over 10,000 fish (ODFW 1991).

Fish Habitat: Beavers were probably historically numerous in the tributary streams, which would have created pool, backwater, and wetland habitats. Although there are no recorded accounts of beaver activity from the 1800s, interviews with watershed residents provide clues that beavers were once more abundant, especially in the lower portions of key tributaries.

Natural Disturbance Patterns: There is evidence that, historically, the Oregon Coast Range experienced infrequent forest fires that covered large areas. On August 25, 1849, Lieutenant Theodore Talbot reported from the central Coast Range that: "The mountains were enveloped with such a dense mass of smoke, occasioned by some large fires to the south of us, that we could see but little of the surrounding country. These fires are of frequent occurrence in the forests of Oregon, raging with violence for months, until quelled by continued rains of the winter season…" (Lincoln County Historical Society 1980, p. 3).

Floods: There are a number of recorded accounts of flooding in the Yaquina Watershed. Major floods were noted in 1889-1890, 1911, 1921, 1964, and 1996.

Settlement History and Management Trends

Summary: Since the period of settlement in the 1870s, lowland forests and areas along the streams have been cleared for homes, agriculture, and grazing.

Logging: Big Elk Creek provided a convenient method for moving logs to the mill sites: "The logs would slide down [the hill] into the river or river bottom. Sometimes they would build chutes at the bottom of the hill leading to the river, and when the logs slid to the bottom of the hill, they would hit the chute and slide into the river…After they got the logs in the river they would raft them down to the mill…" (Hodges 1978, p. 218).

Fishing, Hatcheries, and Fish Population Trends: Commercial fishing for coho salmon in the Yaquina Basin began in the 1880s (ODFW 1991). Gillnets were the most common gear used in the river between Elk City and the mouth. It is estimated that in 1908 nearly 26,000 coho salmon were canned (ODFW 1991).

Appendix II-C
A Historical Conditions Time Line for a Watershed in Oregon

APPENDIX II-C: A HISTORICAL CONDITIONS TIME LINE FOR A WATERSHED IN OREGON

(From the Weyerhaeuser Co.'s South Fork of the Coos River Watershed Analysis 1998.)

Coos Indians

1853	Pioneers arrive
1853-1884	"Rowboat" Pioneers clear "woodsy-bottoms"
1874	Earliest log drive documented
1880s	Smith Basin logging with bull teams
1890	Big flood with snow
1891-1917	US Army Corps of Engineers blast boulders and remove snags
1897	Fish hatchery established
1900s	Scowboats, ferries, and steamers
1909	Flood year
1910	½-mile channel blasted from McKnights Landing to Salmon Creek
1900s	Summer homes built
1909	Flood year
1924 & 1932	Coos River ice-bound
1942	Lower splash dam built
1943	Tioga splash dam built
1945	Flood year
1954	Flood year
1955	Flood year
1957	Splash dams removed

Appendix II-D
Organization of Historical Information on Watershed Resources by Subwatershed Locations

APPENDIX II-D: ORGANIZATION OF HISTORICAL INFORMATION ON WATERSHED RESOURCES BY SUBWATERSHED LOCATIONS

Subwatershed	Channel/Riparian Habitat	Fish Species and Abundance	Water Quality	Other Observations
Beaver Creek	1950 stream habitat survey report: A commercial fisherman on Yaquina River reported…logging on Beaver Creek…left the stream badly jammed…[He] stated that Beaver Creek was a good salmon producing stream…[The stream was surveyed.] The bottom is composed mostly of clay and mud with a few small patches of gravel…Three impassible obstructions [were noted] (OR Fish Comm.) 1953 stream habitat survey report of the lower 3.5 miles: In this lower part the water is brownish colored and the bottom is badly silted in the pools. The upper part of the stream appears to have good spawning areas of fine gravel (OR Fish Comm.)	1991 ODFW Fish Management Plan: Spawning chum salmon observed in some years (p. 8) 1953 stream habitat survey report: A resident living about 1.5 miles up Beaver Creek stated that large fish resembling silver salmon were seen…Silver and trout fry were quite abundant near the mouth even though visibility in the colored water was poor. Silver fry present to end of survey. (OR Fish Comm.)	68/July @ 1:45 and Lower tributaries at mouth: 56ºF @ 3:00 53ºF @ 3:50 57ºF @ 3:55 (OR Fish Comm. 1953)	[Before the logger] moves from this area he should be required to clean up the stream in the area of his logging operation. The three impassable obstructions…must be removed…The remaining slash and debris should be removed to bring the area into full production. Although this stream is not considered to be a good salmon stream in this section, it is only by utilizing all possible spawning areas of every stream that the runs of salmon can be maintained at a high level (OR Fish Comm. 1950) [The logger] responsible for debris in the [lower portion of Beaver Creek] should be made to clean up this mess while they are still logging the area (OR Fish Comm. 1953) (Mapped Channel Modification)
Bull Creek	1953 stream habitat survey report of the lower 1.25 miles: A farmer living near the mouth…says that it is primarily a silver stream, with very few other fish entering it. He says the stream often goes dry just above the mouth during the summer, but there is plenty of water this year. From the mouth upstream for about 0.5 mile the stream [has a] good cover of alders. Above this the stream opens out into a broad meadow of 0.25 mile with some willows growing along the stream. Beyond the meadow…alders again cover the stream (OR Fish Comm.)	1953 stream habitat survey report of the lower 1.25 miles: Silver fry were seen in small numbers the entire length of survey…(OR Fish Comm.)	56/July @ 11:45 and 53ºF @ 12:25 above tributary (OR Fish Comm. 1953)	

Appendix II-E
Blank Forms

Form HC-1: Historical Channel and Riparian Modification Inventory

Watershed: **Page_____of_____**

Name: **Date:**

Site No.	Historical Channel and Riparian Modification Activity Description	Data/Information Source	Channel Habitat Type	Channel Length (mi)

Form HC-2: Historical Channel and Riparian Modifications Confidence Evaluation

Watershed: **Form # ____ of ______**

Area, sub-basin:

Name of mapper(s):

Technical expertise or relevant experience:

Confidence in historical channel and riparian modification mapping:

- ☐ **Low to moderate:** Used one source of historical information; unsure of the credibility
- ☐ **Moderate:** Used several sources of historical information that reach the same conclusion
- ☐ **Moderate to high:** Used source of information from agency records or from other trained observers; multiple sources of historical information that reach the same conclusion
- ☐ **High:** Used source of information from agency records or from other trained observers with documented quality control; or multiple sources of historical information that reach the same conclusion and photographic documentation
- ☐ **If none of the above** categories above fits, describe your own confidence level and rationale:

Component III
Channel Habitat Type Classification

Table of Contents

Component III
Channel Habitat Type Classification

INTRODUCTION

The Watershed Fundamentals component of this manual describes how the setting and structure of the landscape influences the shape of the stream channels. Drawing on several existing stream classification systems, we have assigned a basic number of channel types for Oregon streams that we are calling Channel Habitat Types1 (CHTs). This stream classification will enable you to better understand how land use impacts can alter the channel form, and to identify how different types of channels will respond to restoration efforts. Both channel modifications and restoration will ultimately effect fish habitat.

The stream classification system is described in this component, along with mapping instructions. In Appendix III-A, you will find more detailed descriptions for each of the channel habitat types, including a drawing and photo of the physical setting common to the unit, an example from a topographic map, and a list of physical attributes common to these types of streams. In addition, Appendix III-A presents background material on stream classification, theory, and methodology. The overall assessment process is designed to identify areas of the watershed in need of enhancement and restoration. To help evaluate restoration options, we have included general guidelines for restoration by channel type in Appendix III-A. The channel type classifications apply to broad areas; therefore, a more thorough field verification of actual conditions will be necessary before project implementation.

Because this stream classification is a composite of existing work, we expect that changes and additions to the individual stream types may be made as the classification is applied in Oregon and field data is compiled. At that point, channel type “variants” within each CHT can be identified.

Critical Questions

1. What is the distribution of CHTs throughout the watershed?

2. What is the location of CHTs that are likely to provide specific aquatic habitat features, as well as those areas which may be the most sensitive to changes in watershed condition?

Assumptions

1. Stream channels form specific patterns in response to the surrounding geology and geomorphology, and these patterns can be used to identify CHTs.

2. Channel habitat types have consistent responses to changes in inputs of sediment, water, and wood across the State of Oregon.

3. The distribution of CHTs throughout the stream network and the condition of the characteristics within the CHTs influence aquatic habitat quality.

Materials Needed

You will need the following equipment and supplies to complete the mapping:

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

- 1:24,000-scale Oregon Department of Forestry (ODF) base maps (from Start-Up and Identification of Watershed Issues component)

- A Mylar overlay the size of the base map (optional)

- Sharp pencil, colored pencils, permanent marking pens (fine-point) in a variety of colors

Additional materials or data, where available:

- Recent ***stereo aerial photographs*** covering the entire assessment area (from Start-Up and Identification of Watershed Issues component)

- Stereoscope for 3-D viewing of aerial photographs. Although a mirrored stereoscope (with magnification) is preferable, a simple lens stereoscope is adequate.

- Aerial photo scale for measuring ***riparian area*** widths etc. Scale should be the same as the aerial photographs used.

- Map wheel for measuring lengths.

- Stream survey results, if available

Necessary Skills

The minimum skills necessary to produce the CHT maps include (1) the ability to read and use topographic maps, and (2) an eye for visualizing 3-D landscape patterns from topographic maps. The ability to use aerial photographs and a general understanding of the local geology and the geologic processes shaping the stream system in the watershed will aid in the accomplishment of this task, but is not required. Complex channel networks and channel sensitivity issues may require the aid of a hydrologist or geomorphologist.

Final Products of the CHT Classification Component

The final products from this step include:

- Map CHT-1: Channel Segment Map
- Map CHT-2: Preliminary Channel Habitat Type Map
- Map CHT-3: Final Channel Habitat Type Map
- Form CHT-1: Channel Habitat Type Field Verification
- Form CHT-2: CHT Summary Sheet
- Form CHT-3: Confidence Evaluation
- Short summary report (optional)

METHODS

Overview

The methodology presented here describes the steps to divide streams in the watershed into different CHTs. ***Stream segments*** are initially broken out based on channel gradient (Step 2) and ***channel confinement*** (Step 3), and mapped on Map CHT-1. The stream segments are then grouped together based on channel pattern and valley width, and assigned to a tentative CHT (Step 4); a preliminary CHT map (Map CHT-2) is then produced. Although channel pattern, valley width, and channel gradient can be determined with reasonable accuracy from topographic maps, channel confinement is difficult and in some cases impossible to determine from maps alone, and may require additional work. Consequently, methods for improving the quality or confidence in your mapping are discussed in Step 5; including the use of stream survey information, consulting with local experts, using aerial photographs, and field-verifying initial calls. All field-verification information is recorded on Form CHT-1. When the analyst is satisfied with the CHT calls that have been made, a final CHT map is produced (Map CHT-3), along with a form that summarizes the distribution of CHTs in the watershed (Form CHT-2). Copies of Map CHT-3 and Form CHT-2 are distributed to the other analysts. Channel Habitat Type sensitivity is evaluated in Step 6. In Step 7, the analyst evaluates confidence in the final mapping products. Finally, in Step 8, the CHT analyst will prepare for the Watershed Condition Evaluation.

Step 1: Prepare Maps and Materials

Gather all of the items listed in the Materials section. Base maps of the watershed showing the entire stream network, and watershed and subwatershed boundaries, should have been prepared in the Start-Up and Identification of Watershed Issues component (refer to that component if you have not received a base map).

US Geological Survey (USGS) maps at the 7.5-minute or 1:24,000 scale have been used to prepare the base maps. Keep in mind that some of the individual maps used to make up the base map of the watershed may have a different ***contour interval*** than others. Be sure to check the contour intervals, as the accuracy of your stream typing is dependent on your ability to know and use this information. Scale and contour dimensions are found on the bottom center of the maps used to make up the base map. Maps with large areas of little relief may show intermediate contours only in those areas. The stream segments and CHTs from the following steps can be drawn directly on copies of the base map.

Before beginning, take a moment to study the base map. Notice the network of streams, their positions within the watershed, and the patterns of similarities between streams within sub-basins or areas of similar topography and size. Note that not all the CHTs described in this section will necessarily be present in your watershed, and that the distribution of types may vary from the headwaters to the mouth of the watershed. You will want to familiarize yourself with the attributes of each CHT before mapping them in your watershed. Figure 1 illustrates the basic characteristics of each CHT; Appendix III-A provides detailed descriptions of each CHT.

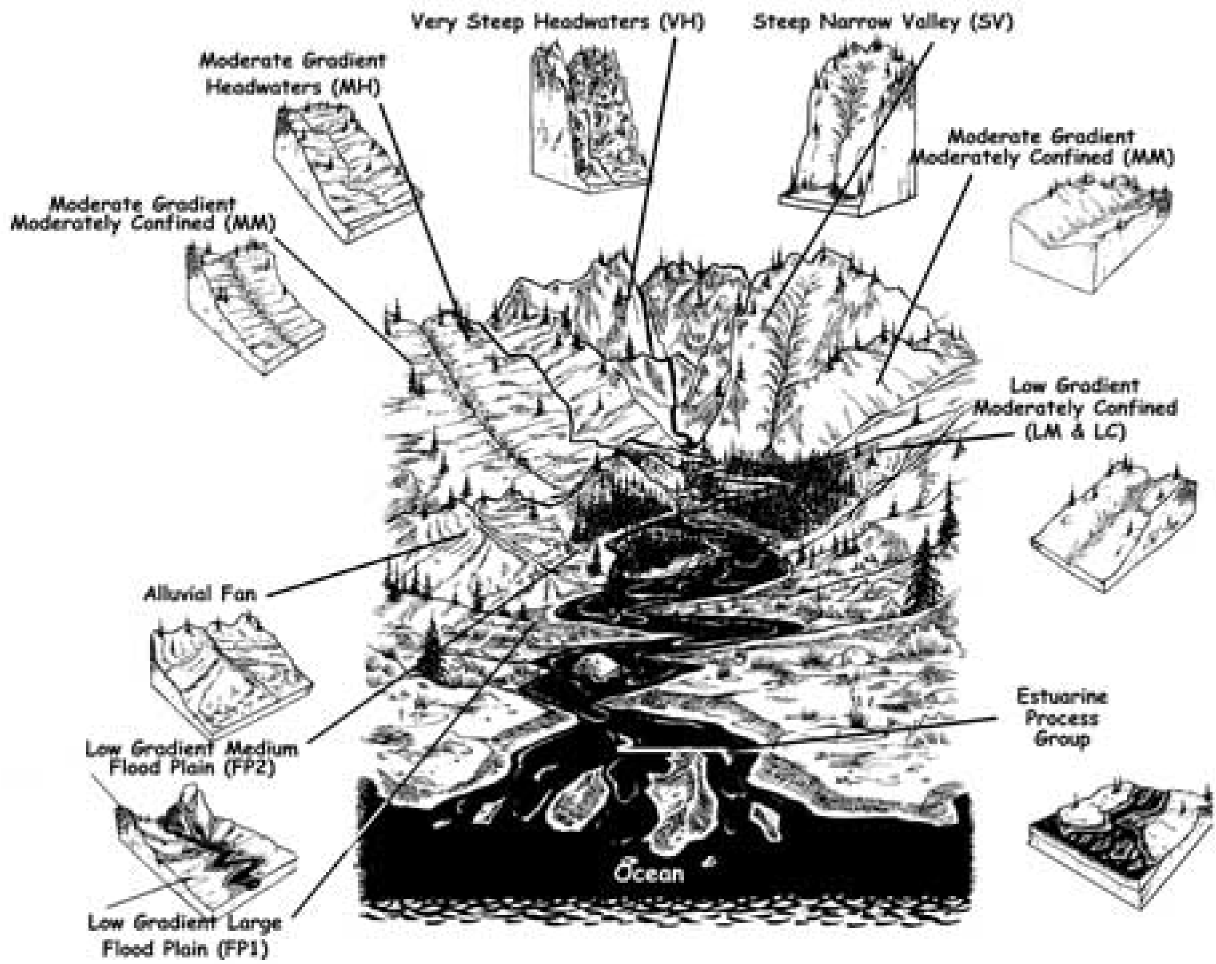


Figure 1. Examples of CHTs and their relative position in the watershed.

Step 2: Break Out Stream Segments Based on Gradient Class

The first cut at dividing the channel network into similar types is based on ***channel gradient class***. Six different gradient classes are used (shown in the box below) Segments may vary in length, but will be similar with respect to channel gradient. Sixteen percent is chosen as the upper limit of the channel network due to the dominance of terrestrial rather than fluvial processes in these areas.

CHANNEL GRADIENT CLASSES

<1%	4-8%
1-2%	8-16%
2-4%	>16%

Channel gradient is determined by dividing the difference in elevation by the horizontal distance of any given length of stream. Determining this ratio from the base map can de done in a number of ways. In one method, measure the distance between contours or number of contours within a given distance either with a ruler (for relatively straight channels), or using a map wheel (for sinuous channels). Table 1 provides information for determining slope from 1:24,000-scale maps with a 20-foot or 40-foot contour interval.

Table 1. Determining channel slope on 1:24,000-scale maps.

Channel Slope (%)	20-ft contour interval		40-ft contour interval	
	Distance Between Contours (ft)	Contours per 1,000 ft of Channel	Distance Between Contours (ft)	Contours per 1,000 ft of Channel
1	2,000	-	4,000	-
2	1,000	1	2,000	-
4	500	2	1,000	1
8	250	4	500	2
16	125	8	250	4

Another approach would be to use a gradient template printed on a clear piece of Mylar that can be laid over the stream channel; the gradient is read directly from the template. Channel segments must be relatively straight to use this approach, however. Examples of gradient templates are found in Schuett-Hanes et al. (1994).

A third method to map channel gradient is to employ a ***Geographic Information System*** (GIS), although this method requires an expertise that may render it impractical. In addition, field verification of GIS products is necessary. (See the sidebar below, Using GIS to Map Gradient, for more information.)

Determining channel gradient from topographic maps is subject to a certain amount of error. In particular, lower-gradient channels are more subject to mapping and analyst calculation error than steeper channels. This problem should be taken into consideration when field-verification sites are selected. This potential error, coupled with the overall greater sensitivity/responsiveness of lower-gradient channels, is the rationale for having a greater number of gradient classes in the lower range.

In order to prevent an unmanageable number of segments within any given stream system, a minimum segment length of 1,000 feet is suggested. Another rule of thumb is that segments should cover a minimum of three contours. Major waterfalls should be broken out as separate segments regardless of length. Additional segment breaks are located at junctions of major tributaries, because the addition of water, sediment, or wood can alter physical characteristics and fish habitat. It is important to be as consistent as possible when identifying segment breaks.

An example is provided in Figure 2 of three segments delineated in the "Skunk Creek" subwatershed. Segment breaks are first drawn on Map CHT-1 using a pencil line drawn across the channel to mark the upstream and downstream boundary of each segment. The stream segments are then numbered using a sub-basin code and sequential number (for example SC1, SC2, and SC3 for Skunk Creek segments 1, 2, and 3; see Figure 2). This numbering by sub-basin allows for a minimum of renumbering should segments be divided or combined, and allows for a common, site-specific reference for all analysts.

USING GIS TO MAP GRADIENT

Preliminary channel gradients have been successfully mapped using a Geographic Information System (GIS). GIS programs can be written to calculate and code channel gradients between individual contours or to "smooth" them by a running average. If GIS resources are available to your watershed council, this may be another tool for the mapping exercise. However, employment of other tools is recommended to supplement the GIS mapping.

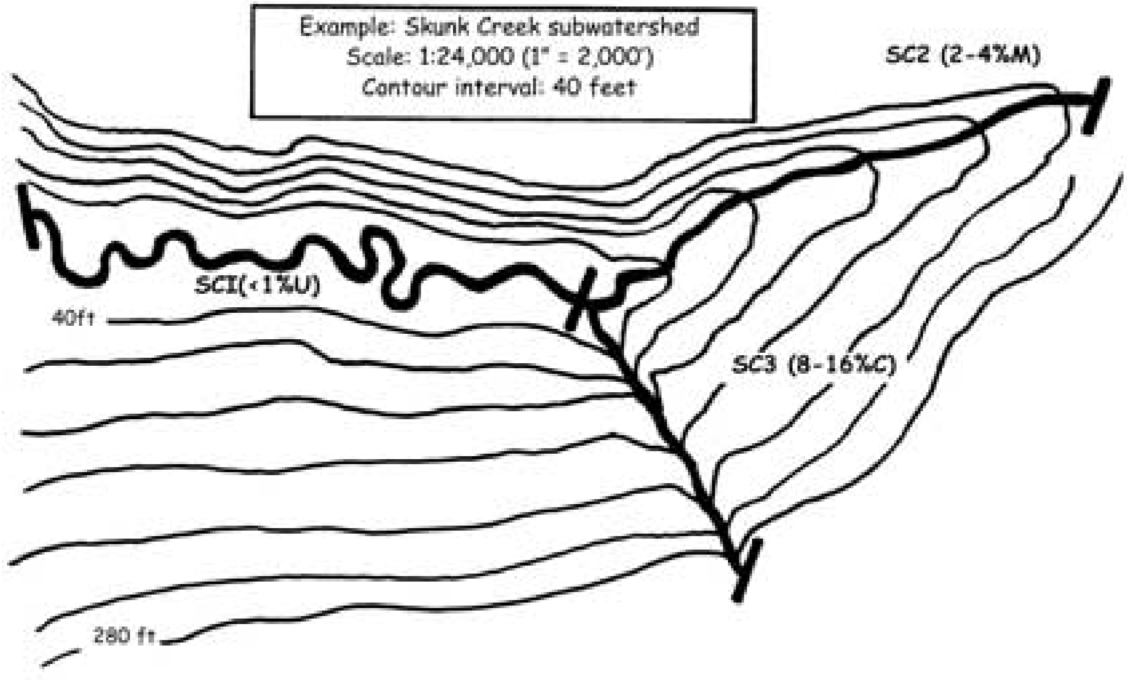


Figure 2. The stream segments delineated in a subwatershed are numbered using a sub-basin code and sequential number (e.g., SC1, SC2, and SC3 for Skunk Creek segments 1, 2, and 3). This numbering by sub-basin allows for a minimum of renumbering should segments be divided or combined, and allows for a common, site-specific reference for all analysts. Each segment is also labeled with the appropriate gradient class.

Each segment is also labeled with the appropriate gradient class. For example, segment SC1 is 4.2 inches long as measured with a map wheel (8,400 ft), and crosses no contour lines. Therefore, the gradient is <0.5% (<40 ft/8,400 ft), and the segment is labeled as "<1%." For segment SC2, the distance between the 40-foot contour and the 200-foot contour is 2.2 inches (4,400 ft); therefore, the gradient is 3.6% [(200 - 40)/4,400], and the gradient class is labeled as "2-4%." Finally, for segment SC3, the distance between the 280-foot contour and the 40-foot contour is 1.2 inches (2,400 ft); therefore, the gradient is 10% [(280 - 40)/2,400], and the gradient is labeled as "8-16%."

Step 3: Estimate Channel Confinement

Channel confinement is difficult to determine from topographic maps and has been the subject of considerable confusion. This is unfortunate, as the ability of a stream to move laterally directly affects aquatic habitat quality and is of prime concern to land managers. Much of the problem is due to misinterpretation of terminology. Definitions related to channel confinement and entrenchment discuss the ratio of the active channel width to the floodplain width (Moore et al. 1997, Washington Forest Practices Board 1997, Rosgen 1996, Overton et al. 1995). Unfortunately, floodplain width is often interpreted as valley width or some measure of historic floodplain. For the purposes of this manual, we have adopted the most commonly used and scientifically valid definition, which defines confinement as the ratio of the ***bankfull width*** to the width of the modern floodplain. Bankfull width is the width of the channel at the point at which overbank flooding begins, and often occurs as flows reach the 1.5-year ***recurrence interval*** level. Modern floodplain is defined as the flood-prone area (Rosgen 1996), but geomorphologists caution that it may or may not correspond to the 100-year floodplain. Obviously, this is an area where consistency by the analyst is important.

Table 2. Channel confinement classes.

Map Code	Confinement Class	Floodplain Width
U	Unconfined	>4x bankfull width
M	Moderately confined	>2x but <4x bankfull width
C	Confined	<2x bankfull width

Confinement classes are presented in Table 2. While determination of this ratio solely from topographic maps is prone to error, especially in low-gradient streams entrenched into historic terraces or alluvial valleys, this exercise presents a first cut at determining channel confinement.

Referring to the example shown in Figure 2 for "Skunk Creek," note the meandering and sinuous channel pattern of segment SC1. This meandering channel pattern, combined with the low gradient of the reach, is often indicative of streams with wide floodplains. The confinement class ("U" [unconfined] for segment SC1) should be noted in pencil on Map CHT-1 next to the gradient class, as shown in Figure 2. For segment SC2 in the figure, note how the contour lines approach the channel at approximately right angles. This suggests that the valley may allow some room for a narrow floodplain to develop. The initial estimate of confinement for segment SC2 would be marked on Map CHT-1 as "M" (moderately confined). Segment SC3 appears from the map to be an example of a confined valley (note the V-shape of the contours as they approach the stream) with little room for floodplain development, and would be marked on the map as "C" (confined).

Step 4: Assign Initial CHT Designation

Following segment mapping of the channel network, segments can be clustered into groups of similar gradient, confinement, and size, and mapped on Map CHT-2. Using the variables of channel gradient, confinement, and where appropriate, size and valley form, produces a consistent, accurate, and concise framework to define the typing system. It is often beneficial to start CHT grouping in headwater regions, where the "choices" of probable CHTs are limited. **The most difficult areas to group are usually low-gradient reaches**. Table 3 provides a list of CHTs into which most channels can be placed. A more complete description of these channel types is located in Appendix III-A. Note that any system with the goal of organizing channels statewide into a limited number of channel types works better for some channel types than others. As such, the descriptors for each CHT are general, and variability of channel conditions within each CHT exists. The analyst is encouraged to note "variant" conditions within each of the channel types. In some cases, it may be necessary to modify or add channel types to fit unusual situations. These alterations to the channel types presented should be kept to a minimum and documented thoroughly.

Following Table 3 is a key (Figure 3) that provides a general guide for assigning CHTs. You are strongly cautioned, however, that the key is meant only as a tool, and will not always result in assignment of the appropriate CHT. You are encouraged to employ as many tools as possible in assigning CHTs.

Table 3. Channel Habitat Types.

Code	CHT Name	Gradient	Channel Confinement	Size
ES	Small Estuary	<1%	Unconfined to moderately confined	Small to medium
EL	Large Estuary	<1%	Unconfined to moderately confined	Large
FP1	Low Gradient Large Floodplain	<1%	Unconfined	Large
FP2	Low Gradient Medium Floodplain	<2%	Unconfined	Medium to large
FP3	Low Gradient Small Floodplain	<2%	Unconfined	Small to medium
AF	Alluvial Fan	1-5%	Variable	Small to medium
LM	Low Gradient Moderately Confined	<2%	Moderately confined	Variable
LC	Low Gradient Confined	<2%	Confined	Variable
MM	Moderate Gradient Moderately Confined	2-4%	Moderately confined	Variable
MC	Moderate Gradient Confined	2-4%	Confined	Variable
MH	Moderate Gradient Headwater	1-6%	Confined	Small
MV	Moderately Steep Narrow Valley	3-10%	Confined	Small to medium
BC	Bedrock Canyon	1->20%	Confined	Variable
SV	Steep Narrow Valley	8-16%	Confined	Small
VH	Very Steep Headwater	>16%	Confined	Small

Note: Stream size refers to the ODF designations based on average annual streamflow. Small streams possess flows less than or equal to 2 cubic feet per second (cfs). Medium streams possess flows greater than 2 but less than 10 cfs. Large streams possess flows of 10 cfs or greater. Stream sizes are mapped at 1:24,000 for the entire state, with the exception of the southeast quarter of the state.

To demonstrate the use of the key in Figure 3, we will use the three segments from the Skunk Creek example. Figure 4 is an overview of the subwatershed that contains Skunk Creek. Segment SC1 is less than 2% gradient and unconfined. From the key, then, we see that this segment may be either an FP3 CHT if it is a small stream (according to the ODF size classification), an FP2 CHT if it is medium-sized, or an FP1 CHT if it is a large stream. Referring to Appendix III-A, we find that the FP1 CHT is found in large streams, FP2 in large or medium streams, and FP3 is found in small to medium-sized streams. So because segment SC1 is labeled "L" (this information will be on your base map), it is either an FP1 or FP2 CHT. Reading the descriptions from Appendix III-A, we find that the FP1 type is usually found at the lowest end of the stream basin (as in this example), and may have stream gradients of $\leq$1% (as in the case of segment SC1). Consequently, we would type segment SC1 as an FP1 CHT.

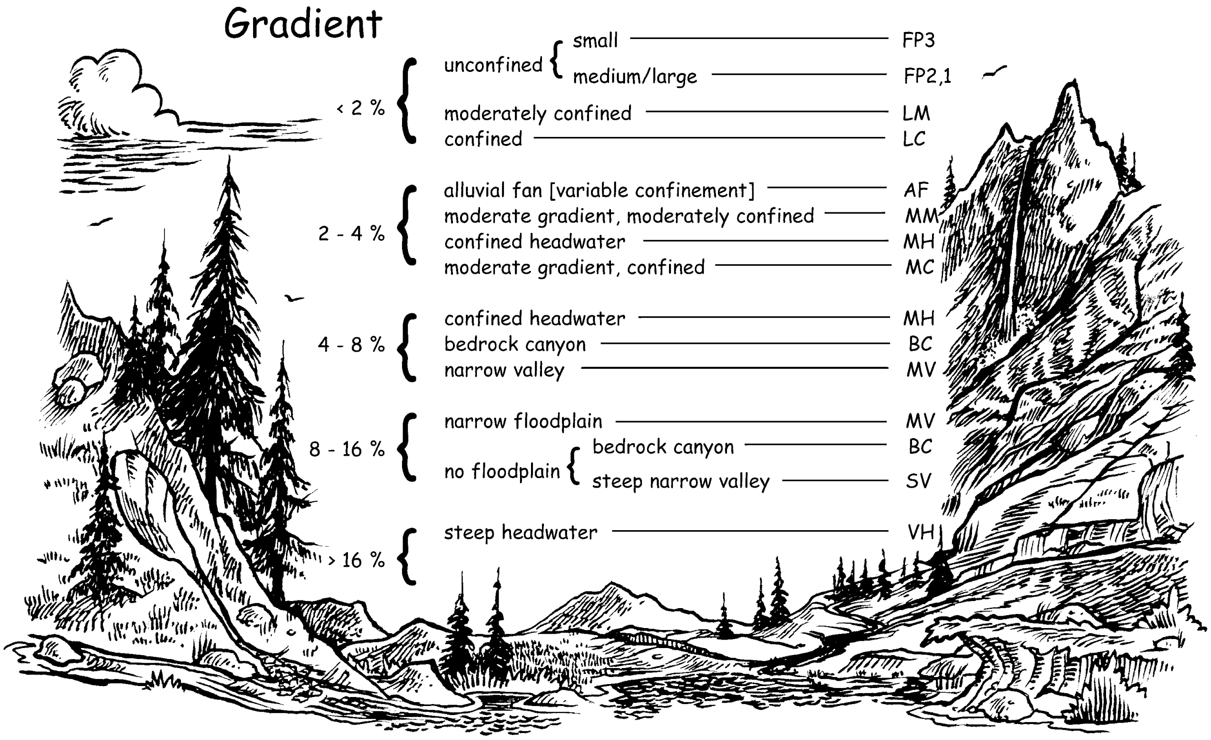


Figure 3. This flow chart provides a general guide for assigning CHTs.

Continuing with our example, segment SC2 was in the 2% to 4% gradient class and moderately confined. Using the key provided in Figure 3, we find that the possible CHTs are AF (Alluvial Fan), MM (Moderate Gradient Moderately Confined), or MH (Moderate Gradient Headwater). Channel Habitat Type MC (Moderate Gradient Confined) is eliminated because it applies to segments that are confined. Referring to the descriptions for the three possible choices from Appendix III-A, we find that the description of the AF type does not fit the characteristics observed on the topographic map, and so can be eliminated. Reading the description of the MH type given in Appendix III-A, we find that this CHT occurs in headwater locations, usually in small streams. The description for CHT MM appears to best fit segment SC2.

Using the key for segment SC3 we find three possible choices for the 8-16% gradient range: MV (Moderately Steep Narrow Valley), BC (Bedrock Canyon), and SV (Steep Narrow Valley) types. From the description in Appendix III-A, we can probably eliminate the BC type; although it is difficult to tell without field observations, it does not appear to be a deep canyon or gorge. The descriptions of both the MV and SV types appear to fit segment SC3 well, and without further investigation we may not be able to decide which of the two is most appropriate.

After the segments have been grouped into CHTs, prepare a preliminary CHT map (Map CHT-2) with each segment color-coded to a particular CHT. You may wish to make a photocopy of Map CHT-1, or use a Mylar overlay on Map CHT-1. Sign and date the map. Because most preliminary CHT maps will be modified, preparation of a GIS version of the map at this point may not be prudent.

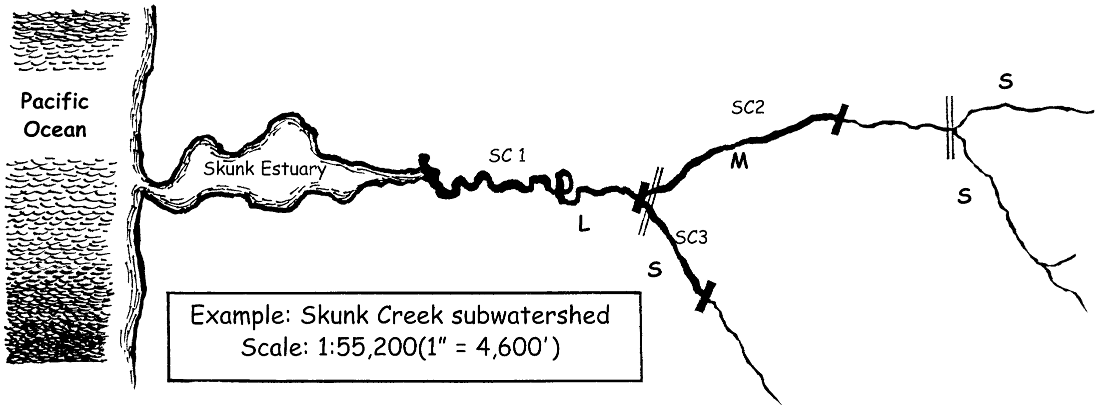


Figure 4. This overview of the example Skunk Creek subwatershed provides stream size classification (large, medium, small), which helps in classifying CHT.

Step 5: Improve the Mapping

The following subsections offer suggestions for improving the Preliminary Channel Habitat Type Map. These tools, as well as additional information gathered from other watershed analysts, should be employed in the production of the Final Channel Habitat Type Map.

Compare with Stream Surveys

Oregon Department of Fish and Wildlife (ODFW) stream habitat surveys will likely be available for some parts of your watershed. These field observations can be consulted to verify your segmenting for those areas covered by the survey. (See Caution sidebar.) In areas with extensive survey information, it may be beneficial to use this information as a tool in initial segment delineation. Consult the summary for each surveyed reach for the following attributes: channel slope and confinement, valley floor types, channel form, and adjacent landforms.

CAUTION

Some surveyed stream reaches have been found to be inconsistently defined, and do not necessarily correspond to changes in the indicator attributes above. Also remember that the segments delineated above will be combined into CHTs that may correspond with ODFW reaches. If a reach includes more than one of your preliminary segment breaks, or extends beyond an obvious change in channel gradient or confinement, then you may need to consult the line-by-line field data for the stream within your segment breaks rather than the reach summary information.

Consult an Expert

Local experts (agency personnel, consultants, etc.) may volunteer to assist the watershed council with the watershed assessment. Although this stream classification is new, these experts will be familiar with similar channel classifications and may be able to assist you. Work through the mapping procedures first, then ask your local expert to check your work or help with questions you have. In addition, local residents are usually very knowledgeable about stream conditions. While locals may not be familiar with terms such as channel confinement, they likely would know if flood flows are contained within the channel for a particular section of stream.

Aerial Photographs

If you have experience in using aerial photographs and access to photos, you can improve your confidence in assigning CHTs by viewing the stream system with photographs. Attributes such as valley features, presence of side-channels, and gravel deposition are often observable from aerial photographs. It should be noted, however, that many features of small, forested stream channels cannot be determined from aerial photographs.

Field Verification

The purpose of the field assessment is not only to verify CHT calls, but also collect data concerning specific channel characteristics. These characteristics reflect the type and magnitude of channel processes and give an indication of the response of the channel to alteration of factors, which influence channel form and maintenance.

A field visit to a sampling of different CHTs identified from the initial map exercise will also help you build confidence in the mapping procedure and identify local differences in controls leading to variations in channel form. Where time, resources, and opportunities allow, conduct a field verification and complete the Channel Habitat Type Field Verification form (Form CHT-1) for each area visited. Where practical, attach the corresponding portion of the topographic map on the back of the form to show the locations of field observations/measurements for the segment in question.

In order to efficiently gather this type of information, a sampling design must focus on representative reaches and allow extrapolation to other channel segments. The following are guidelines for selecting field sites:

- Sample a variety of the gradient and confinement classes present in the watershed.
- Increase sample size in channel segments that are likely to respond to changes in the input factors of wood, sediment, flow (unconfined to moderately confined channels with minimal vertical or horizontal controls, as well as low-gradient reaches).
- Sample segments that capture the geographic and geologic variability within the watershed.
- Sample upstream and downstream of major tributary confluences to determine gross differences in sub-basin characteristics.
- Sample segments that reflect the general range of land management intensity.
- Sample segments that have been subjected to events capable of altering overall ***morphologic features*** (debris flow or dam break flood segments, segments that have undergone significant widening or aggradation, etc.)
- Sample key fish habitat areas, if known.
- Sample areas of known or suspected habitat degradation.

There is no set minimum number of segments that should be sampled , but increasing the sample size will greatly increase the accuracy and usefulness of the final product.

Following application of the tools presented above, produce the Final Channel Habitat Type Map (Map CHT-3). Form CHT-2 (CHT Summary Sheet) should also be produced. If GIS is available, Map CHT-3 can first be digitized, and Form CHT-2 generated from the GIS. If GIS is not available, a map wheel can be used to determine CHT mileage in the watershed. This information, along with the CHT map, allows the analysts to understand the extent and location of various CHTs.

Step 6: Determine CHT Sensitivity

While clustering stream segments into CHTs addresses the critical question concerning channel type distribution in the watershed, it does not address the second question concerning identification of those portions of the channel network that are the most responsive to changes in the factors which impact channel development. Differences in gradient, confinement, and bed ***morphology*** suggest that different channel types are more or less responsive to adjustment in channel pattern, location, width, depth, sediment storage, and bed roughness (Montgomery and Buffington 1993). These changes in channel characteristics will in turn trigger alterations of aquatic habitat conditions. The more responsive areas are most likely to exhibit physical changes from land management activities, as well as restoration efforts.

In general, responsive portions of the channel network are those that lack the terrain controls which define confined channels. These unconfined or moderately confined channels display visible changes in channel characteristics when flow, sediment supply, or the supply of roughness elements such as ***large woody debris*** (LWD) are altered. These areas are commonly referred to as response reaches, and usually possess an active floodplain. At the other end of the responsive spectrum would be those channels whose characteristics and form are not easily altered, such as a Bedrock Canyon. Some channels, such as Alluvial Fans, can have a broad range of sensitivity, ranging from low to high. Figure 5 identifies the general responsiveness of CHTs.

In Appendix III-A, each of the CHTs is rated with respect to the general sensitivity of the channel to changes in the input factors of wood, sediment, and peak flows. A rating of low, moderate, or high is assigned based on the anticipated response of the channel. Table 4 describes the anticipated magnitude of response associated with these qualitative ratings. The CHT descriptions given in Appendix III-A present more detailed information concerning anticipated channel response. The most accurate sensitivity calls are made with the help of field verification.

Step 7: Evaluate Confidence in Mapping

Fill out the Confidence Evaluation (Form CHT-3) for mapping the CHTs. If the type or quality of information used to map the watershed differs significantly from area to area, fill out a form that evaluates each general area (i.e., high-gradient streams all over the watershed, surveyed stream reaches, a particular tributary). The form is self-explanatory.

As a final step in mapping, the analyst should highlight on Map CHT-3 those CHTs that are considered highly responsive.

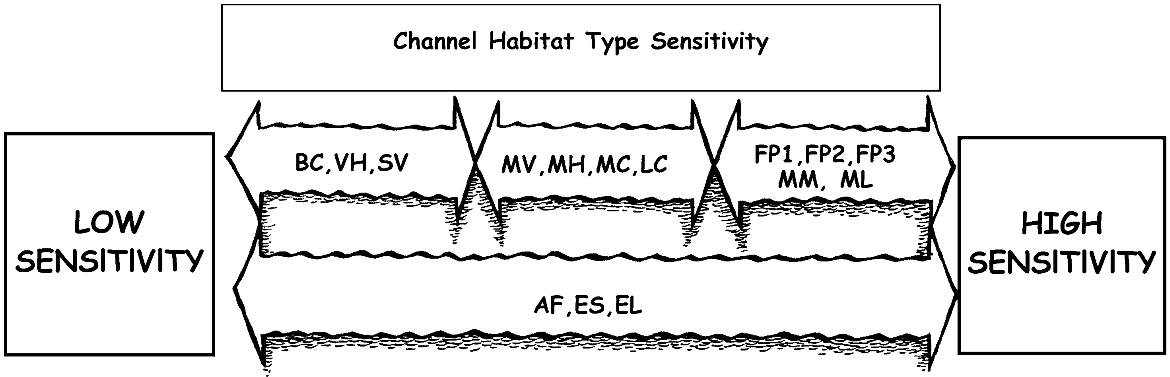


Figure 5. Different channel types respond differently to adjustment in channel pattern, location, width, depth, sediment storage, and bed roughness. Such changes may not only result in alteration of aquatic habitat, but the more responsive areas are most likely to exhibit physical changes from land management activities and restoration efforts.

Step 8: Prepare for Condition Evaluation

The final portion of the CHT assessment procedure is preparation for the Watershed Condition Evaluation component of the watershed assessment. In addition to finalizing the CHT map and associated forms, the analyst should review the channel information collected. This review should lead the analyst to a point where he/she knows not only the type and likely location of sensitive stream channels in the watershed, but where an understanding is gained of overall channel condition. Often the analyst will be capable of determining the dominant processes that are most responsible for channel condition. **It is useful to prepare a short written summary of channel conditions for presentation during the Watershed Condition Evaluation stage of the process.**

As an example of the type of information brought forth during the Watershed Condition Evaluation, suppose the channel analyst has determined that a particular portion of the stream channel network is highly responsive, moderate gradient, moderately confined, and undergoing significant bank erosion and widening. The channel analyst learns from the sediment sources analyst that numerous recent landslides that reach the channel have occurred in the basin just upstream from the sensitive reach. Together, the analysts theorize that recent increases in landslide frequency have resulted in excessive amounts of sediment being delivered to the channel, resulting in the channel widening. This type of “cross referencing” to determine key linkages is one of the ultimate goals of the entire assessment procedure. If the channel analyst can bring forth not only the where and what of the stream network, but some rudimentary understanding of the why, then a clearer picture of overall watershed health emerges.

Table 4. Channel response descriptions.

Rating	LWD	Fine Sediment	Coarse Sediment	Peak Flows
High	Critical element in maintenance of channel form, pool formation, gravel trapping/sorting, bank protection.	Fines are readily stored with increases in available sediment resulting in widespread pool filling and loss of overall complexity of bed form.	Bedload deposition dominant active channel proces; general decrease in substrate size, channel widening, conversion to plane-bed morphology if sediment is added.	Nearly all bed material is mobilized; significant widening or deepening of channel.
Moderate	One of a number of roughness elements present; contributes to pool formation and gravel sorting.	Increases in sediment would result in minor pool filling and bed fining.	Slight change in overall morphology; localized widening and shallowing.	Detectable changes in channel form; minor widening, scour expected.
Low	Not a primary roughness element; often found only along channel margins.	Temporary storage only; most is transported through with little impact.	Temporary storage only; most is transported through with little impact.	Minimal change in physical channel characteristics, some scour and fill.

REFERENCES

Cupp, C.E. 1989. Stream Corridor Classification for Forested Lands of Washington. State of Washington, Timber/Fish/Wildlife Ambient Monitoring Program, Olympia.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D. Hurley. 1986. A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context. Environmental Management 10(2):199-214.

Gregory, S.V., G.A. Lamberti, and K.M.S. Moore. 1989. Influence of Valley Floor Landforms on Stream Ecosystems. US Department of Agriculture Forest Service General Technical Report PSW-110, pp. 3-8.

Humphrey, J.H., R.C. Hunn, and G.B. Shea. 1985. Hydraulic Characteristics of Steep Mountain Streams During Low and High Flow Conditions, and Implications for Fishery Habitat. In Proceedings, Symposium on Small Hydropower and Fisheries. American Fisheries Society, Denver, Colorado.

Leopold, L.B. 1994. A View of the River. Harvard University Press, Cambridge, Massachusetts.

Montgomery, D.R., and J.M. Buffington. 1993. Channel Classification, Prediction of Channel Response, and Assessment of Channel Condition. Washington State Timber/Fish/Wildlife Report TFW-SH10-93-002, Olympia.

Moore, K., K. Jones, and J. Dambacher. 1997. Methods for Stream Habitat Surveys. Aquatic Inventory Project, Natural Production Program: Oregon Department of Fish and Wildlife.

Oregon Department of Land Conservation and Development. 1987. Estuary Plan Book.

Overton, C.K., J.D. McIntyre, R. Armstrong, S.L. Whitwell, and K.A. Duncan. 1995. User's Guide to Fish Habitat: Descriptions that Represent Natural Conditions in the Salmon River Basin, Idaho. US Forest Service Intermountain Research Station, INT-GTR-322, Boise, Idaho.

Paustian, S.J. (editor), et al. 1992. Channel Type Users Guide for the Tongass National Forest, Southeast Alaska. US Department of Agriculture Forest Service, Alaska Region, R10 Technical Paper 26.

Rosgen, D.L. 1994. A Classification of Natural Rivers. Catena 22:(169-199).

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology.

Schuett-Hanes, D., A. Pleus, L. Bullchild, and S. Hall. 1994. Ambient Monitoring Program Manual. Northwest Indian Fisheries Commission, TFW-AM9-94-001, Olympia, Washington.

Washington Forest Practices Board. 1997. Standard Methodology for Conducting Watershed Analysis. Version 4.0.

Whittier, T.R., R.M. Hughes, and D.P. Larsen. 1988. Correspondence Between Ecoregions and Spatial Patterns in Stream Ecosystems in Oregon. Canadian Journal of Fisheries and Aquatic Science 45:1264-1278.

GLOSSARY

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

channel gradient class: Channel gradient is the slope of the channel bed along a line connecting the deepest points (thalweg) of the channel. Channel reaches are then grouped according to gradient into stream gradient classes (<1%, 1-2%, 2-4%, etc.)

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, ***channel pattern***, and ***confinement***. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

contour interval: A line of equal elevation drawn on a topographic map.

Geographic Information System (GIS): A computer system designed for storage, manipulation, and presentation of geographical information such as topography, elevation, geology etc.

large woody debris (LWD): Logs, stumps, or root wads in the stream channel, or nearby. These function to create pools and cover for fish, and to trap and sort stream gravels.

morphologic features: From the Greek root meaning structure or form; in stream channels, those physical features (such as gradient and confinement) that reflect the influence of processes which operate on a landscape scale (such as geology and climate).

morphology: A branch of science dealing with the structure and form of objects. Geomorphology as applied to stream channels refers to the nature of landforms and topographic features.

recurrence interval(s) (return interval): Determined from historical records. The average length of time between two events (rain, flooding) of the same size or larger. Recurrence intervals are associated with a probability. (For example, a 25-year flood would have a 4% probability of happening in any given year.)

riparian area: The area adjacent to the stream channel that interacts and is dependent on the stream for biologic integrity.

stereo aerial photo: Pairs of photos taken from the air that can be viewed through a stereoscope to reveal three-dimensional features of the landscape.

stream segment: Contiguous stream reaches that possess similar stream gradient and confinement, and which can be used for analysis.

Appendix III-B
Blank Forms

Form CHT-1: Channel Habitat Type Field Verification

Name:____ Date:__________

Watershed/sub-basin:____

Segment location:____

Oregon stream size:____

Preliminary channel habitat type:__________________ Final channel habitat type:________

Stream name:____

Township/Range/Section:____

Average of________observations/measurements over_________length (ft) of channel.

Channel slope:

Single or multiple channels:

Floodplain width:

Bankfull channel width (from top of right bank to top of left bank):

Ratio of floodplain width to bankfull width:

Describe material in stream banks:

Size of average bed particles: silt/clay (<0.062 mm); sand (0.062 to 2.0 mm); gravel (2 to 64 mm); cobbles (64 to 257 mm); boulders (257 to 2,032 mm); bedrock

Rough sketch of valley and stream cross section—add scale:

Comments:

Channel habitat type determination:

- ☐ Same as initial type
- ☐ Differs from initial channel habitat type by:
  Can be extrapolated to the following areas:
- ☐ Divided into additional type (CAUTION: Can you provide the same mapping resolution everywhere appropriate in the basin based on this field verification? If not, lumping is better.)

Form CHT-2: CHT Summary Sheet

Analysts Name:

Date: **Page** **of**

Watershed:

Sub-basin	ES	EL	FP1	FP2	FP3	AF	LM	LC	MM	MC	MH	MV	BC	SV	VH
Entire Watershed															

Form CHT-3: Channel Habitat Type Classification Confidence Evaluation

Name:____ Date:____________________

Technical expertise or relevant experience:____

Watershed Name:________________________ Subwatershed Name:__________________________

Channel types:____

Resources used:

- ☐ Topographic maps
- ☐ ODF stream sizes
- ☐ Other ______________________________
- ☐ Field verification
- ☐ Stream surveys

Confidence in base map stream coverage:

- ☐ Local expert says high / low (circle one) degree of accuracy based on field experience (provide name of local expert):
- ☐ High degree of accuracy because stream mapping based primarily on field verification of presence/absence of streams (provide source of info/mapping):
- ☐ No verification; suspect some streams not mapped (explain rationale):
- ☐ No verification; suspect many streams not mapped (explain rationale; what types?):
- ☐ Additional criteria/relevant information (describe):

Confidence in channel habitat typing:

- ☐ **Low to moderate:** Unsure of procedures, didn't consult expert, didn't use field surveys, no field verification
- ☐ **Moderate:** Understood and followed procedures, but no field verification
- ☐ **Moderate:** Some field verification, but found range of conditions hard to type
- ☐ **Moderate to high:** Field surveys available and useful for many streams, but no field verification
- ☐ **Moderate to high:** Some field verification on questionable segments only
- ☐ **High:** Used field surveys and field-verified many segments of all types
- ☐ **If none of the above** categories fits, describe your own confidence level and rationale:

Recommendations for additional field verification, if any, and why:

Appendix III-A
Descriptions of Channel Habitat Types

Table of Contents

Appendix III-A
Descriptions of Channel Habitat Types

CHANNEL HABITAT TYPING BACKGROUND

Stream classification systems can be organized on different scales within the watershed: from as large as the entire channel network down to individual pools or microhabitats within those pools. The channel types in this classification system are centered in the middle of this hierarchy, and incorporate landscape features such as valley type as well as **stream reach**[1] features such as gradient. The variables selected to describe each channel type remain relatively constant within time scales of concern to land management. The scale is small enough to predict patterns in channel physical characteristics, yet large enough to be identified from topographic maps and limited field work. Table III-A-1 compares attributes of current stream classification methodologies.

Drawing on these existing stream classification systems, we have assigned a basic number of channel types for Oregon streams that we are calling Channel Habitat Types (CHTs). This stream classification system will enable users to make inferences about how land use impacts can alter physical channel form and process and, therefore, fish habitat. Note that the commonly utilized attributes of stream **gradient** and **confinement** are the prime identifying features of any CHT. Additionally, valley shape and stream size may guide assignment of CHTs to a stream system. The intent of this section is not to "reinvent the wheel" concerning stream channel classification, but to adapt existing systems to capture the variability of Oregon's stream channels.

This appendix is patterned after the *Channel Type User Guide Tongass National Forest* (Paustian et al. 1992.) The purpose of this appendix is to provide users with sufficient information to understand the characteristics of each CHT. The information in this appendix is intentionally brief. This appendix is designed to give a picture of channel type characteristics. The information refers to typical channel type conditions, and is intended to summarize the most frequent channel type conditions found in Oregon. Although channel type characteristics are relatively consistent, there will be variability within map units. Therefore, site-specific channel characteristics and management interpretations should be field-verified for project planning.

It is important to remember that CHTs cannot be managed as isolated segments. Stream reaches in one part of a watershed can be affected by activities taking place in a different part of the watershed, either upstream, downstream, or on adjacent land areas.

Finally, the following sections present a channel responsive statement for each CHT. It should be noted that these are general statements, and site-specific parameters such as geology and climate greatly influence the type and magnitude of a channel's response.

---

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this appendix.

Table III-A-1. Comparison of basic diagnostic features of key stream channel classification methods.

Basic Stream Classification Diagnostic Features	Frissell et al. 1986, Seg/Reach Systems [1]	Cupp 1989[2]	Paustian et al. 1992[3]	Montgomery & Buffington 1993 Levels II, III, IV	Rosgen 1996 Levels I, II	Moore et al. 1997 ODFW hab. Survey [4]
Valley bottom shape [5]	qualitative	x	x	implied	x	x
Valley bottom slope and/or stream gradient [5]	x	x	x	x	x	x
Side-slope gradient [5]	qualitative	x	x			x
Incision depth or entrenchment			x		x	x
Bankfull width			x		x	x
Active channel width/ depth ratio					x	
Valley bottom width: active channel width ratio		x		qualitative confinement	uses entrenchment	x
Position in the drainage network, stream order[6], or drainage area [5]	x	x	x	implied		x
Bed features, channel morphology	x			x	Inferred	x
Plan view channel pattern [5]	x	x	x		x	unconstrained channels only
Stream-adjacent landforms		x				x
Other criteria	lithology, riparian veg., soil assocs., bank composition		dominant substrate, bank composition	sediment supply/sources, substrate; defines reach types	substrate	substrate, bank composition, riparian data, LWD, other
Initial delineation		maps	aerial photographs		I-remote sensing, existing inventories; II-field measure-ments	field surveys
Number of basic channel groups [7]		5	9	8	9	habitat unit level

1 Oriented to small mountain streams in forested environments; provides theoretical framework rather than specific categories.
2 Developed for forested lands in Washington State.
3 Developed for Tongass National Forest, Alaska.
4 Method is more of a habitat survey than channel classification system.
5 Those criteria identifiable from maps.
6 Montgomery and Buffington believe stream order inappropriate as a foundation for geomorphic channel classification due to differences in mapping detail, drainage density differences between basins, discharge, and landscape controlling factors.
7 Basic Channel Groups:
F - flat cross-section profile, M - moderate gradient sideslopes, V - V-shaped valleys, U - U-shaped valleys, H - headwater tributaries (Cupp 1989), ES - estuarine, PA - palustrine, FP - floodplain, GO - glacial outwash, AF - alluvial fan, LC - large contained, MM - moderate gradient mixed control, MC - moderate gradient contained, HC - high gradient contained (Paustian et al. 1992) braided, regime, pool-riffle, plane bed, step-pool, cascade, bedrock, colluvial (Montgomery and Buffington 1993)

The general format of each CHT description is as follows:

TITLE

Each description begins with the naming convention that includes the CHT name and the channel mapping symbol that can be used as a shorthand name for a given CHT. Following the title is a narrative description of the typical location and physical characteristics of the CHT.

A drawing and photo of the physical setting for the CHT, and an illustrated example from a topographic map, will be included in each description.

CHANNEL ATTRIBUTES

Stream gradient
Valley shape
Channel pattern
Channel confinement
Position in drainage
Dominant substrate

CHANNEL RESPONSIVENESS

This section presents information concerning the general responsiveness of the channel to alterations in the supply of sediment, wood, and high flows. Relative ratings are discussed based on the magnitude of the potential **morphologic response** of the channel. Refer to Table 4 in the Channel Habitat Type Assessment for a description of the low, moderate, and high ratings. Obviously, the discussions dealing with **large woody debris** (LWD) are pertinent to coastal and mountainous regions where wood is available. In eastern Oregon, many channels of the Columbia and Snake River plateau are naturally devoid of wood, or have a very limited supply. In these regions, wood will not be a major influence on the physical characteristics of the channel.

Large Woody Debris

This section discusses the importance of large wood for maintaining stream channel structure and habitat diversity.

Fine Sediment

This section evaluates the potential impacts, locations, and duration of fine-sediment inputs to this CHT.

Coarse Sediment

This section evaluates the potential impacts and duration of coarse-sediment inputs to this CHT.

Peak Flows

This section evaluates the potential impacts and duration of changes in peak flows to this CHT.

RIPARIAN ENHANCEMENT OPPORTUNITIES

This section presents management concerns for in-stream and near-stream management activities, as well as **riparian** management opportunities.

The following section begins the CHT descriptions.

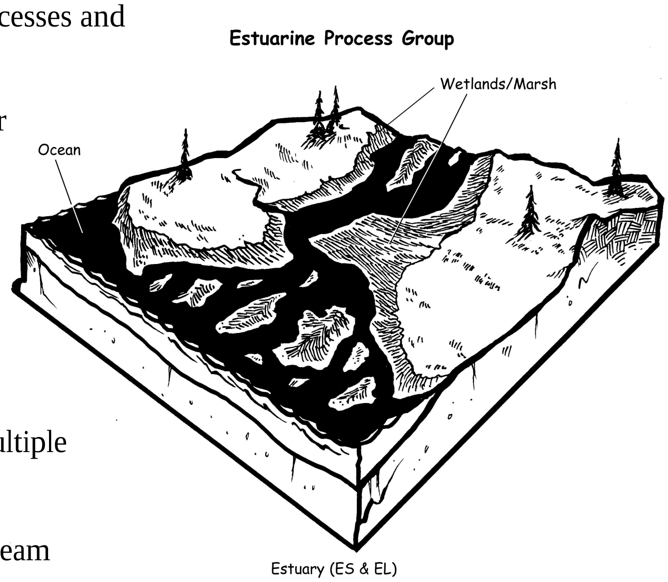
SMALL ESTUARINE CHANNEL
ES

These channels are found at the mouths of drainages along outer coastal beaches or bays. They are **intertidal** streams that occur exclusively within **estuary** landforms, usually draining a small, high-relief or moderate-sized watershed. They are associated with saltwater marshes, meadows, **mudflats**, and **deltas**.

These streams are predominantly sediment depositional channels associated with low-relief coastal landforms. Stream energy is low due to nearly flat gradients, with substrate material consisting mainly of small gravels, sand, and silt. Channel morphology is strongly influenced by tidal stage. Fine-grained stream banks are highly sensitive to erosion. Beach erosion processes often have a dominant influence on deposition and erosion in the outer coastal estuarine streams.

The original boundary of an estuary may be difficult to determine due to modifications associated with marinas, highways, or reclamation. Many coastal estuaries have been delineated through county, state, or municipal planning processes and may include the predevelopment boundaries.

The state has produced an excellent reference for estuaries, particularly as it relates to classification and land use (Oregon Department of Land Conservation and Development 1987).



CHANNEL ATTRIBUTES

Stream gradient:	≤1%
Valley shape:	Broad
Channel pattern:	Sinuous, single, or multiple
Channel confinement:	Unconfined
Oregon stream size:	Small, medium
Position in drainage:	Bottom, mouth of stream
Dominant substrate:	Small gravel, sand

CHANNEL RESPONSIVENESS

These channels are low-energy areas where sediment deposition is a dominant process. While channel sensitivity in estuaries can vary, the unconfined nature of these areas tends to attenuate changes over space and time. Abandonment and reoccupation of **relic channels** commonly occurs, but it may be a slow process.

Large Woody Debris: Moderate

Unless in jams, wood often has limited influence on the overall **morphology** of the channel. Accumulations can be associated with channel shifting. Although wood is often the only roughness element present in these channels, the high sedimentation rate limits pool development and gravel sorting. The primary aquatic habitat role of wood may be refuge cover.

Fine Sediment: Moderate to High

Fine sediment is deposited at a relatively high rate, strongly influencing the arrangement of channels. In most smaller estuaries, an increase in the sediment supply would result in bar formation or reoccupation of relic channels. Localized bank erosion or downcutting could be expected if the sediment supply were to decrease.

ES – Small Estuary

Scale: Half (1:48,000)
Contour Interval: 40 feet

Coarse Sediment: Low to Moderate

Although these channels can be deposition zones for coarse sediment, the delivery rate to estuarine channels is usually low due to sedimentation upstream. In some basins, deposits likely influence channel configuration at the upper end of the estuary.

Peak Flows: Low

Estuarine channels are usually capable of transporting high flows with a minimum of alteration to the primary physical characteristics of the channel. Flows tend to spread out across the valley rather than cause streambed **scour**. Localized bank erosion is expected if new channels are developed.

RIPARIAN ENHANCEMENT OPPORTUNITIES

Many enhancement efforts in estuaries are related to long-term preservation of the area. As these channels harbor unique biologic communities, limiting development is a common strategy. Structural enhancement activities often involve dike breaching or removal to reconnect wetlands or *sloughs*.

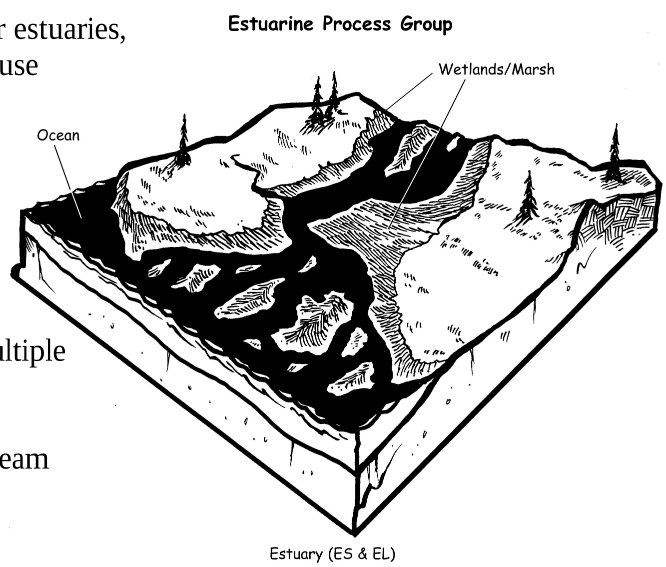
LARGE ESTUARINE CHANNEL
EL

These channels are most commonly found at the mouths of drainages along outer coastal beaches or bays. They are intertidal streams that occur exclusively within estuary landforms, usually draining a high-relief or moderate-sized watershed. They are associated with saltwater marshes, meadows, mudflats, and deltas.

These streams are predominantly depositional channels associated with low-relief coastal landforms; therefore, sediment retention is a dominant process. Stream energy is low due to nearly flat gradients, and substrate material consists mainly of small gravels, sand, and silt. Water flow and depth are strongly influenced by tidal stage. Fine-grained stream banks are highly sensitive to erosion. Beach erosion processes often have a dominant influence on deposition and erosion in the outer coastal estuarine streams.

The original boundary of an estuary may be difficult to determine due to modifications for marinas, highways, or reclamation. Many coastal estuaries will have been delineated through county, state, or municipal planning processes and may include the predevelopment boundaries.

The state has produced an excellent reference for estuaries, particularly as it relates to classification and land use (Oregon Department of Land Conservation and Development 1987).



CHANNEL ATTRIBUTES

Stream gradient:	≤1%
Valley shape:	Broad
Channel pattern:	Sinuous, single, or multiple
Channel confinement:	Unconfined
Oregon stream size:	Large
Position in drainage:	Bottom, mouth of stream
Dominant substrate:	Small gravel, sand

CHANNEL RESPONSIVENESS

These channels are low- to moderate-energy areas where sediment deposition is a dominant process. Although channel sensitivity in estuaries can vary, the unconfined nature of these areas tends to attenuate changes over space and time. Abandonment and reoccupation of relic channels commonly occurs, but it may be a slow process.

Large Woody Debris: Low to Moderate

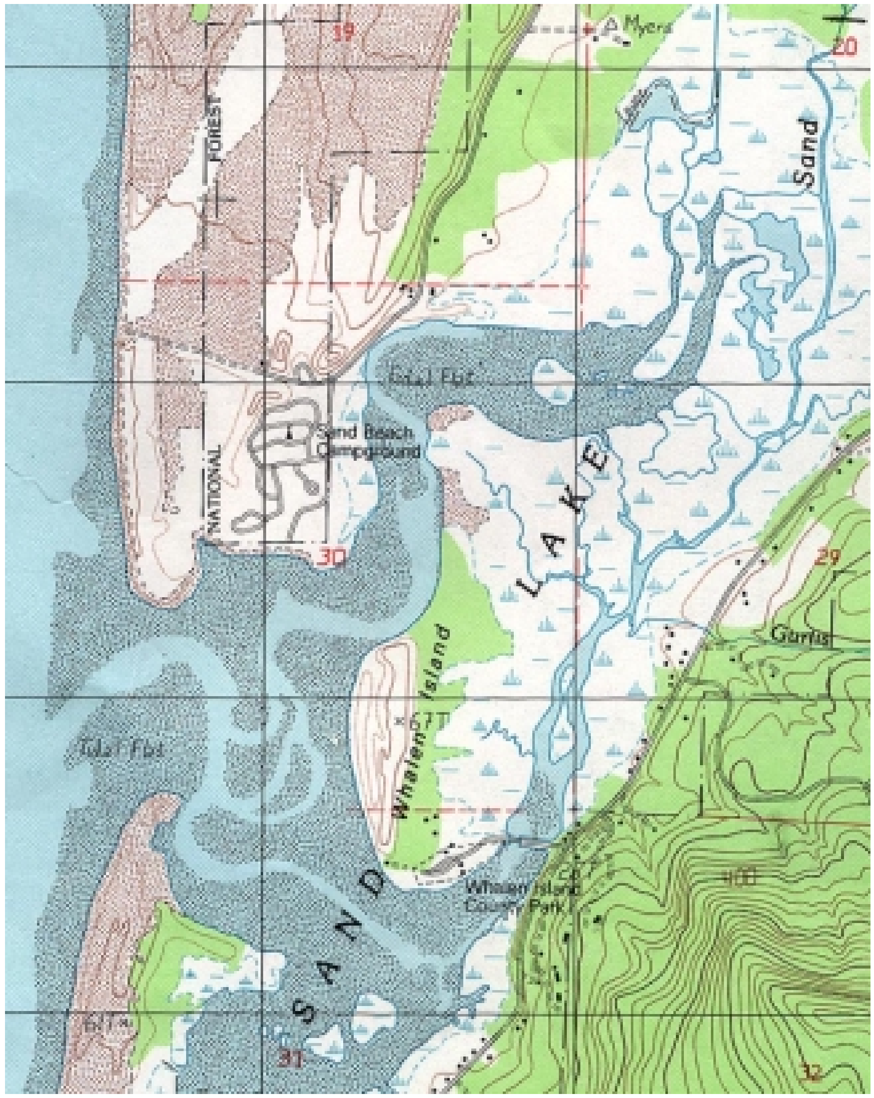
Unless in jams, wood often has limited influence on the overall morphology of the channel. Accumulations can be associated with channel shifting. Although wood is often the only roughness element present in these channels, the high sedimentation rate limits pool development and gravel sorting. The primary aquatic habitat role of wood may be refuge cover.

Fine Sediment: Moderate to High

Fine sediment is deposited at a relatively high rate, strongly influencing the arrangement of channels. In most smaller estuaries, an increase in the sediment supply would result in bar formation or reoccupation of relic channels. Localized bank erosion or downcutting could be expected if the sediment supply were to decrease.

Coarse Sediment: Low to Moderate

Although these channels can be deposition zones for coarse sediment, the delivery rate to estuarine channels is usually low due to sedimentation upstream. In some basins, deposits likely influence channel configuration at the upper end of the estuary.



EL – Large Estuary

Scale: Full (1:24,000)
Contour Interval: 40 feet

Peak Flows: Low

Estuarine channels are usually capable of transporting high flows with a minimum of alteration to the primary physical characteristics of the channel. Flows tend to spread out across the valley rather than cause streambed scour. Localized bank erosion is expected if new channels are developed.

RIPARIAN ENHANCEMENT OPPORTUNITIES

Many enhancement efforts in estuaries are related to long-term preservation of the area. As these channels harbor unique biologic communities, limiting development is a common strategy. Structural enhancement activities often involve dike breaching or removal to reconnect wetlands or sloughs.

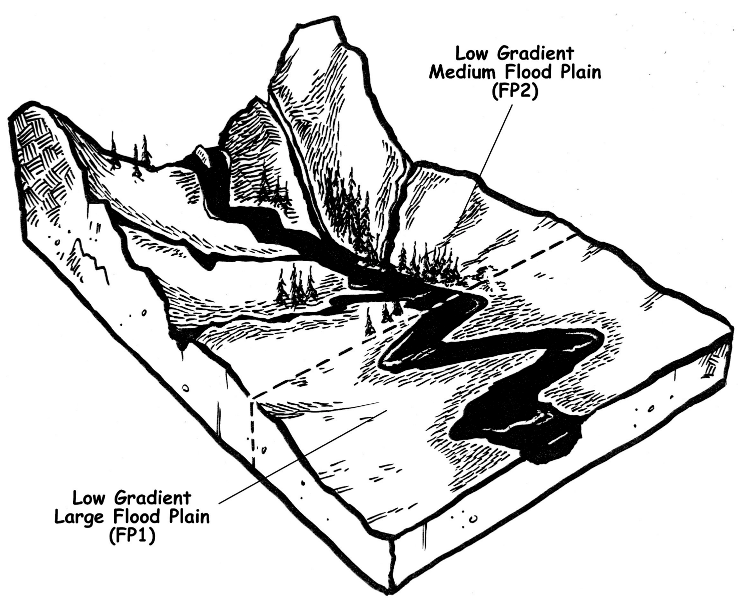
LOW GRADIENT LARGE FLOODPLAIN CHANNEL
FP1

FP1 channels are lowland and valley bottom channels of large watersheds. They may also occupy uplifted estuaries along the coast. Normally, these channels have extensive valley floodplains and river terraces. Sloughs, **oxbows**, wetlands, and abandoned channels are common in large river corridors. Smaller tributary streams may flow through channels abandoned by the main river. Numerous overflow **side-channels**, extensive gravel bars, avulsions, and log jams in forested basins are characteristic. They may be bordered on one bank by steep bluffs, marine terraces, or gentle slopes.

These channels function as sediment deposition systems, with short-term storage of fine sediment. Fines are typically mobilized during most high-flow events. Small side-channels dissecting the floodplain are common. In-channel wood accumulations are less stable than in smaller floodplain channels due to higher flood flows and greater channel width. Historically, many of these channels that drained forested areas contained significantly more wood than observed today.

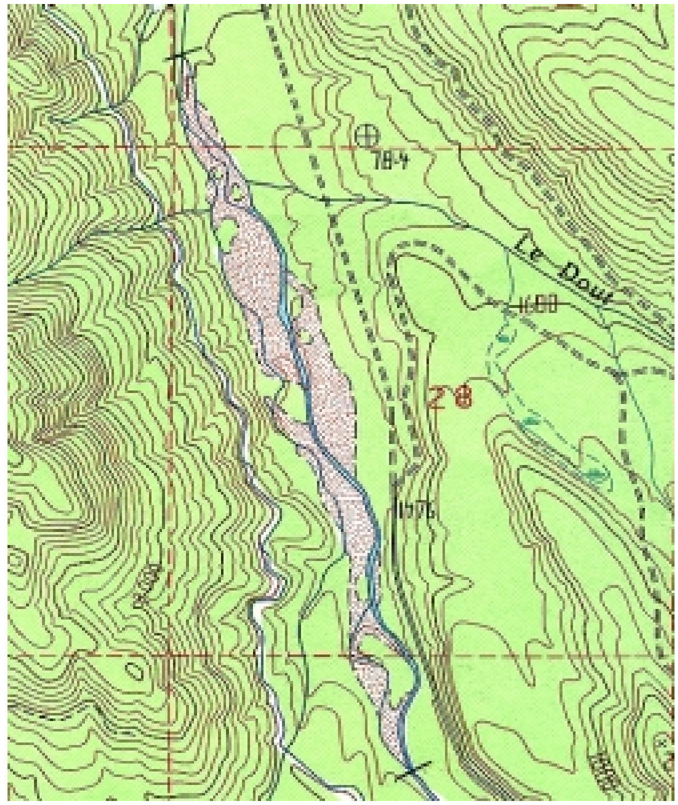
CHANNEL ATTRIBUTES

Stream gradient:	≤1%
Valley shape:	Broad valley, floodplain
Channel pattern:	Sinuous, single to multiple channels
Channel confinement:	Unconstrained
Oregon stream size:	Large
Position in drainage:	Bottom, low in drainage
Dominant substrate:	Sand to cobble



CHANNEL RESPONSIVENESS

Floodplain channels can be among the most responsive in the basin. The limited influence of confining terrain features and fine substrate allows the stream to move both laterally and vertically. Although often considered low-energy systems, these larger channels can mobilize large amounts of sediment during high flows. This often results in channel migration and new channel formation.



FP1 – Low Gradient Large Floodplain

Scale: Full (1:24,000)`
Contour Interval: 40 feet

Large Woody Debris: Moderate to High

Because of the great stream power, only large pieces or accumulations of pieces are likely to impact overall channel conditions. The role of wood and the amount and distribution of pieces is highly variable over time, as high flows regularly change conditions. Single pieces are likely to be associated with pools in side-channels and localized sediment depositions. Accumulations of wood are often responsible for the creation of midchannel bars and side-channel development.

Fine Sediment: Moderate

Fine sediment is easily mobilized by most of these channels. Increases in the supply of fines may cause temporary storage and pool filling, but moderate to high flows will mobilize the majority of the sediment. Deposition may be more permanent in smaller side-channels, and pool filling and minor shifts in side-channel location could occur.

Coarse Sediment: High

Floodplain channels are generally depositional areas for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, the channel is particularly vulnerable to widening, lateral movement, side-channel development, and **braiding**. Overall aquatic habitat complexity is reduced as pools are filled and obstructions such as large boulders or bedrock outcrops are buried.

Peak Flows: Low to Moderate

Large floodplain channels are usually capable of transporting high flows with a minimum of alteration to the primary physical characteristics of the channel. Flows tend to spread out across the valley rather than cause streambed scour. Localized bank erosion is expected as new channels are developed.

RIPARIAN ENHANCEMENT OPPORTUNITIES

Due to the unstable nature of these channels, the success of many enhancement efforts is questionable. Opportunities for enhancement do occur, however, especially in channels where lateral movement is slow. Lateral channel migration is common, and efforts to restrict this natural pattern will often result in undesirable alteration of channel conditions downstream. Smaller side-channels may be candidates for efforts that improve shade and bank stability, but it is likely that these efforts may be more beneficial and longer-lived elsewhere in the basin.

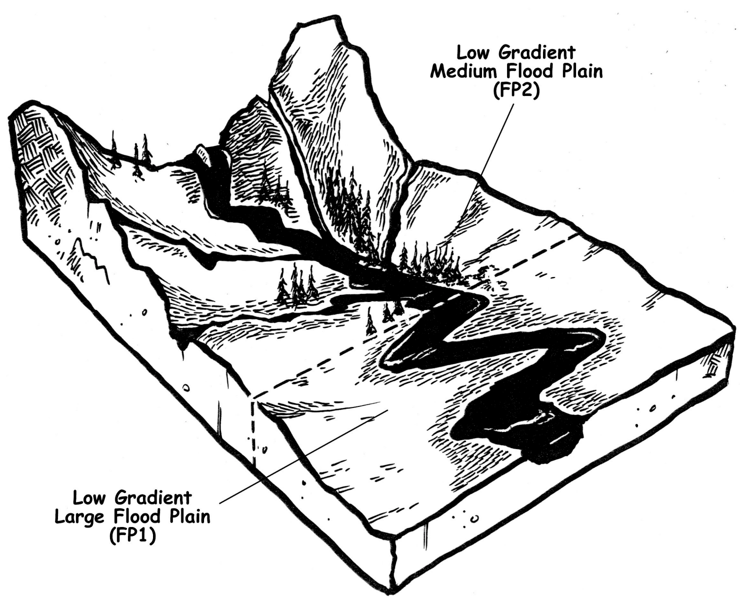
LOW GRADIENT MEDIUM FLOODPLAIN CHANNEL
FP2

FP2 channels are main-stem streams in broad valley bottoms with well-established floodplains. **Alluvial fans**, dissected **foot slopes**, and hill slope and lowland landforms may directly abut FP2 floodplains. Channels are often sinuous, with extensive gravel bars, multiple channels, and terraces. These channels are generally associated with extensive and complex riparian areas that may include such features as sloughs, side-channels, wetlands, beaver pond complexes, and small groundwater-fed tributary channels.

Sediment deposition is prevalent, with fine-sediment storage evident in pools and **point bars**, and on floodplains. Bank erosion and bank-building processes are continuous, resulting in a dynamic and diverse channel morphology. Stream banks are composed of fine alluvium and are susceptible to accelerated bank erosion with the removal or disturbance of stream-bank vegetation and root mats. Channel gradient is low, and high stream flows are not commonly contained within the active channel banks, resulting in relatively low stream power.

CHANNEL ATTRIBUTES

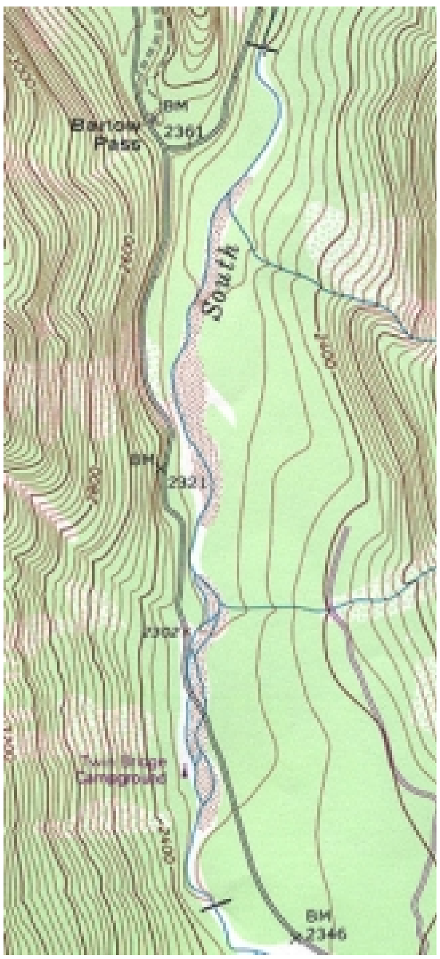
Stream gradient:	≤2%
Valley shape:	Broad, flat, or gentle landforms
Channel pattern:	Single to multiple channels, sinuous
Channel confinement:	Unconfined
Oregon stream size:	Large to medium
Position in drainage:	Middle to lower end of drainage basin
Dominant substrate:	Sand to cobble



CHANNEL RESPONSIVENESS

Floodplain channels can be among the most responsive in the basin. The limited influence of confining terrain features and fine substrate allows the stream to move both laterally and vertically. Although often considered low -energy systems, these channels can mobilize large mounts of sediment during high flows. This often results in channel migration and new channel formation.

Large Woody Debris: High



FP2 – Low Gradient Medium Floodplain

Scale: Full (1:24,000)
Contour Interval: 40 feet

Because of the high sedimentation rates, only large pieces or accumulations of smaller pieces are likely to impact overall channel conditions. The role of wood, as well as the amount and distribution of pieces, is variable over time, as high flows and stream power regularly change conditions. Single pieces are likely to be associated with pools in side-channels and localized sediment depositions. Accumulations of wood are often responsible for the creation of midchannel bars and side-channel development.

Fine Sediment: Moderate

Increases in the supply of fines may cause temporary storage and pool filling, but moderate to high flows will mobilize the majority of the sediment. Deposition may be more permanent in smaller side-channels, and pool filling and minor shifts in side-channel location could occur.

Coarse Sediment: High

Floodplain channels are generally depositional areas for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, the channel is particularly vulnerable to widening, lateral movement, side-channel development, and braiding. Overall aquatic habitat complexity is reduced, as pools are filled and obstructions such as large boulders or bedrock outcrops are buried.

Peak Flows: Low to Moderate

These floodplain channels are usually capable of transporting high flows with a minimum of alteration to the primary physical characteristics of the channel. Flows tend to spread out across the valley rather than cause streambed scour. Localized bank erosion is expected as new channels are developed, especially if the sediment supply has been increased.

RIPARIAN ENHANCEMENT OPPORTUNITIES

Due to the unstable nature of these channels, the success of many enhancement efforts is questionable. Opportunities for enhancement do occur, however, especially in channels where lateral movement is slow. Lateral channel migration is common, and efforts to restrict this natural pattern will often result in undesirable alteration of channel conditions downstream. Side-channels may be candidates for efforts that improve shade and bank stability.

LOW GRADIENT SMALL FLOODPLAIN CHANNEL FP3

FP3 streams are located in valley bottoms and flat lowlands. They frequently lie adjacent to the toe of foot slopes or hill slopes within the valley bottom of larger channels, where they are typically fed by high-gradient streams. They may be directly downstream of a small alluvial fan and contain wetlands. FP3 channels may dissect the larger floodplain. These channels are often the most likely CHT to support beavers, if they are in the basin. Beavers can dramatically alter channel characteristics such as width, depth, form, and most aquatic habitat features.

These channels can be associated with a large floodplain complex and may be influenced by flooding of adjacent main-stem streams. Sediment routed from upstream high- and moderate-gradient channels is temporarily stored in these channels and on the adjacent floodplain.

CHANNEL ATTRIBUTES

Stream gradient:	≤2%
Valley shape:	Broad
Channel pattern:	Single to multiple channels
Channel confinement:	Moderate to unconfined
Oregon stream size:	Small to medium
Position in drainage:	Variable
Dominant substrate:	Sand to small cobble

CHANNEL RESPONSIVENESS

Floodplain channels can be among the most responsive in the basin. The limited influence of confining terrain features and fine substrate allows the stream to move both laterally and vertically. Although often considered low-energy systems, these channels can mobilize large amounts of sediment during high flows. This often results in channel migration and new channel formation.

Large Woody Debris: High

In forested basins, these channels are likely to have relatively high wood counts. Those located at the foot of high-gradient channels or along the margin of a large floodplain channel are especially subject to wood availability. Wood can readily affect channel pattern, location, and dimension. Wood is likely to be a major channel roughness element, often associated with pools or spawning gravel distribution.

Fine Sediment: Moderate to High

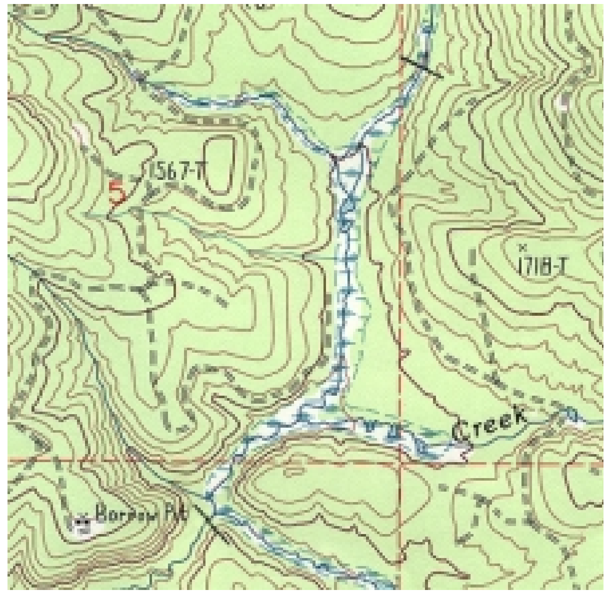
The location of these channels often dictates a high sediment input to the stream. These channels are sediment deposition zones, with side-channels particularly vulnerable to **aggradation** and shifting. If a large and persistent source of sediment is available, pool filling and channel migration could result.

Coarse Sediment: High

Floodplain channels are generally depositional areas for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, the channel is particularly vulnerable to widening, lateral movement, side-channel development, and braiding. Overall aquatic habitat complexity is reduced as pools are filled and obstructions such as large boulders or bedrock outcrops are buried.

Peak Flows: Low

Floodplain channels are usually capable of transporting high flows with a minimum of alteration to the primary physical characteristics of the channel. Flows tend to spread out across the valley rather than cause streambed scour. Localized bank erosion is expected as new channels are developed.



FP3 – Low Gradient Small Floodplain

Scale: Full (1:24,000)
Contour Interval: 40 feet

RIPARIAN ENHANCEMENT OPPORTUNITIES

Floodplain channels are, by their nature, prone to lateral migration, channel shifting, and braiding. While they are often the site of projects aimed at channel containment (diking, filling, etc.), it should be remembered that floodplain channels can exist in a dynamic equilibrium between stream energy and sediment supply. As such, the active nature of the channel should be respected, with restoration efforts carefully planned.

The limited power of these streams offers a better chance for success of channel enhancement activities than the larger floodplain channels. While the lateral movement of the channel will limit the success of many efforts, localized activities to provide bank stability or habitat development can be successful.

ALLUVIAL FAN CHANNEL
AF

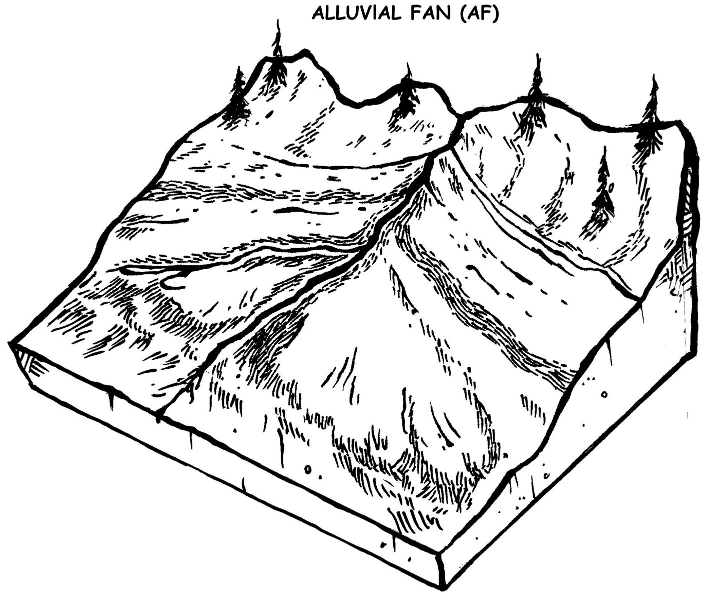
Alluvial fans are generally tributary streams that are located on foot-slope landforms in a transitional area between valley floodplains and steep mountain slopes. Alluvial fan deposits are formed by the rapid change in transport capacity as the high-energy mountain-slope stream segments spill onto the valley bottom. Channel pattern is highly variable, often dependent on substrate size and age of the landform. Channels may change course frequently, resulting in a multibranched stream network. Channels can also be deeply incised within highly erodible alluvial material. Smaller alluvial fan features may be difficult to distinguish from FP3 channels.

CHANNEL ATTRIBUTES

Stream gradient:	1-12%
Valley shape:	Where hill slopes open into broad valley
Channel pattern:	Single to multiple channels spread across the fan surface
Channel confinement:	Variable
Oregon stream size:	Small to medium
Position in drainage:	Lower end of small tributaries
Dominant substrate:	Fine gravel to large cobble

CHANNEL RESPONSIVENESS

The response of alluvial fans to changes in input factors is highly variable. Response is dependent on gradient, substrate size, and channel form. **Single-thread channels** confined by high banks are likely to be less responsive than an actively migrating multiple-channel fan. The moderate-gradient and alluvial substrate of many fans results in channels with a moderate to high overall sensitivity.



Large Woody Debris: Variable

AF – Alluvial Fan

Scale: Full (1:24,000)
Contour Interval: 40 feet

In forested basins, these channels are likely to have relatively high wood counts. Those located at the foot of high-gradient channels are especially subject to wood availability. Wood can readily affect channel pattern, location, and dimension. Wood is likely to be a major channel roughness element, although the high sediment supply limits development of pools.

Fine Sediment: Moderate to High

The location of these channels often dictates a high sediment input to the stream. These channels are sediment deposition zones for larger particles, although a significant portion of the fine sediment will be transported through higher-gradient fans. In lower-gradient fans, or those with heavy sediment input loads, the fine- and coarse-sediment deposition promotes channel migration and the development of multiple channels.

Coarse Sediment: High

Alluvial fans are depositional areas for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, the channel is vulnerable to widening, lateral movement, side-channel development, and braiding.

Peak Flows: Moderate to High

The capability of alluvial fans to pass large flows is highly variable. As the channel is bedded in alluvial material, high flows are capable of moving the channel bed, particularly in the higher-energy regions at the head of the fan. This often results in downcutting or creation of multiple channels.

RIPARIAN ENHANCEMENT OPPORTUNITIES

As many alluvial fans are actively moving at a rate greater than most channels, they are generally not well-suited to successful enhancement activities. Although they are considered responsive channels, long-term success of enhancement activities is questionable. High sediment loads often limit the success of efforts to improve habitat complexity such as wood placement for pool development.

LOW GRADIENT MODERATELY CONFINED CHANNEL
LM

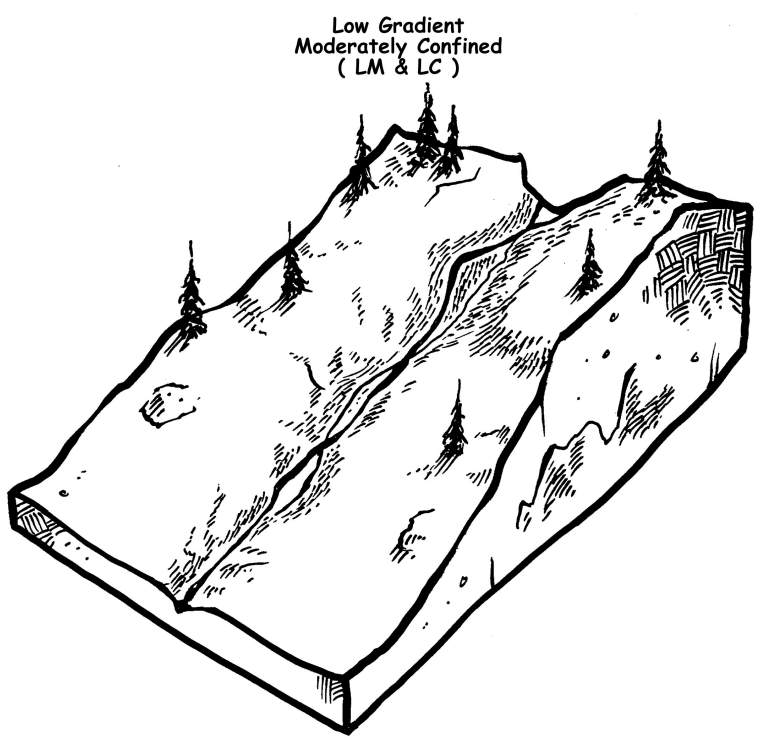
These channels consist of low-gradient reaches that display variable confinement by low terraces or hill slopes. A narrow floodplain approximately two to four times the width of the active channel is common, although it may not run continuously along the channel. Often low terraces accessible by flood flows occupy one or both sides of the channel. The channels tend to be of medium to large size, with substrate varying from bedrock to gravel and sand. They tend to be slightly to moderately sinuous, and will occasionally possess islands and side-channels. Because of the difficulty in assessing the degree of confinement and the height of stream-bank terraces from maps or air photos, these channels are often misidentified as LC channels unless field-checked.

CHANNEL ATTRIBUTES

Stream gradient:	<2%
Valley shape:	Broad, generally much wider than channel
Channel pattern:	Single with occasional multiple channels
Channel confinement:	Variable
Oregon stream size:	Variable, usually medium to large
Position in drainage:	Variable, often main-stem and lower end of main tributaries
Dominant substrate:	Fine gravel to bedrock

CHANNEL RESPONSIVENESS

The unique combination of an active floodplain and hill-slope or terrace controls acts to produce channels that can be among the most responsive in the basin. Multiple roughness elements are common, with bedrock, large boulders, or wood generating a variety of aquatic habitat within the stream network.



LM – Low Gradient Moderately Confined

Scale: Full (1:24,000)
Contour Interval: 40 feet

Large Woody Debris: Moderate to High

In forested basins, wood alone or in combination with other elements is associated with pool formation and maintenance, bar formation, and, occasionally, side-channel development. These channels may have relatively low wood numbers due to past management activities.

Fine Sediment: Moderate to High

The location of these channels often dictates a high sediment input to the stream. These channels can be sediment deposition zones for larger particles, although a significant portion of the fine sediment may be transported, particularly in bedrock channels. Increases in fine-sediment supply will likely result in filling of margin pool and bed-fining of side-channels and low-velocity areas. Decreases in sediment supply may induce scour in nonbedrock channels or localized bank erosion.

Coarse Sediment: Moderate to High

These channels are depositional areas for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, pools are filled, and the influence of large boulders, wood, and bedrock control structures is lessened. If significant amounts of large sediment are added, the channel is particularly vulnerable to widening, lateral movement, side-channel development, and localized scour.

Peak Flows: Moderate

These channels are capable of passing most high flows without adjustments to the overall dimensions of the channel. Development of point or **medial bars** is likely in basins with high sediment loads, as is side-channel development. Localized bed or bank scour is possible on bends in the main channel.

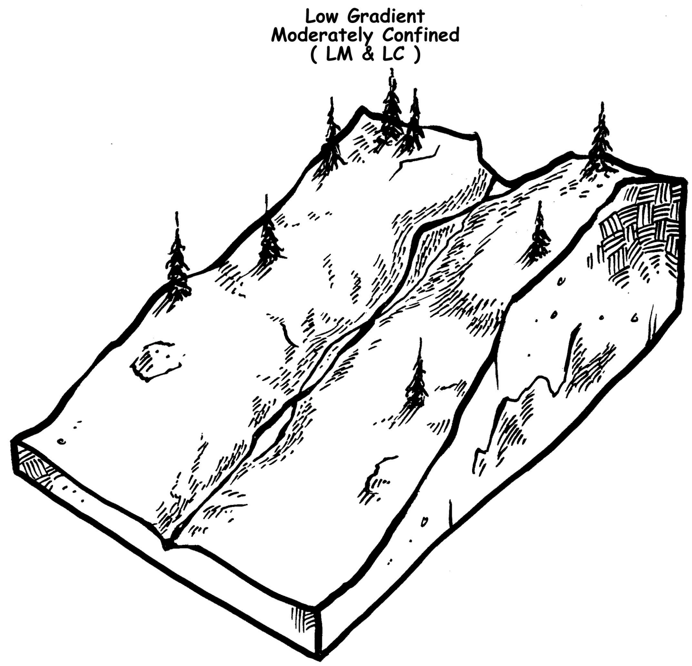
RIPARIAN ENHANCEMENT OPPORTUNITIES

Like floodplain channels, these channels can be among the most responsive of channel types. Unlike floodplain channels, however, the presence of confining landform features often improves the accuracy of predicting channel response to activities that may affect channel form. Additionally, these controls help limit the destruction of enhancement efforts common to floodplain channels. Because of this, LM channels are often good candidates for enhancement efforts.

In forested basins, habitat diversity can often be enhanced by the addition of roughness elements such as wood or boulders. Pool frequency and depth may increase, and side-channel development may result from these efforts. Channels of this type in nonforested basins are often responsive to bank stabilization efforts such as riparian planting and fencing. Beavers are often present in the smaller streams of this channel type, and fish habitat in some channels may benefit from beaver introduction through side-channel and scour pool development. Introduction of beavers, however, may have significant implications for overall channel form and function, and should be thoroughly evaluated by land managers as well as biologists as a possible enhancement activity.

LOW GRADIENT CONFINED CHANNEL
LC

LC channels are incised or contained within adjacent, gentle landforms or incised in volcanic flows or uplifted coastal landforms. Lateral channel migration is controlled by frequent bedrock outcrops, high terraces, or hill slopes along stream banks. They may be bound on one bank by hill slopes and lowlands on the other, and may have a narrow floodplain in places, particularly on the inside of meander bends. Stream-bank terraces are often present, but they are generally above the current floodplain. The channels are often stable, with those confined by hill slopes or bedrock less likely to display bank erosion or scour than those confined by alluvial terraces.



High-flow events are well-contained by the upper banks. High flows in these well-contained channels tend to move all but the most stable wood accumulations downstream or push debris to the channel margins. Stream banks can be susceptible to landslides in areas where steep hill slopes of weathered bedrock, glacial till, or volcanic-ash parent materials abut the channel.

CAUTION: Some degree of caution should be exercised in evaluating channels that have downcut into alluvial material set in a wide flat valley. If the stream banks are high enough to allow a floodplain width less than two times the bankfull width, then the stream meets the definition of confined. However, some streams meeting this definition may have recently downcut, effectively reducing floodplain width as the channel deepens. It is beyond the scope of this manual to deal with technical issues such as rate of channel incision. The analyst, however, should note channels that display evidence of recent downcutting, low channel banks, and evidence of abandoned floodplain. For whatever reason, these channels may be transitioning from LM to LC channels, and should receive additional scrutiny before assigning the proper CHT.

CHANNEL ATTRIBUTES

Stream gradient:	<2%
Valley shape:	Low- to moderate-gradient hill slopes with limited floodplain
Channel pattern:	Single channel, variable sinuosity
Channel confinement:	Confined by hill slopes or high terraces
Oregon stream size:	Variable, usually medium to large
Position in drainage:	Variable, generally mid to lower in the larger drainage basin
Dominant substrate:	Boulder, cobble, bedrock with pockets of sand/gravel/cobble

CHANNEL RESPONSIVENESS

The presence of confining terraces or hill slopes and control elements such as bedrock limit the type and magnitude of channel response to changes in input factors. Adjustment of channel features is usually localized and of a modest magnitude.

Large Woody Debris: Low to Moderate

In larger forested basins, wood numbers are often low in this channel type. This may be in part due to land management activities, but these channels usually display sufficient energy to route wood downstream. Also, limited lateral movement of the channel reduces the recruitment of wood from bank erosion. Wood is often present in jams or as large single pieces capable of withstanding high-energy flows. Even in streams of this channel type that are smaller and display less energy, wood may be routed or retained above the elevation of the bankfull channel, where it has limited impact on aquatic habitat.

LC – Low Gradient Confined

Scale: Full (1:24,000)
Contour Interval: 20 feet

Fine Sediment: Low

The confining nature of the landforms that define this channel type tends to focus enough stream energy to route most introduced fine sediment downstream. In basins with high background sediment levels, such as sand and siltstone-bedded channels in the Coast Range, supply may approach or surpass transport capacity, resulting in pool filling and **bed fining**.

Coarse Sediment: Moderate

These channels can be depositional areas for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, pools are filled, and the influence of large boulders, wood, and bedrock control structures is lessened. If significant amounts of large sediment are added, the channel is particularly vulnerable to widening, lateral movement, side-channel development, or scour.

Peak Flows: Low to Moderate

These channels have limited floodplain, and are capable of passing most high flows without adjustments to the overall dimensions of the channel. Development of point or medial bars is likely in basins with high sediment loads. Localized bed or bank scour is possible on bends in the main channel.

RIPARIAN ENHANCEMENT OPPORTUNITIES

These channels are not highly responsive, and in channel enhancements may not yield intended results. In basins where water-temperature problems exist, the confined nature of these channels lends itself to establishment of riparian vegetation. In nonforested land, these channels may be deeply incised and prone to bank erosion from livestock. As such, these channels may benefit from livestock access control measures.

MODERATE GRADIENT MODERATELY CONFINED CHANNEL MM

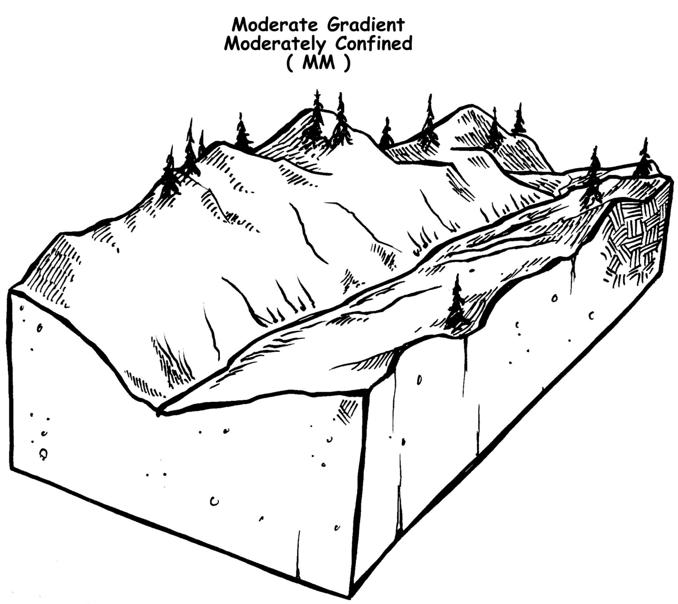
This group includes channels with variable controls on channel confinement. Alternating valley terraces and/or adjacent mountain-slope, foot-slope, and hill-slope landforms limit channel migration and floodplain development. Similar to the LM channels, a narrow floodplain is usually present, and may alternate from bank to bank. Bedrock steps with cascades may be present.

CHANNEL ATTRIBUTES

Stream gradient:	Generally 2-4%
Valley shape:	Narrow valley with floodplain or narrow terrace development
Channel pattern:	Usually single channel, low to moderate sinuosity
Channel confinement:	Variable
Oregon stream size:	Variable, usually medium to large
Position in drainage:	Mid to lower portion of drainage basins
Dominant substrate:	Gravel to small boulder

CHANNEL RESPONSIVENESS

The unique combination of a narrow floodplain and hill-slope or terrace controls acts to produce channels that are often the most responsive in the basin. The combination of higher gradients and the presence of a floodplain set the stage for a dynamic channel system. Multiple roughness elements such as bedrock, large boulders, or wood may be common, resulting in a variety of aquatic habitats within the stream network.



Large Woody Debris: High

In forested basins, wood alone or in combination with other elements is associated with pool formation and maintenance, bar formation and gravel sorting, and, occasionally, side-channel development. LWD may be the primary factor responsible for forming pools in forested systems. Due to the moderate gradient, smaller pieces are transported downstream or form jams. A change in the wood supply would likely have significant impact on pool condition, sediment movement, bar development, and, possibly, side-channel condition.

Fine Sediment: Moderate

The location of these channels often dictates a high sediment input to the stream. These channels can be sediment deposition zones for larger particles, although the moderate gradient produces enough energy to route most of the fine sediment downstream. Increases in fine-sediment supply will likely result in filling of margin pool and bed fining of side-channels and low-velocity areas. Decreases in sediment supply may induce scour in nonbedrock channels or localized bank erosion

Coarse Sediment: Moderate to High

Unless the channel is quite large, these channels may be temporary storage areas for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, pools are filled, and the influence of large boulders, wood, and bedrock control structures is lessened. If significant amounts of large sediment are added, the channel is particularly vulnerable to widening, lateral movement, side-channel development, or scour. Steeper channels within this CHT would likely transport a greater portion of the load and not be as responsive as lower-gradient reaches.

MM – Moderate Gradient Moderately Confined

Scale: Full (1:24,000)
Contour Interval: 40 feet

Peak Flows: Moderate

These channels have limited floodplain, and are capable of passing most high flows without adjustments to the overall dimensions of the channel. The higher energy induced by steeper gradients can result in development of point or medial bars in basins with high sediment loads, as well as side-channel development. Localized bed or bank scour is possible on bends in the main channel.

RIPARIAN ENHANCEMENT OPPORTUNITIES

Like floodplain channels, these channels are among the most responsive of channel types. Unlike floodplain channels, however, the presence of confining landform features improves the accuracy of predicting channel response to activities that may affect channel form. Additionally, these controls help limit the destruction of enhancement efforts, a common problem in floodplain channels. The slightly higher gradients impart a bit more uncertainty as to the outcome of enhancement efforts when compared to LM channels. MM channels, however, are often good candidates for enhancement efforts.

In forested basins, habitat diversity can often be enhanced by the addition of roughness elements such as wood or boulders. Pool frequency and depth may increase as well as side-channel development as the result of these efforts. Channels of this type in nonforested basins are often responsive to bank stabilization efforts such as riparian planting and fencing.

Beavers are often present in the smaller streams of this channel type, and fish habitat in some channels may benefit from beaver introduction through side-channel and scour pool development. Introduction of beavers, however, may have significant implications for overall channel form and function, and should be thoroughly evaluated by land managers as well as biologists as a possible enhancement activity.

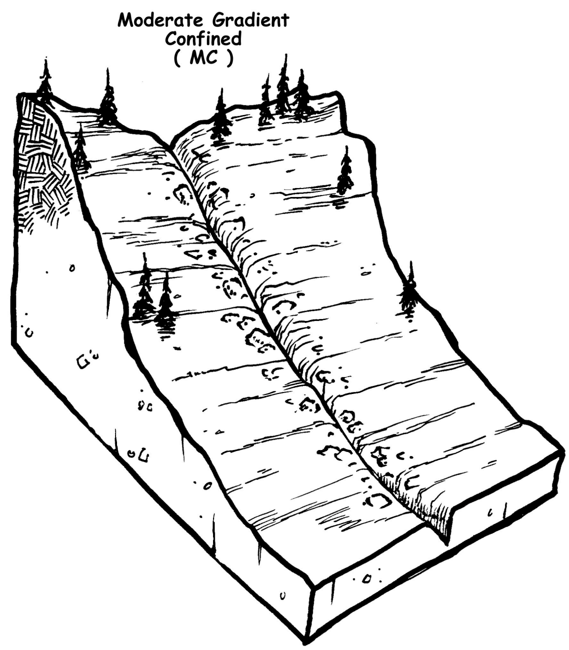
MODERATE GRADIENT CONFINED CHANNEL
MC

MC streams flow through narrow valleys with little river terrace development, or are deeply incised into valley floors. Hill slopes and mountain slopes composing the valley walls may lie directly adjacent to the channel. Bedrock steps, short falls, cascades, and boulder runs may be present; these are usually sediment transport systems. Moderate gradients, well-contained flows, and large-particle substrate indicate high stream energy. Landslides along channel side slopes may be a major sediment contributor in unstable basins.

CHANNEL ATTRIBUTES

Stream gradient:	2-4%, may vary between 2 to 6%
Valley shape:	Gentle to narrow V-shaped valley, little to no floodplain development
Channel pattern:	Single, relatively straight or conforms to hill-slope control
Channel confinement:	Confined
Oregon stream size:	Variable
Position in drainage:	Middle to lower
Dominant substrate:	Coarse gravel to bedrock

CHANNEL RESPONSIVENESS



The presence of confining terraces or hill slopes and control elements such as bedrock substrates limits the type and magnitude of channel response to changes in input factors. Adjustment of channel features is usually localized and of a modest magnitude.

Large Woody Debris: Low

In larger forested basins, wood numbers are often low in this channel type. This may be, in part, due to past land management activities, but these channels usually display sufficient energy to route wood downstream. Also, limited lateral movement of the channel reduces the recruitment of wood from bank erosion. Wood is often present in jams or as large single pieces capable of withstanding high-energy flows. Even in streams of this channel type that are smaller and display less energy, wood may be routed or retained above the elevation of the bankfull channel, where it has limited impact on aquatic habitat.

Fine Sediment: Low

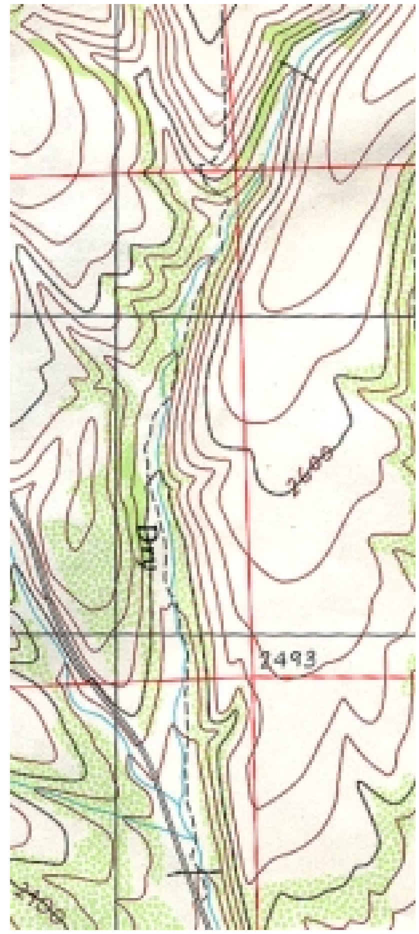
The confining nature of the landforms and the moderate gradient combine to produce enough stream energy to route most introduced fine sediment downstream. Localized pool filling and bed fining may occur if a large and persistent source exists.

Coarse Sediment: Moderate

These channels can be both a transport or deposition area for coarse sediment. When the supply of coarse sediment surpasses the transport capabilities of the stream, pools are filled, and the influence of large boulders, wood, and bedrock control structures is lessened. If significant amounts of large sediment are added, the channel is particularly vulnerable to widening, limited lateral movement, or scour.

Peak Flows: Moderate

These channels have limited floodplain, and are capable of passing most high flows without adjustments to the overall dimensions of the channel. Development of point or medial bars is likely in basins with high sediment loads. Localized bed or bank scour is possible on bends in the main channel.



MC – Moderate Gradient Confined

Scale: Full (1:24,000)
Contour Interval: 40 feet

RIPARIAN ENHANCEMENT OPPORTUNITIES

These channels are not highly responsive, and in-channel enhancements may not yield intended results. Although channels are subject to relatively high energy, they are often stable. In basins where water-temperature problems exist, the stable banks generally found in these channels lend themselves to establishment of riparian vegetation. In nonforested land, these channels may be deeply incised and prone to bank erosion from livestock. As such, these channels may benefit from livestock access control measures.

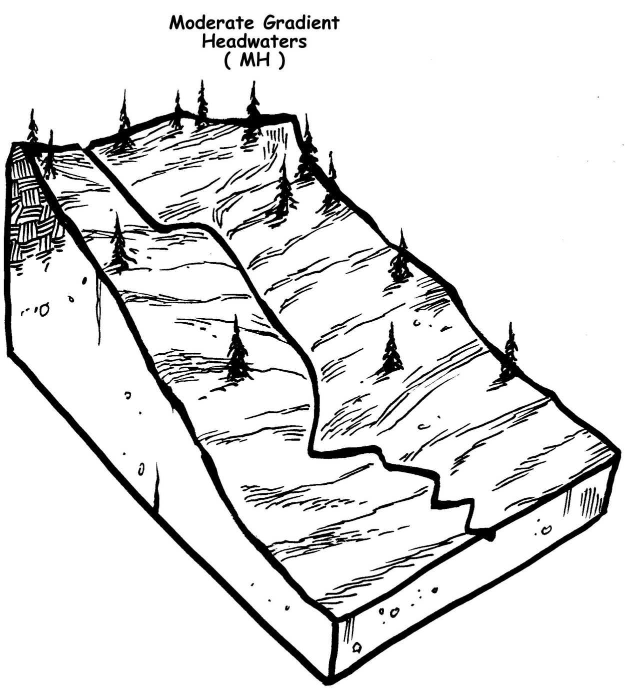
MODERATE GRADIENT HEADWATER CHANNEL
MH

These moderate-gradient headwater channels are common to plateaus in Columbia River basalts, young volcanic surfaces, or broad drainage divides. They may be sites of headwater beaver ponds. These channels are similar to LC channels, but occur exclusively in headwater regions. They are potentially above the **anadromous fish** zone.

These gentle to moderate headwater streams generally have low streamflow volumes and, therefore, low stream power. The confined channels provide limited sediment storage in low-gradient reaches. Channels have a small upslope drainage area and limited sediment supply. Sediment sources are limited to upland surface erosion.

CHANNEL ATTRIBUTES

Stream gradient:	1-6%
Valley shape:	Open, gentle V-shape valley
Channel pattern:	Low sinuosity to straight
Channel confinement:	Confined
Oregon stream size:	Small
Position in drainage:	Upper, headwater
Dominant substrate:	Sand to cobble, bedrock; boulders may be present from erosion of surrounding slopes and soils



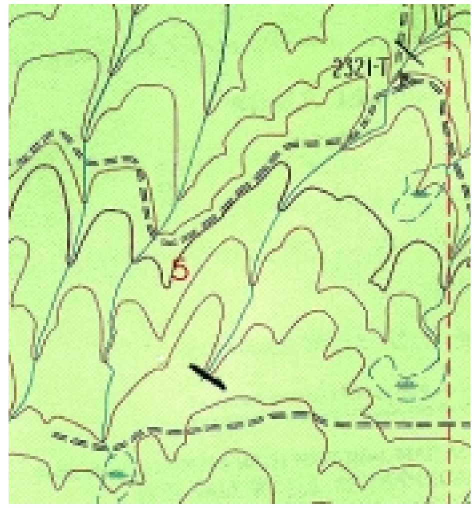
CHANNEL RESPONSIVENESS

The low stream power and presence of confining terraces or hill slopes and control elements such as bedrock substrates limit the type and magnitude of channel response to changes in input factors. Adjustment of channel features is usually localized and of a moderate magnitude.

Large Woody Debris: Moderate

Wood numbers and influence is quite variable in these channels. While the low stream energy may limit the magnitude of response associated with wood, wood numbers can be high and wood may be the dominant roughness element. In these cases, wood is critical for pool and cover habitat formation and maintenance.

Fine Sediment: Moderate



MH – Moderate Gradient Headwater

Scale: Full (1:24,000)
Contour Interval: 40 feet

The confining nature of the landforms that define this channel type tends to focus enough stream energy to route much of the introduced fine sediment downstream. Localized pool filling and bed fining can occur in lower-gradient reaches.

Coarse Sediment: Moderate to High

The low energy in these small channels is incapable of transporting larger sediment. Increases in the sediment load can easily overwhelm the channel and result in widening, lateral movement, or scour. In some basins, the location of these channels makes them vulnerable to inputs of sediment and wood from slides.

Peak Flows: Moderate

These channels have limited floodplain, and are capable of passing most high flows without adjustments to the overall dimensions of the channel. Localized bed or bank scour is possible on bends in the main channel.

RIPARIAN ENHANCEMENT OPPORTUNITIES

These channels are moderately responsive. In basins where water-temperature problems exist, the stable banks generally found in these channels lend themselves to establishment of riparian vegetation. In nonforested land, these channels may be deeply incised and prone to bank erosion from livestock. As such, these channels may benefit from livestock access control measures.

MODERATELY STEEP NARROW VALLEY CHANNEL
MV

MV channels are moderately steep and confined by adjacent moderate to steep hill slopes. High flows are generally contained within the channel banks. A narrow floodplain, one channel width or narrower, may develop locally.

MV channels efficiently transport both coarse bedload and fine sediment. Bedrock steps, boulder cascades, and chutes may be common features. The large amount of bedrock and boulders create stable streambanks; however, steep side slopes may be unstable. Large woody debris is found commonly in jams that trap sediment in locally low-gradient steps.

CHANNEL ATTRIBUTES

Stream gradient:	4-8%, may vary between 3 to 10%
Valley shape:	Narrow, V-shaped valley
Channel pattern:	Single channel, relatively straight similar to valley
Channel confinement:	Confined
Oregon stream size:	Small to medium
Position in drainage:	Mid to upper
Dominant substrate:	Small cobble to bedrock

CHANNEL RESPONSIVENESS

The gradient and presence of confining terraces or hill slopes and control elements such as bedrock substrates limit the type and magnitude of channel response to changes in input factors. Adjustment of channel features is localized and of a minor magnitude.

Large Woody Debris: Moderate

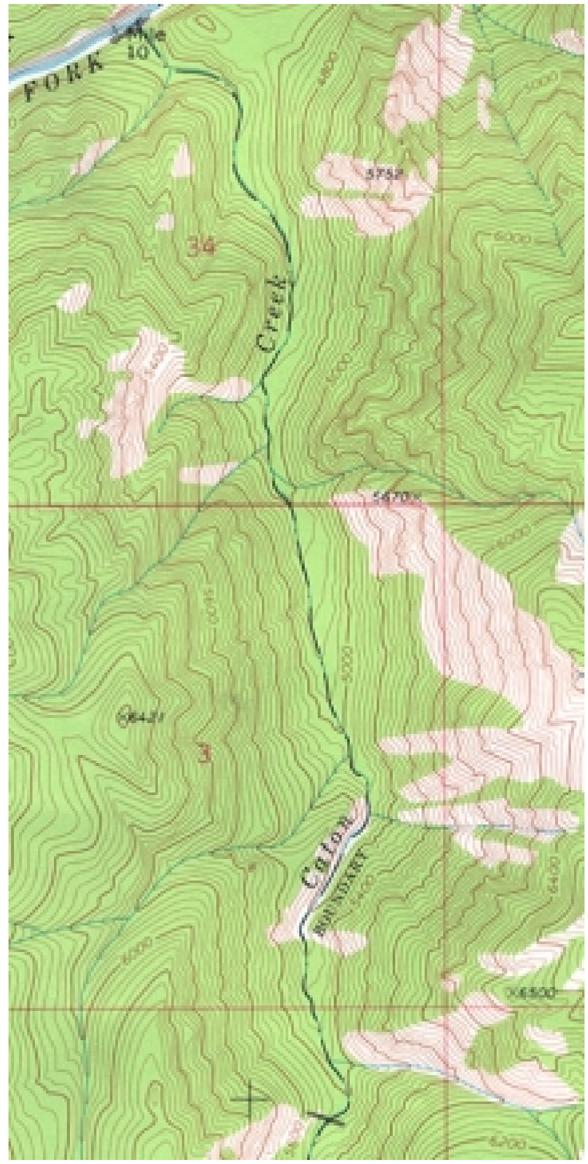
In larger forested basins, wood numbers are often high in this channel type. Wood is present in jams or as single pieces capable of withstanding high-energy flows. Large woody debris may be the primary element responsible for pool formation and development. In bedrock systems, wood has less influence, and is often transported downstream.

Fine Sediment: Low

The confining nature of the landforms and the higher gradients combine to produce enough stream energy to route most introduced fine sediment downstream. Filling of lateral pools and lower-energy areas may result from increases in the sediment supply.

Coarse Sediment: Moderate

These channels are usually transport reaches for coarse sediment, although lower-energy sections can retain sediment and adjust channel dimensions. When the supply of coarse sediment surpasses the transport capabilities of the stream, pools are filled, and the influence of large boulders, wood, and bedrock control structures is lessened.



MV – Moderately Steep Narrow Valley

Scale: Full (1:24,000)
Contour Interval: 40 feet

Peak Flows: Moderate

These channels have limited floodplain, and are capable of passing most high flows without adjustments to the overall dimensions of the channel. Development of point or medial bars is likely in basins with high sediment loads. Localized bed or bank scour is possible on bends in the main channel.

RIPARIAN ENHANCEMENT OPPORTUNITIES

These channels are not highly responsive, and in channel enhancements may not yield intended results. Although channels are subject to relatively high energy, they are often stable. In basins where water-temperature problems exist, the stable banks generally found in these channels lend themselves to establishment of riparian vegetation. In nonforested land, these channels may be deeply incised and prone to bank erosion from livestock. As such, these channels may benefit from livestock access control measures.

BEDROCK CANYON CHANNEL
BC

BC channels are associated with valley bottom gorge landforms typically cut through bedrock with long, steep, side-slope walls. Channel features include cascades, rapids, and major falls, although long pools may exist.

CHANNEL ATTRIBUTES

Stream gradient:	>4%, can be locally lower
Valley shape:	Canyons, gorges, very steep mountain side slopes
Channel pattern:	Single channel, straight
Channel confinement:	Tightly confined by bedrock slopes
Oregon stream size:	Variable
Position in drainage:	Variable
Dominant substrate:	Bedrock, large boulders

CHANNEL RESPONSIVENESS

The bedrock side slopes and channel bed severely limit the sensitivity of these channels to change. They are the least responsive of the identified channel types.

Large Woody Debris: Low

Wood is generally transported out of these reaches, although jams can develop in lower-gradient canyons. Bedrock is the defining roughness element, with wood playing a minor role.

Fine Sediment: Low

The confining nature of the landform produces enough stream energy to route most introduced fine sediment downstream. Temporary storage of fines in low-gradient pools may occur.

Coarse Sediment: Low

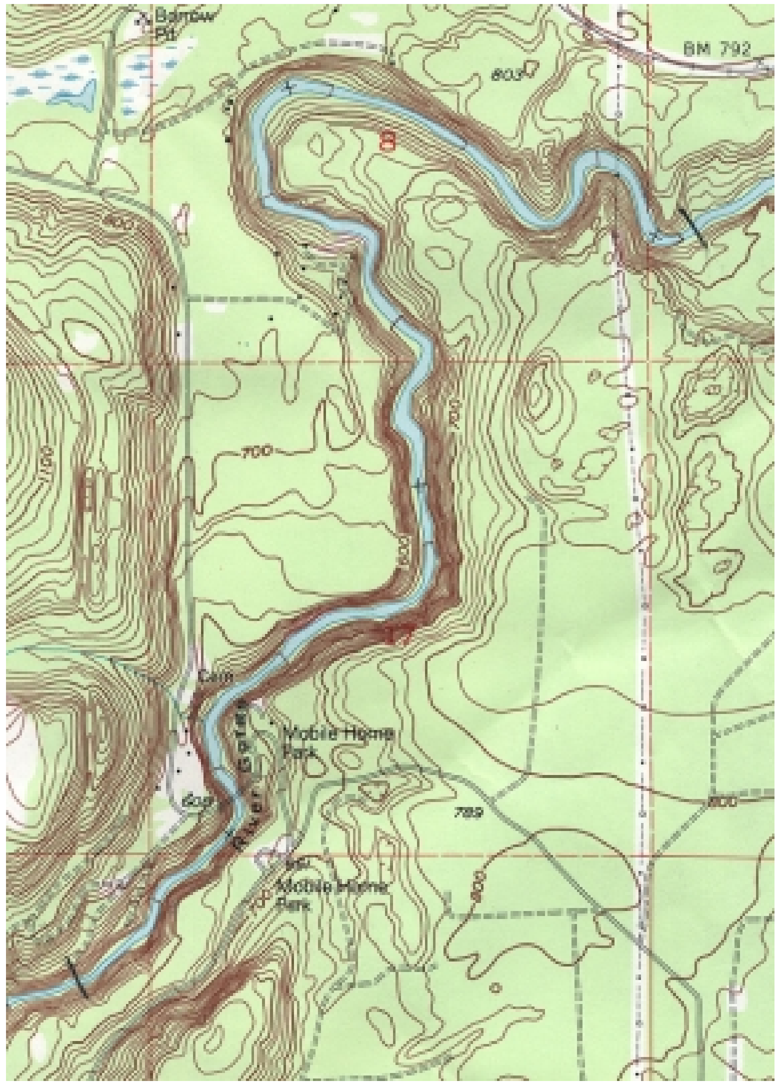
These channels are usually transport reaches for coarse sediment, although lower-energy sections can retain sediment for a limited time.

Peak Flows: Low

These channels have no floodplain, and are capable of passing high flows without adjustments to the overall dimensions of the channel.

RIPARIAN ENHANCEMENT OPPORTUNITIES

These channels are not responsive, and are generally a poor site for enhancement efforts.



BC – Bedrock Canyon

Scale: Full (1:24,000)
Contour Interval: 20 feet

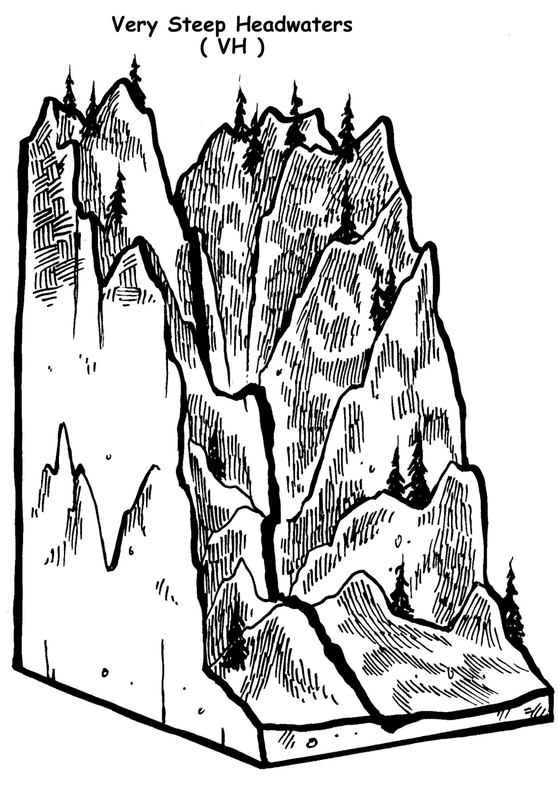
STEEP NARROW VALLEY CHANNEL
SV

VERY STEEP HEADWATER
VH

These two channel types are very similar, except that VH channels are steeper. Because of this similarity, they are presented together. SV channels are situated in a constricted valley bottom bounded by steep mountain or hill slopes. Vertical steps of boulder and wood with scour pools, cascades, and falls are common. VH channels are found in the headwaters of most drainages or side slopes to larger streams, and commonly extend to ridge-tops and summits. These steep channels may be shallowly or deeply incised into the steep mountain or hill slope. Channel gradient may be variable due to falls and cascades.

CHANNEL ATTRIBUTES

Stream gradient:	SV 8-16%, VH >16%
Valley shape:	Steep, narrow V-shaped valley
Channel pattern:	Single, straight
Channel confinement:	Tightly confined
Oregon stream size:	Small, small-medium transition
Position in drainage:	Middle upper to upper
Dominant substrate:	Large cobble to bedrock



CHANNEL RESPONSIVENESS

The gradient and presence of confining terraces or hill slopes and control elements such as bedrock substrates limit the type and magnitude of channel response to changes in input factors. Adjustment of channel features is localized and of a minor magnitude. These channels are also considered source channels supplying sediment and wood to downstream reaches, sometimes via landslides.

Large Woody Debris: Moderate

In larger forested basins, wood numbers are often high in these channel types. Large woody debris may be the primary element responsible for pool formation and development. In bedrock systems, wood has less influence, and is often transported downstream.

Fine Sediment: Low

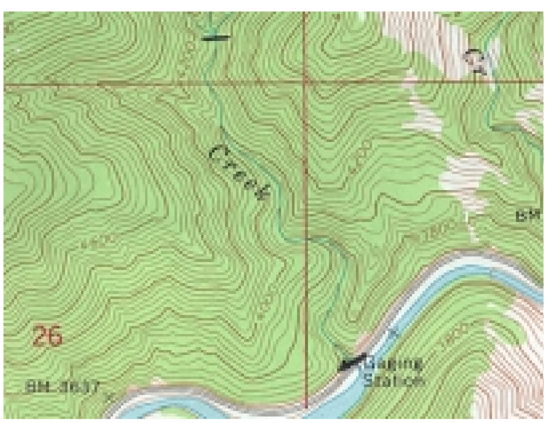
The confining nature of the landforms and the higher gradients combine to produce enough stream energy to route most introduced fine sediment downstream. Filling of lateral pools and lower-energy areas may result from increases in the sediment supply.

Coarse Sediment: Low to Moderate

These channels are usually transport reaches for coarse sediment, although lower-energy sections can retain sediment and adjust channel dimensions. When the supply of coarse sediment surpasses the transport capabilities of the stream, pools are filled, and the influence of large boulders, wood, and bedrock control structures is lessened. Minor channel widening or scour can occur.

Peak Flows: Low

These channels have limited floodplain, and are capable of passing most high flows without adjustments to the overall dimensions of the channel. Localized bed or bank scour is possible.

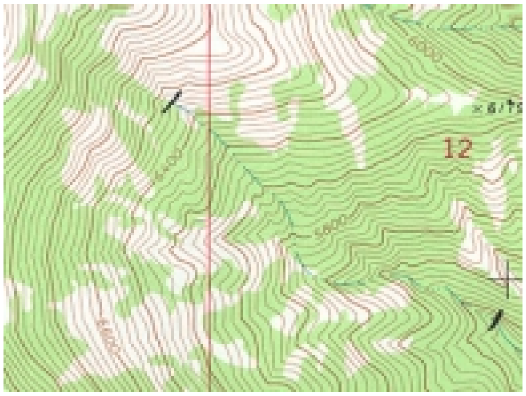


SV – Steep Narrow Valley

Scale: Full (1:24,000)
Contour Interval: 40 feet

RIPARIAN ENHANCEMENT OPPORTUNITIES

These channels are not highly responsive, and in channel enhancements may not yield intended results. Although channels are subject to relatively high energy, they are often stable. In basins where water-temperature problems exist, the stable banks generally found in these channels lend themselves to establishment of riparian vegetation. This may also serve as a recruitment effort for LWD in the basin.



VH – Very Steep Headwater

Scale: Full (1:24,000)
Contour Interval: 40 feet

REFERENCES

Cupp, C.E. 1989. Stream Corridor Classification for Forested Lands of Washington. State of Washington, Timber/Fish/Wildlife Ambient Monitoring Program, Olympia.

Frissell, C.A., W.J. Liss, C.E. Warren, and M.D.Hurley. 1986. A Hierarchical Framework for Stream Habitat Classification: Viewing Streams in a Watershed Context. Environmental Management 10(2):199-214.

Montgomery, D.R., and J.M. Buffington. 1993. Channel Classification, Prediction of Channel Response, and Assessment of Channel Condition. Washington State Timber/Fish/Wildlife Report TFW-SH10-93-002, Olympia.

Moore, K., K. Jones, and J. Dambacher. 1997. Methods for Stream Habitat Surveys. Aquatic Inventory Project, Natural Production Program: Oregon Department of Fish and Wildlife.

Oregon Department of Land Conservation and Development. 1987. Estuary Plan Book.

Paustian, S.J. (editor), et al. 1992. Channel Type Users Guide for the Tongass National Forest, Southeast Alaska. US Department of Agriculture Forest Service, Alaska Region, R10 Technical Paper 26.

Rosgen, D.L. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, CO.

GLOSSARY

aggradation: Raising of the channel bed elevation due to sediment deposition.

alluvial fan: An area where large amounts of sediment are deposited by a stream as the stream gradient rapidly decreases.

anadromous fish: Fish that move from the sea to fresh water for reproduction.

bed fining: An increase in the amount of fine sediment (<2 mm) in the stream channel bed.

braiding: Branching of a stream into many channels.

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

delta: At a river's mouth, the sediment deposits found between the diverging channels.

estuary: Area of a river mouth where the fresh water of a river mixes with ocean water.

foot slope: Area located at the bottom of a hill slope.

gradient: Channel gradient is the slope of the channel bed along a line connecting the deepest points (thalweg) of the channel.

intertidal: The shore region between high and low tide.

large woody debris (LWD): Logs, stumps, or root wads in the stream channel, or nearby. These function to create pools and cover for fish, and to trap and sort stream gravels.

medial bar: Sediment deposit in a river that protrudes above the water surface and is not connected to shore.

morphologic response: In stream channels, the response or change in the characteristics that define the channel.

morphology: A branch of science dealing with the structure and form of objects. Geomorphology as applied to stream channels refers to the nature of landforms and topographic features.

mudflat: Intertidal zone whose substrate consists primarily of silt and clay and is usually unvegetated.

oxbow: A bow-shaped river bend.

point bar: A sediment deposit in a river that protrudes above the water surface and is located primarily on the inside of bends in the channel.

relic channel: A channel historically occupied by a river, but that currently does not convey flow.

riparian area: The area adjacent to the stream channel that interacts and is dependent on the stream for biologic integrity.

scour: Removal of sediment from the bed or banks of a river by the energy of moving water.

side-channel: A channel that is separated from the main channel, usually by an island.

single-thread channel: A stream channel that has no side channels, braiding, or islands.

slough: A side channel within an estuary.

stream reach: A section of stream possessing similar physical features such as gradient and confinement.

Component IV
Hydrology and Water Use

Table of Contents

Table of Contents (continued)

Component IV
Hydrology and Water Use

INTRODUCTION

The Watershed Fundamentals component of this manual presents an overview of the natural hydrologic cycle and potential impacts of human activities. Alterations to the natural hydrologic cycle potentially cause increased **peak flows**[1] and/or reduced **low flows** resulting in changes to water quality and aquatic ecosystems. The degree to which hydrologic processes are affected by land use depends on the location, extent, and type of land use activities. When potential impacts are recognized, **best management practices** (BMPs) can be followed to minimize some of the potential hydrologic impacts; mitigation will be necessary to address other impacts.

Evaluating potential impacts from land and water use on the **hydrology** of a watershed is the focus of this component. It is important to recognize that hydrologic processes are complicated; we have attempted to provide enough direction for you to identify how land uses may be affecting your watershed's hydrology. Figure 1 provides an overview of the steps you will be following to complete the Hydrology and Water Use Assessment component. This assessment does not attempt to address every hydrologic process potentially affected; the goal is to gain an understanding of the major potential impacts.

The assessment process is separated into two sections (Figure 1). Section I characterizes the hydrology of the watershed and assesses the locations and type of potential impacts. Section II evaluates the consumptive water uses and identifies locations and types of potential impacts associated with water use. Each section may be completed independently by different people who collaborate at the end to complete a map of potential hydrologic impacts and reaches of water use concerns. Appendix IV-A contains all the forms necessary to complete both sections of the assessment. Appendix IV-B includes reference tables to help complete the forms. Appendix IV-C provides information on resources to obtain necessary data. Finally, Appendix IV-D provides additional background information on how land uses can impact the hydrologic function of a watershed, and information on water rights law.

LINKAGES TO OTHER COMPONENTS

Information on peak-flow history in the watershed (Step 3) will be used in the Historical Conditions Assessment component. Withdrawal of water from a stream during the driest and hottest times of the year potentially stresses aquatic organisms. Information from the Fish and Fish Habitat Assessment component will be required to determine specific stream reaches that are sensitive to water use impacts. The Water Quality and Riparian/Wetlands assessments require an understanding of the hydrology and water use in the watershed.

During the Watershed Condition Evaluation component, subwatersheds where potential hydrologic impacts are identified will be evaluated for evidence of channel response (i.e., widening, loss of complexity, etc.) to changes in flow.

---

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

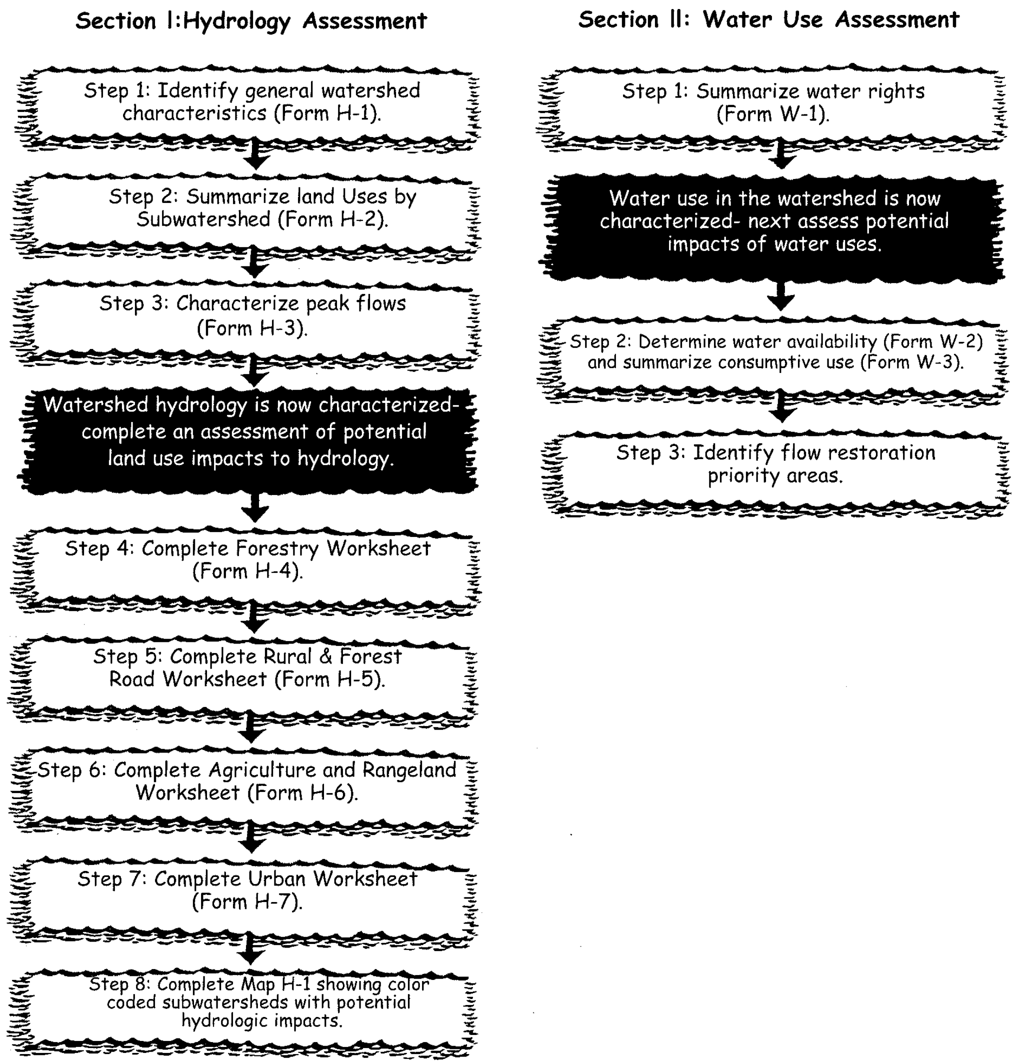


Figure 1. The screen for potential forestry impacts on hydrology focuses on timber harvest in this step and follows the pathways shown in this flow chart. Subwatersheds that end up in the shaded box at the bottom left have the potential for peak-flow impacts from forestry.

SECTION I: HYDROLOGY

Critical Questions

1. What land uses are present in your watershed?
2. What is the flood history in your watershed?
3. Is there a probability that land uses in the basin have a significant effect on peak flows?
4. Is there a probability that land uses in the basin have a significant effect on low flows?

Assumptions

- Urbanization (including industrial use), agriculture, range-land use, and forestry are the primary land uses that may impact hydrology.

- Peak flows and low flows are the hydrologic processes most significantly impacted by land use activities.

- Hydrologic soil condition is an indicator of **infiltration** rate.

- **Groundwater** impacts are implicitly addressed through the changes in infiltration rates.

- In forested basins, the greatest potential for peak-flow increases over background conditions are due to road rerouting of water and changes in snow accumulation and melt in harvested areas during **rain-on-snow events**.

- The decreased **evaporation** and **transpiration** from tree removal more than offset the reduced infiltration; therefore, low flows tend to increase in the short-term due to forest harvesting.

- BMPs to mitigate peak-flow impacts will also mitigate low-flow impacts from agricultural and urban land uses.

- Impervious surfaces and roads are good indicators of urbanization and subsequent impacts to the hydrology of a watershed.

Materials Needed

- Watershed Base Map (from Start-Up and Identification of Watershed Issues component)

- Refined Land Use Map with subwatersheds identified (from Start-Up and Identification of Watershed Issues component)

- **Ecoregion** map for the watershed (from Start-Up and Identification of Watershed Issues component)

- Aerial photographs and/or **orthophoto** quadrangle maps (most recent)

- Mean annual precipitation map, available from one of the sources listed in the box below

- Map of *2-year, 24-hour precipitation* (Miller et al. 1973). This map is available on line at the Desert Research Institute, Western Regional Climate Center (see list in the box below for Internet address), or can be ordered (for a cost of $9) from National Weather Service Office of Hydrology, W/OH2 Station 7144, 1325 East-West Highway, Silver Spring, MD 20910; (301) 713-1669.

Oregon Climate Service	Desert Research Institute	State Service Center for GIS
Strand Hall, Room 326 Oregon State University Corvallis, OR 97331-2209 (541) 737-5705	Western Regional Climate Center P.O. Box 60220 Reno, NV 89506-0220 (702) 677-3143	Dept. of Administrative Services 155 Cottage Street NE Salem, OR 97310 (503) 378-2166
Internet address: http://www.ocs.orst.edu/	*Internet address:* http://www.wrcc.dri.edu/	*Internet address:* http://www.sscgis.state.or.us/

STREAMFLOW DATA SOURCES	
USGS Portland District Office 10615 SE Cherry Blossom Drive Portland, OR 97216 (503) 251-3265 *Internet address:* http://wwworegon.wr.usgs.gov/	• Digital data available at Web site • US Geological Survey, Open-File Report 90-118, "Statistical Summaries of Streamflow Data in Oregon: Volume 1: Monthly and Annual Streamflow, and Flow-Duration Values" • US Geological Survey, Open-File Report 93-63, "Statistical Summaries of Streamflow Data in Oregon: Volume 2: Annual Low and High Flow, and Instantaneous Peak Flow" Prepared in cooperation with the Oregon Water Resources Department (OWRD, 1993).
Oregon Water Resources Department 158 12th Street NE Salem, OR 97310 (503) 378-8455 *Internet address:* http://www.wrd.state.or.us/	• Digital data available at Web site

- Daily average and peak streamflow data and map of streamflow collection sites. Available from the sources listed at the top of this page.

- Natural Resources Conservation Service (NRCS) county soil survey. Your local library or county extension agent will probably have copies. If not, order a copy from the State Conservationist, Federal Building Room 1640, 1220 SW 3rd Avenue, Portland, OR 97204-3221; (503) 414-3201s; Internet address http://www.statlab.iastate.edu/soils/nssc/

- Other relevant published reports and/or unpublished documents from city, county, state, or federal agencies or private consultants (local, regional, or statewide), such as Basin Plans written by the Oregon Water Resources Department (OWRD) and others.

Necessary Skills

Characterization of watershed hydrology requires mathematical, statistical, and technical tools. The analyst would benefit from a familiarity with computer spreadsheets and/or use of a calculator, as well as an understanding of simple statistics such as the mean (or average) and ratios. Internet access will provide the analyst with more readily available sources of data.

Final Products of the Hydrology Section

Form H-1: General Watershed Characteristics
Form H-2: Land Use Summary
Form H-3: Annual Peak Flow Summary
Form H-4: Forestry Worksheet
Form H-5: Agriculture and Range Land Worksheets
Form H-6: Forest and Rural Road Worksheet
Form H-7: Urban and Rural Residential Worksheet
Form H-8: Hydrologic Issue Identification Summary
Map H-1: Potential Risks of Land Use on Hydrology

Hydrologic Condition Characterization

Step 1: Identify General Watershed Characteristics (Form H-1)

For each subwatershed, fill in the information requested on Form H-1. This form is designed to help you compile watershed-specific information that relates to the local hydrology. You will identify basic watershed features such as drainage area, minimum and maximum **elevations**, and mean annual precipitation. If you have **Geographic Information System** (GIS) support, some of the information can be calculated using GIS. Otherwise, use the Watershed Base Map or US Geological Survey (USGS) topographic maps and a map of mean annual precipitation to find the information. Subwatershed drainage areas can be estimated by using GIS, a **planimeter,** or the grid method described in the Start-Up and Identification of Watershed Issues component.

Step 2: Summarize Land Uses in the Watershed (Form H-2)

Enter the estimated areas of each land use in each subwatershed onto Form H-2. Consult the Refined Land Use Map from the Start-Up component to identify the different land uses present in the watershed and subwatersheds. The areas in each land use can be either estimated using GIS, a planimeter, or the grid method.

Step 3: Characterize Peak Flows (Form H-3)

The purpose of this step is to identify the peak-flow-generating processes within your watershed and to graph the peak-flow history over time. Identification of the peak-flow-generating processes are needed to complete the hydrologic condition assessment (page 8), and will help you understand the type of conditions that generate peak flows in your watershed. Compiling and graphing information on flood history will provide context for understanding the extent of channel disturbance found in your watershed, help you to understand the cycles of flooding in the watershed, and confirm or dispel public perceptions about flood history.

Identifying Peak-Flow-Generating Processes

The Ecoregion Appendix provides information on peak-flow-generating processes by elevation zone within each ecoregion of Oregon. For watersheds located in western Oregon you can also check to see if any stream gage(s) in your watershed were analyzed in the hydrologic process identification study conducted by Greenberg and Welch (1998). Using the ecoregion map and the base map (showing subwatersheds), estimate the acres and percent area in each subwatershed that fall into one of the following peak-flow-generating processes categories: rain (including thunderstorms), rain-on-snow, **spring snowmelt**. Record this information on Form H-3.

Graphing Peak-Flow History

Identify the USGS streamflow gage(s) that are in or near your watershed (see streamflow data sources in the Materials Needed section and Appendix IV-C). Some watersheds in Oregon contain one or more stream gages while many unfortunately have none. If no gage is or was present in your watershed, find the closest gages in adjacent watersheds in the same ecoregion. Gages located in adjacent watersheds will not necessarily be representative of conditions in your watershed (see Criteria sidebar at the top of page 8). The USGS Web site is a good starting point to find stream gages in your area. (Gages are listed by county and river basin, and close-up maps can be viewed

CRITERIA* FOR GAGE SELECTION FOR RECORD EXTENSION OR UNGAGED BASINS

1) Basin areas within same order of magnitude
2) Similar mean basin elevation above gage
3) Similar precipitation
4) Similar geology and topography
5) No or insignificant out-of-stream diversions

* Robison 1991.

online that show gage location.) Records of peak flow can also be downloaded from the USGS Web site. The **annual peak flow** series (through 1995) have also been compiled for selected gages in western Oregon by Greenberg and Welch (1998) and may be adequate for this portion of the assessment.

To obtain representative data for a watershed, the gage records should be at least 10 years in length. It is not necessary that the **gaging station** be currently in operation. Historic records can be extremely useful data sources. Gage records should represent unregulated streamflow; a gage downstream of a reservoir will not record natural peak flows, but will reflect the modified streamflow.

On Form H-3, list in chronological order the **water year**[2], peak-flow amount, and date of peak flow for each of the annual peak-flow events. Use additional copies of Form H-3 if more than one gage is located in your watershed. Also on Form H-3, rank each peak flow with a number from highest to lowest (i.e., the largest peak flow is assigned the number 1). Alternatively, the **recurrence interval** associated with each peak flow can be given in place of the ranking. Recurrence intervals may be available for the gage records in your area (see streamflow data sources in the Materials Needed section), or you could calculate them, although a discussion of determining recurrence intervals is beyond the scope of this document. Graph the annual peak flow using a spreadsheet, or use the blank graph provided on Form H-3.

Hydrologic Condition Assessment

The hydrologic condition assessment is a "screening" process designed to identify land use activities that have the **potential** to impact the hydrology of your watershed. The techniques presented here are not definitive; more technical analyses are necessary to determine the magnitude of impacts. For instance, this manual uses a simple percentage of watershed in roads as an indicator of peak-flow increase potential but, in reality, the condition and location of roads is at least as or more important than the quantity of roads. Roads that are on ridge-tops or not hydrologically connected to stream channels, because they use adequate drainage, should not contribute as much to change the hydrology as a "well-connected road." The techniques listed in this document can be used to assess whether the potential problems may increase peak flows or reduce low flows. If, at the end of this assessment, the watershed council believes that land uses have a probability of impacting flows, they may choose to pursue more definitive assessment techniques.

We have developed a simple set of methods to prioritize those subwatersheds most likely to need restoration from a hydrologic perspective. Because hydrology is such a complex subject, the screening process only deals with the most significant hydrologic process affected by land use (i.e., **runoff**). Four separate worksheets were developed to evaluate land uses in the watershed:

[2] A water year is measured from October 1 of the previous year through September 30 of the current year. For example, water year 1960 started on October 1, 1959, and ended on September 30, 1960.

1. Forestry
2. Agriculture and range lands
3. Forest and rural roads
4. Urban and/or rural residential development

Figure 1 illustrates the steps to work through depending on the land uses in your basin. You need not fill out the worksheets for those land uses not present in your watershed. The potential risks from land uses on hydrology will be summarized on Form H-8. Form H-8 can be used, in conjunction with other assessments in this manual, to determine potential restoration opportunities. Special attention should be made to connecting the hydrologic information to the Channel Modification Assessment component. If potential peak-flow problems are identified in a subwatershed, the first step would be to cross-reference with the Channel Modification analyst to determine whether there is corroborating evidence of channel changes in the stream. Hydrologic impacts to aquatic resources are, to a large degree, a function of the **Channel Habitat Type** (CHT). Some CHTs can withstand large changes in flow without substantial change to the hydraulic characteristics, whereas others are very susceptible to peak-flow changes. If low-flow problems are identified, corroborating evidence of channel dewatering should be obtained.

Step 4: Complete Forestry Worksheet (Form H-4)

The screen for potential forestry impacts on hydrology focuses on timber harvest in this step and follows the pathways shown in the flow chart presented in Figure 2. Record your answers on Form H-4. Any subwatersheds that end up in the shaded box at the bottom left of the flow chart have the potential for peak-flow impacts from forestry. Timber harvest in the Rocky Mountains has been found to produce increased spring snowmelt peak flows (Troendle and King 1985); however, it is unknown if the underlying processes would be the same in the moister, more maritime conditions that are found in Oregon. If your watershed is in an area in which spring snowmelt produces the annual maximum flows, you may wish to consider some alternative analysis beyond the scope of this methodology.

Before starting the forestry worksheet, **first read through the tasks listed below**. This will help you be more efficient in answering all the questions found in the flow chart in Figure 2. Refer back to the flow chart to gain an overall perspective on where these steps are leading you. Use the information you collected on earlier forms (where available) to help you with the tasks. Also have Form H-8 handy.

Task 1: Identify the peak-flow-generating processes for each subwatershed. Using Form H-3, note the percent area in each subwatershed that is in the rain, rain-on-snow, and spring snowmelt categories. If more than 75% of any subwatershed is in the rain category mark Column 5 on Form H-4 as low potential risk of peak-flow enhancement (WFPB 1997). If all subwatersheds are more than 75% in the rain category, skip the remainder of this step and go on to Step 5. If more than 75% of any subwatershed is in the spring snowmelt category, mark Column 5 on Form H-4 as unknown potential risk of peak-flow enhancement. If all subwatersheds are more than 75% in the spring snowmelt category, skip the remainder of this step and go on to Step 5.

Timber Harvest Assessment Tasks

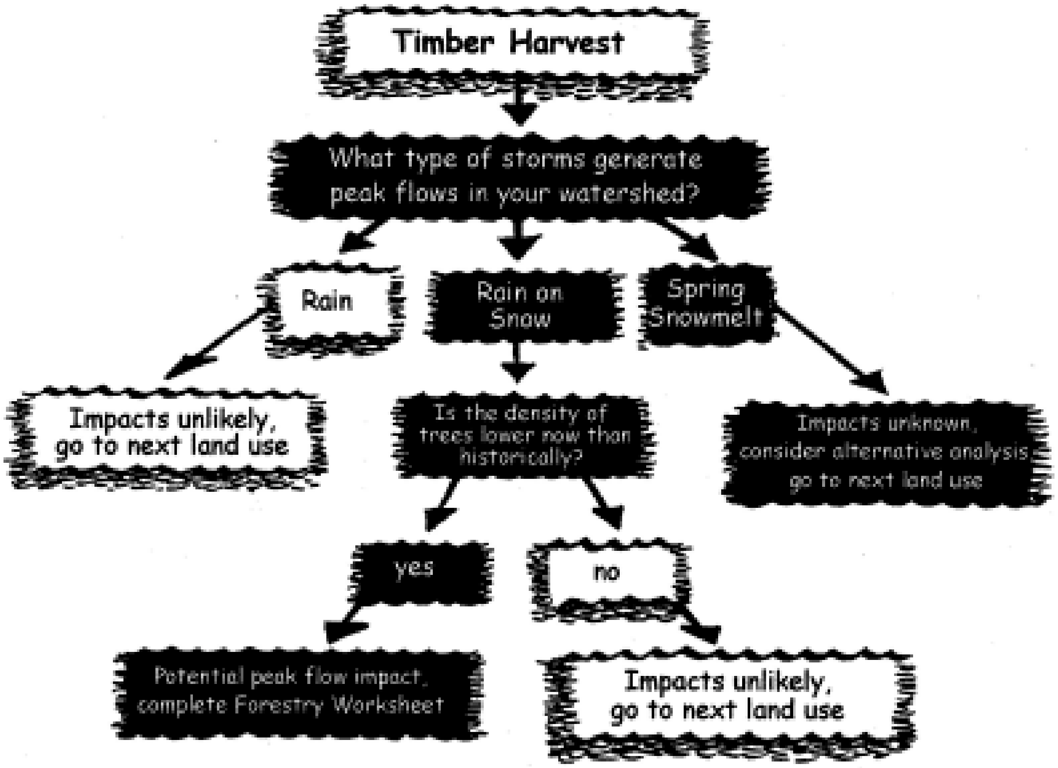


Figure 2. Overview of the steps you will be following to complete the Hydrology and Water Use Assessment component.

Task 2: For the subwatersheds that have not been eliminated in the previous task, estimate the **historic crown closure** for the portions of each subwatershed that are in the rain-on-snow areas, and record this information on Form H-4. (You may need to sketch the boundaries of the rain, rain-on-snow, and/or spring snowmelt areas on your base map. See the Ecoregion Appendix for guidance on how to define these areas). The Ecoregion Appendix includes historic crown closure estimates for each ecoregion in Oregon. Other possible sources to consult include US Forest Service (USFS) plant association documents or watershed analyses, or a local forester or fire ecologist (Oregon Department of Forestry [ODF] or private timber landowner) familiar with the lands in your watershed. If any subwatershed had less than 30% historic crown closure, mark Column 5 on Form H-4 as low potential risk of peak-flow increases. If all subwatersheds had less than 30% historic crown closure, skip the remainder of this step and go on to Step 5.

Task 3: For the subwatersheds that have not been eliminated in previous tasks, estimate the percent of the rain-on-snow areas that **currently** have less than 30% crown closure, and record this information on Form H-4. Use published information if possible, such as USFS watershed analyses or other watershed studies. If published information is not available, contact the forester (ODF and/or private timber companies) in charge of lands in the watershed of interest and request crown closure data; it is preferable that this information be derived from aerial photo coverage or ground inventory and not LANDSAT data. If crown closure coverage is not available from the landowners in the watershed, you will need to determine these areas by examining aerial photographs. If you are not familiar with viewing aerial photographs, consult with a technical specialist who can assist you with this step.

Task 4: Using the information you have entered on Form H-4, and Figure 3, estimate the risk of peak-flow enhancement for the remaining subwatersheds, and record this information on Form H-4. Also enter the results from Columns 4 and 5 onto Form H-8 Column 2.

The graph in Figure 3 is adapted from the Washington State Department of Natural Resources (1991) Interim Rain-on-Snow Rules. Although the graph was derived for Washington State, it was developed using rules of thumb applicable to the Pacific Northwest. For the purpose of screening forested areas of hydrologic concern in Oregon, the risk classes used in the Washington graph were aggregated from three classes to two classes: low risk and potential risk. The boundary between the two classes was set at a lower threshold of concern, based on personal communication with the original author of the Washington graphs (Brunengo, personal communication, 1998). The lines were also tested using the Washington State Forest Practices Board rain-on-snow model for a watershed in the Rogue Basin and a watershed on the western slope of the Cascades in northern Oregon. The line appears to roughly represent peak-flow increases of 8 to 10%, which represents the lower boundary of detectability; the accuracy of good streamflow measurements are within 10% of the true value (USGS 1997) (WFPB 1997).

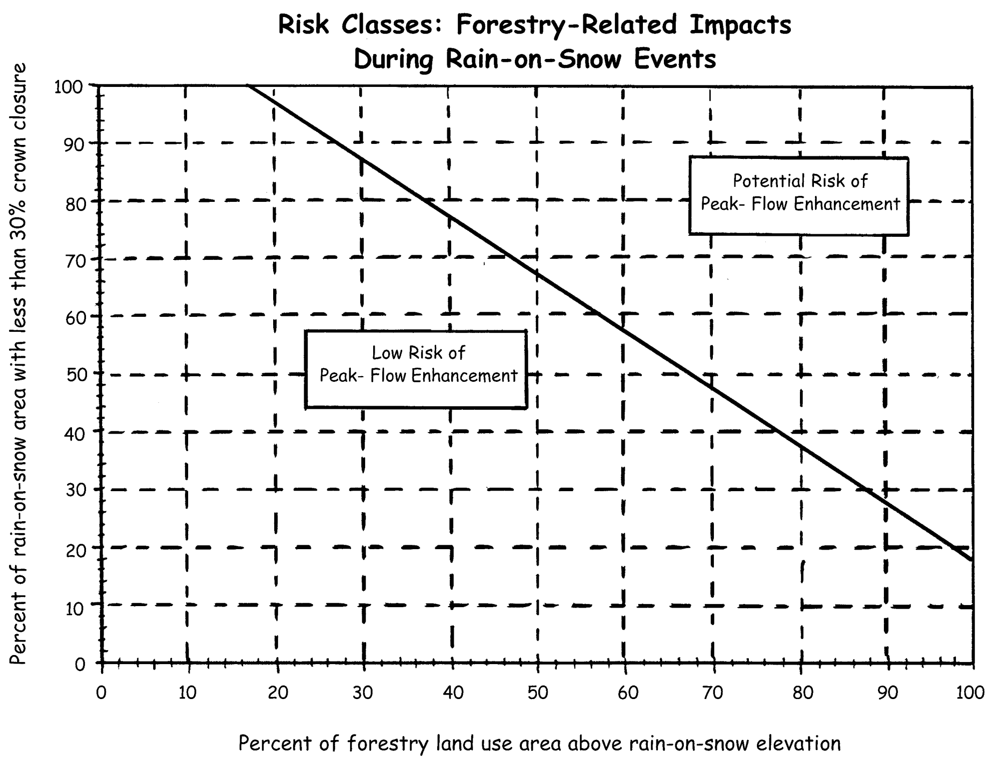


Figure 3. This graph is used to help you estimate the risk of peak-flow enhancement to subwatersheds from forestry-related impacts during rain-on-snow events.

Step 5: Complete Agriculture and Range-Land Worksheet (Form H-5)

The agricultural and range-land screening procedure (Figure 4) is designed to first identify **hydrologic soil groups** (HSG), cover types, and treatments occurring on agricultural lands and range lands in your watershed. Secondly, using tables from the US Department of Agriculture Natural Resources Conservation Service (NRCS) (formerly Soil Conservation Service) methods (USDA 1986), **runoff curve numbers** are assigned to each combination of three parameters: soil group, cover type, and treatment. The hydrologic response will be bracketed using both good hydrologic condition and poor hydrologic condition curve numbers. Comparisons between these runoff values and “background conditions” will serve as the basis for highlighting watersheds that may require further analysis of agricultural impacts.

Three reference tables providing runoff curve numbers are located in Appendix IV-B (Tables B-1 through B-3). The first two tables are for use in humid regions and the third table is for use in arid and semiarid range lands. There is one reference table (B-4) providing runoff depths for the combination of a curve number and a rainfall amount.

For more background information of agricultural and range-land impacts, please refer to Appendix IV-D. Before starting the worksheet, **first read through the tasks listed below**. Also have Form H-8 handy.

Task 1: Using the NRCS soil survey for your county, identify the hydrologic soil groups that are currently being farmed or grazed in your watershed and enter in Column 3 on Table 1 (Form H-5). Fill in Columns 1 and 2 on Table 1 (Form H-5) from Form H-2.

Task 2: Select the subwatershed with the highest percent in agricultural use or utilization of range lands. Complete Task 3 through Task 15 for each hydrologic soil group in this subwatershed.

Task 3: Identify the cover types and treatment practices for the primary hydrologic soil group occurring in the subwatershed selected in Task 2. Use soil survey maps and aerial photos, orthophotos, and anecdotal information from discussions with NRCS or Conservation District personnel (See Tables B-1 through B-3 in Appendix IV-B) to complete this task. Enter the results in Column 1 of Table 2 (Form H-5). (Use a separate Table 2 for each hydrologic soil group in each subwatershed.)

Task 4: The NRCS has defined hydrologic condition classes of good, fair, and poor. Determine the hydrologic condition of each cover type and treatment practice by referring to the footnotes in Tables B-1 through B-3. If conditions are unknown, the hydrologic response can be bracketed by using good and poor categories. Enter the results in Column 2 of Table 2 on Form H-5.

Task 5: Select a curve number using Tables B-1 through B-3 (Appendix IV-B) for the combination of information in Columns 1 and 2 of Table 2 of Form H-5. Enter the selected curve number in Column 3 of Table 2 of Form H-5.

Task 6: Background curve numbers can be determined from Tables B-1 and B-2 for humid regions and Table B-3 for arid/semiarid regions. The background curve number for humid regions may, in many cases, have been "woods" in "good" condition (see shaded row in Table B-2). If this is the case for your subwatershed, select the curve number for the proper hydrologic soil group. If the land was not historically wooded, select the appropriate cover type and associated curve number for the proper hydrologic soil group. Enter the results in Column 4 of Table 2 on Form H-5.

Agriculture/Range-Land Assessment Tasks

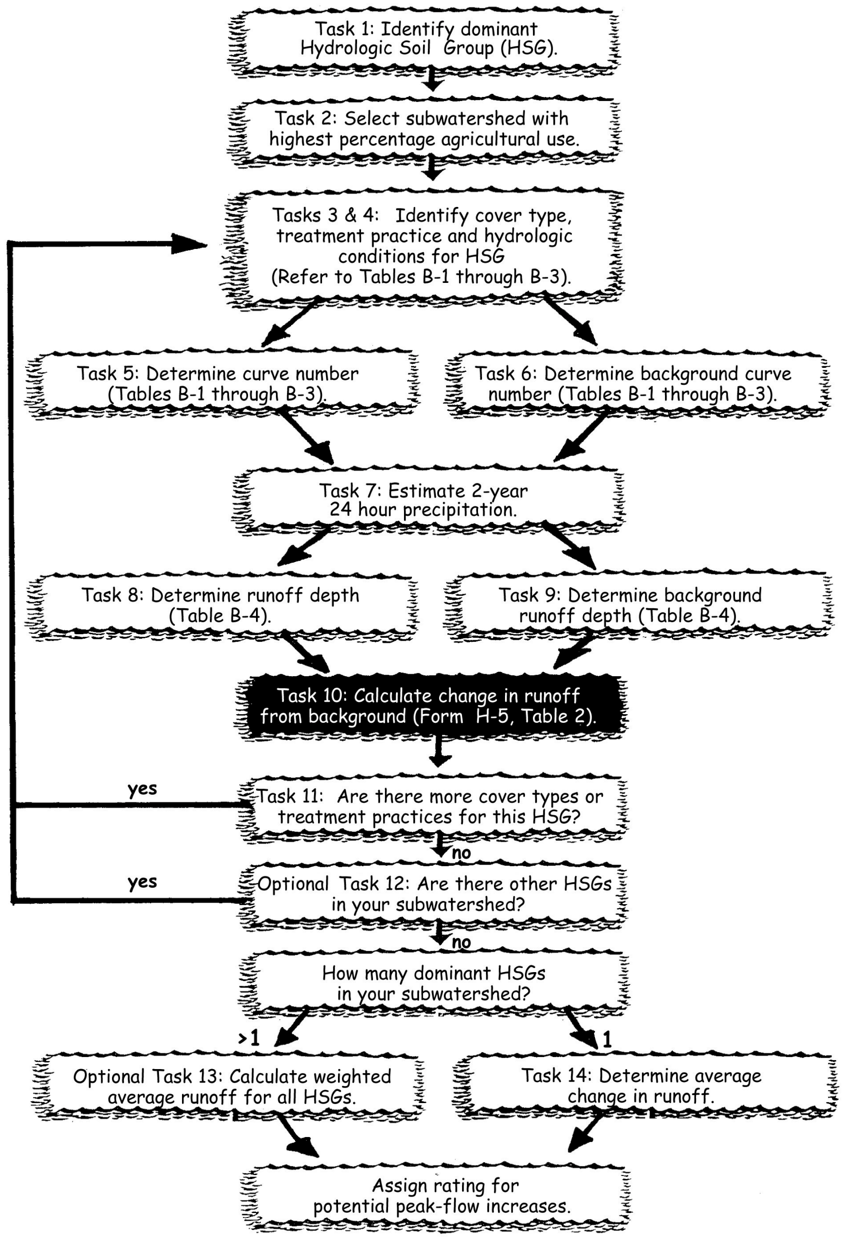


Figure 4. The agricultural and range-land screening procedure, which you will perform following these steps, helps you identify watersheds that may require further analysis of agricultural impacts.

Task 7: Estimate the 2-year, 24-hour precipitation (i.e., annual maximum 24-hour precipitation with a recurrence interval of 2 years or 50% probability of occurring in any given year) for each subwatershed. This information can be obtained from the map in Miller et al. (1973). See the Materials Needed section for information on how to obtain this map. Enter the results in Column 5 of Table 2 on Form H-5.

Task 8: Using the current curve number in Column 3 and rainfall depth in Column 5, read the runoff depth from Table B-4 for each cover type/treatment combination. Interpolate the values shown to obtain runoff depths for curve numbers or rainfall amounts not shown. Enter the results in Column 6 of Table 2 on Form H-5.

Task 9: Using the background curve number in Column 4 and rainfall depth in Column 5, read the runoff depth from Table B-4. Enter the results in Column 7 of Table 2 on Form H-5.

Task 10: Calculate the change in runoff depth from background conditions to current conditions using the following formula:

Column 8 = Column 6 – Column 7

Task 11: Calculate the average change from background for all the combinations of cover type/treatment and hydrologic condition. Add up Column 8 and divide by the number of rows. Enter the result in Column 3 of Table 3 on Form H-5. For that same row, transfer the percentage from Table 1 Column 3 A, B, C, or D to Column 2 of Table 3. If only one dominant hydrologic soil group is present in your subwatershed, go to Task 15 and disregard Columns 4, 5, and 6 on Table 3.

Task 12 (optional): If more than one hydrologic soil group is dominant in your subwatershed, repeat Tasks 3 through 11 and enter the result in Column 5 of Table 3. For that same row, transfer the percentage from Column 3 A, B, C, or D to Column 4 of Table 3.

Task 13 (optional): Compute the weighted average and enter the result in Column 6 of Table 3. For instance, if approximately 45% of agriculture occurs on hydrologic soil group A and 55% occurs on C, then the resultant averages will need to be weighted as follows:

Weighted average = (0.45 x average change from background on HSG A soils) +
(0.55 x average change from background on HSG C soils)

Task 14: Using the subwatershed average change from background (Table 3, Column 3) or the weighted average (Table 3, Column 6), select the potential hydrologic risk from the table to the right and enter it into Column 7 of Table 3 on Form H-5.

Task 15: Enter the results in Columns 6 and 7 of Table 3 onto Form H-8 Columns 3 and/or 4. If the results for this subwatershed indicate a low potential for peak-flow enhancement and the distribution of HSGs is similar in the other subwatersheds, assume low potential in those subwatersheds. If the other subwatersheds show substantial differences in the distribution of HSGs then complete these steps for the next subwatershed with significant agriculture land use.

Potential Risk of Agriculture and/or Range Lands[1]

Change in Runoff From Background (inches)	Relative Potential for Peak-Flow Enhancement
Westside watersheds	
0 to 0.5	Low
0.5 to1.5	Moderate
>1.5	High
Eastside watersheds	
0 to 0.25	Low
0.25 to 0.75	Moderate
>0.75	High

1 Personal Communication (NRCS 1999)

Step 6: Complete Forest and Rural Road Worksheet (Form H-6)

The assessment of forest and rural roads relies on research from several small basins (39 to 750 acres) in the Oregon Coastal Range that documented significant increases (~20%) in peak flows (of smaller floods) after road building when roads occupied greater than 12% of the watershed (Harr et al. 1975). This study also found that in watersheds where roads occupied <5% of the basin, peak-flow changes due to roads were small, inconsistent, and statistically nonsignificant. Recent research from the University of Washington (Bowling and Lettenmaier 1997) documented that road networks in two western Washington watersheds significantly increased the channel network density and tended to show a corresponding increase in peak flows. This study revealed that roads can begin to impact streamflow (~ increase peak of 11%) at lower percent roaded area (estimated 3 to 4% of basin) than the 12% value found in Harr et al. (1975). Based on the range of roaded areas (4% and 12%) and associated peak-flow increases (11% and 20%) documented in these two studies, three categories have been established for the purpose of screening for road impacts to basin hydrology. This assessment assigned a threshold of concern (**high** potential for peak-flow enhancement) of 8% roaded area in order to screen for potential hydrologic impacts prior to a peak-flow increase of 20%. In other words, when the percent roaded area in a subwatershed exceeds 8%, road issues **may** cause hydrologic impacts and further investigation is warranted. A **moderate** category of potential hydrologic impact was established when roaded area occupies from 4 to 8% of a subwatershed, and a **low** potential was assigned to watersheds with roaded areas less than 4% of the total area of the subwatershed.

The focus of the road assessment is to determine the quantity of roads within the watershed but does not account for the condition of the roads. A more refined scale to separate out well-built roads that do not accelerate the delivery of water or sediment to the channel from roads that are poorly constructed is beyond the scope of this section. For example, extension of the surface-water drainage network by roadside ditches is often a major influence of increased flows. Roads with proper culvert placement and frequency may alleviate some of these impacts.

This worksheet is designed to guide you in determining what area of the forestry-designated portion of each subwatershed is occupied by roads, as well as by rural roads in agricultural or range-land areas, and to rate subwatersheds for potential hydrologic impacts. Before starting the worksheet, **first read through the tasks listed below and review Figure 5, which outlines the process**. Also have Form H-8 handy.

Task 1: Using the information from Form H-2, fill in Columns 1 through 3 of Tables 1 and 2 on Form H-6.

Task 2: From the Sediment Sources Assessment component, enter the total linear distance of forest roads in Column 4 of Table 1, Form H-6, and the linear distance of rural roads in Column 4, Table 2 of Form H-6.

Task 3: Determine the area of each subwatershed occupied by roads by multiplying Column 4 by the width of the road (in miles) on Tables 1 and 2. The average width can be determined by measurement of several sites in the field, or determine the width from recent aerial photographs or use a default width of 25 feet (0.0047 miles) for forest roads and 35 feet (0.0066 miles) for rural roads.

Task 4: Compute the percent of the subwatershed in roads by dividing the roaded area value in Column 5 by the forested or rural area in Column 3 and then multiply by 100 for both Tables 1 and 2. Enter the result in Column 6 of Tables 1 and 2, respectively, which represents the percent of the subwatershed occupied by roads.

Task 5: Assign a relative potential for forest and rural road impacts to each subwatershed using the table at lower right. Enter the risk into Column 7 of Tables 1 and 2, Form H-6. Watersheds with a high risk warrant further investigation of road issues.

Task 6: Enter the results in Columns 6 and 7 of Tables 1 and 2 onto Form H-8, Column 5 (Forest Roads) and Column 6 (Rural Roads).

Step 7: Complete Urban and Rural Residential Worksheet (Form H-7)

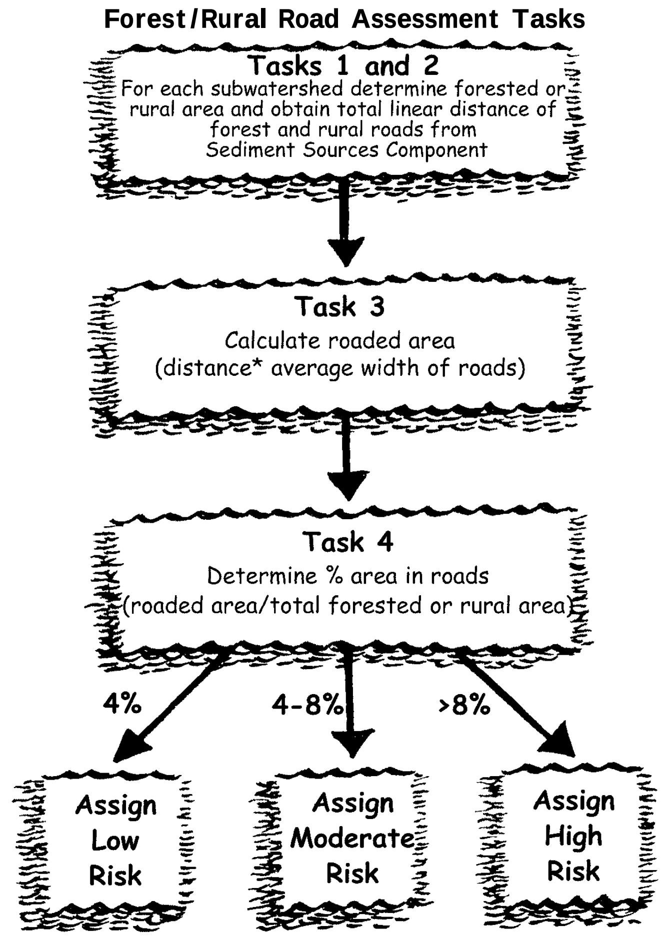


Figure 5. This procedure is designed to guide you in determining what area of the forestry-designated portion of each subwatershed is occupied by roads, as well as by rural roads in agricultural or range-land areas, and to rate subwatersheds for potential hydrologic impacts.

The urban assessment relies on the results from several studies in which the percent of **imperviousness** in a watershed was related to stream quality. Research has identified that the altered hydrologic regime of a watershed under urban conditions is the leading cause of physical habitat changes (May et al. 1997). Schueler (1994) reviewed key findings from 18 urban stream studies relating urbanization to stream quality and concluded that stream degradation occurs at relatively low levels of imperviousness, around 10% Total Impervious Areas (TIA). May et al. (1997) recommends that for Puget Sound lowland streams in Washington, imperviousness must be limited (<5 to 10% TIA) to maintain stream quality, unless extensive riparian buffers are in place.

Potential Risk for Peak-Flow Enhancement

Percent of Forested Area in Roads	Potential Risk For Peak-Flow Enhancement
Less than 4%	Low
4% to 8%	Moderate
Greater than 8%	High

Estimating the area in each subwatershed that is impervious will be the basis for determining potential hydrologic impacts from urbanization. For the purpose of screening these urban impacts, this assessment assigns a high potential for impact to a subwatershed exceeding 10% TIA; when the percent impervious area in a subwatershed exceeds 10%, further investigation is warranted. A moderate potential for impact is assigned to subwatersheds with impervious percentages between 5 and 10%.

Imperviousness is the most common measure of watershed development; however, it can be a time-consuming exercise and costly to calculate percent TIA. If difficulties arise in estimating imperviousness, the extent of development can be expressed in terms of road density. May et al. (1997) established a relationship between watershed urbanization (in % TIA) and sub-basin road density (in mi/mi^2) which can be used to represent the percent imperviousness. Choose either Method 1: Impervious Area Calculation, or Method 2: Urban Road Density Calculation, and proceed to the appropriate table below. **First read through the tasks listed below and review Figure 6, which outlines the process**. Also have Form H-8 handy.

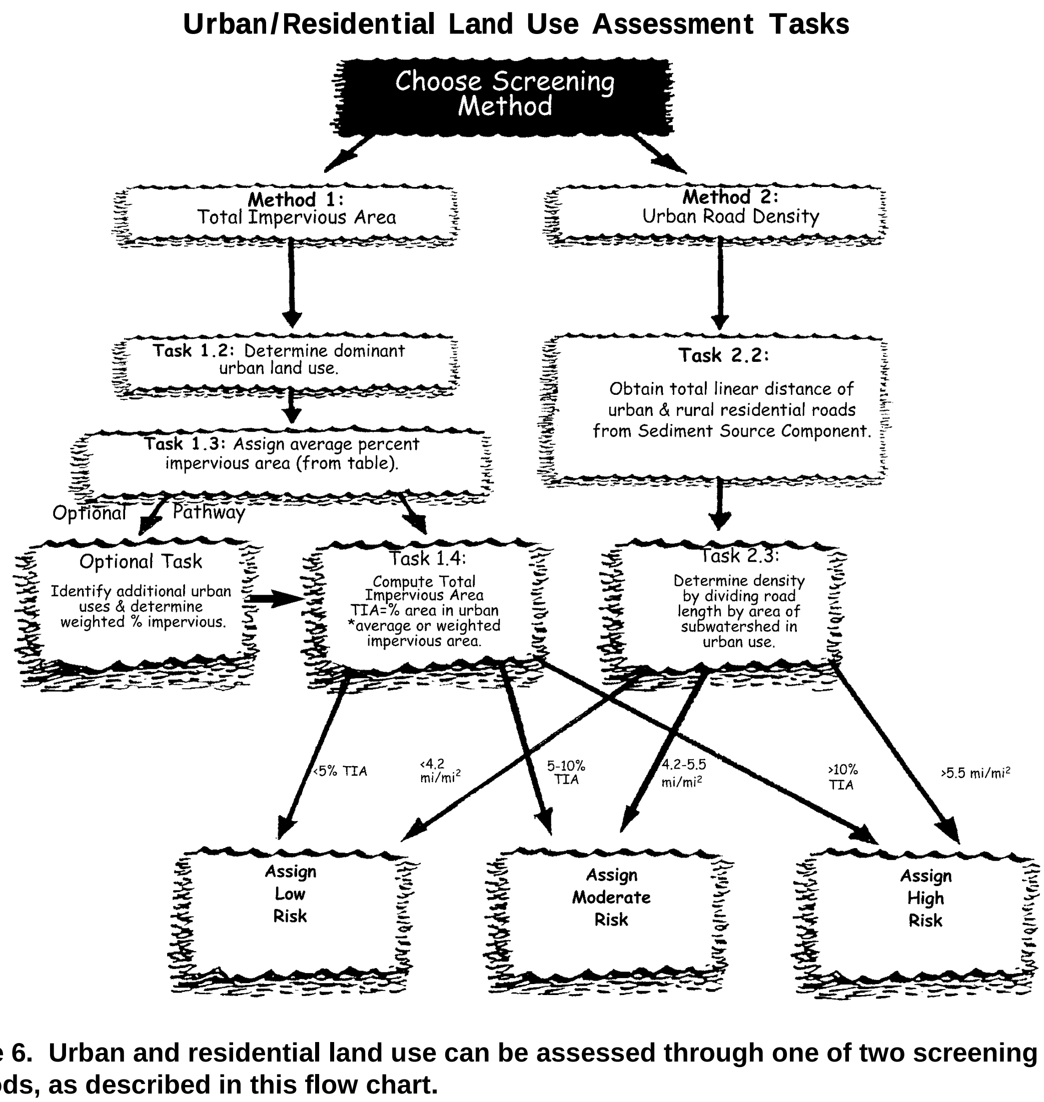


Figure 6. Urban and residential land use can be assessed through one of two screening methods, as described in this flow chart.

Method 1. Impervious Area Calculation

Task 1.1: Using information from Form H-2, fill in Columns 1 and 2 of Table 1, Form H-7.

Task 1.2: Determine the dominant type of urban land use from inspecting aerial photos. Select the type of land use from the table at the right and record in Table 1, Column 3.

Task 1.3: Select the average impervious surface associated with the type of urban land development from the table to the right. Record this information in Column 4 of Table 1, Form H-7.

Optional assessment: Select more than one land type and compute a weighted average of impervious surface by the following equation:

Average Impervious Surfaces, Urban and Residential Development

Type of Land Development	Average Impervious Area* (%)
Urban Districts:	
Commercial and Business	85
Industrial	72
Residential Districts by Average Lot Size:	
1/8 acre or less (town houses)	65
1/4 acre	38
1/3 acre	30
1/2 acre	25
1 acre	20
2 acre	12

* From USDA TR55 1986.

Weighted % Impervious = (% area in land type 1) x (avg. impervious surface) + (% area in land type 2) x (avg. impervious surface)

Task 1.4: Compute the total percent of the basin that is in impervious surfaces by multiplying the percent of the subwatershed designated urban land use (Column 2) by the percent of impervious surfaces in the subwatershed (Column 4). Record this information in Column 5 of Table 1, Form H-7.

Task 1.5: Assign a relative potential for hydrologic impacts using the table to the right. Record this information in Column 6 of Table 1, Form H-7.

Task 1.6: Enter the results of Columns 5 and 6 onto Form H-8, Column 7. Circle the words "Urban Impervious" in the column header to indicate which method you used.

Potential Risk of Peak-Flow Enhancement (Impervious Surface)

Percent of Impervious Surface	Potential for Peak-Flow Enhancement
Less than 5%	Low
5% to 10%	Moderate
Greater than 10%	High

At this point, linkage to the Channel Modification Assessment component should be made to reveal if any field evidence of channel changes has been noted. Channel modifications have been categorized and recorded, and associated degree of impact noted. Channel changes in the urban areas can include any one or more of the following: disconnecting channel from its floodplain, channelizing (straightening channels), and restricting lateral movement by diking or bank armoring, etc.

Method 2. Urban Road Density

May et al. (1997) established a relationship between watershed urbanization (in % TIA) and sub-basin road density (in mi/mi^2) which can be used to represent the percent imperviousness. The regression equation developed by May et. al. (1997) was used to determine the road density that would be expected to correspond to 5% TIA and 10% TIA; the thresholds used in Method 1. In urban areas, when road densities equal or exceed 5.5 mi/mi^2, percent TIA probably exceeds 10% TIA (May et al. 1997). Road densities of 4.2 mi/mi^2 were associated with a percent TIA in the subwatershed of approximately 5%.

Task 2.1: Using information from Form H-2, fill in Columns 1, 2, and 3, Table 2 (Form H-7).

Task 2.2: From the Sediment Sources component, enter the road length in urban and/or rural residential areas in Column 4 of Table 2, Form H-7.

Task 2.3: Divide the road length in Column 4 by the urban area in Column 3. Enter the resulting road density into Column 5.

Task 2.4: Assign a relative potential for peak-flow enhancement to each subwatershed. Watersheds with a road density of greater than 5.5 mi/mi^2 (associated with 10% TIA) should be assigned a high probability of peak-flow enhancement and further investigation of urban issues is warranted. Subwatersheds in which road densities are in the range of 4.2 to 5.5 mi/mi^2 would be expected to have between 5% to 10% TIA and therefore should be assigned a moderate risk as in Method 1. Enter results in Column 6.

Potential Risk of Peak-Flow Enhancement (Road Density)

Road Density (mi/mi^2)	Potential Risk for Peak Flow Enhancement
Less than 4.2	Low
4.2 to 5.5	Moderate
Greater Than 5.5	High

Task 2.5: Enter the results in Columns 5 and 6 onto Form H-8, Column 7, and circle the words "Urban Roads" in the column header to indicate which method you used.

Step 8: Summarize Potential Risk of Land Use on Hydrology (Form H-8)

Steps 4 through 7 have required you to work through a series of tasks and fill out a series of corresponding tables. The last task in each step is to insert the results into the appropriate column on Form H-8. This table now provides an overview of potential peak-flow enhancement from land use activities. Using a new copy of the Base Map, or a Mylar overlay, color-code each subwatershed by the potential risks determined above. Label this Map H-1: Potential Risks of Land Use on Hydrology.

SECTION II: WATER USE

Water use is generally defined by beneficial use categories such as municipal, industrial, irrigated agriculture, etc. Background on these different types of water uses and their associated impacts on a stream system can be found in Appendix IV-D. In this section you will summarize the water rights in your basin and gain an understanding of what beneficial uses these water withdrawals are serving. The assessment of water use is primarily focused on low-flow issues. While low-flow issues can be extremely important, they are difficult to characterize at the screening level. Water use activities can impact low flows, yet the low flows can be enhanced through adopting water conservation measures to keep more water in the stream system.

Critical Questions

- For what beneficial use is water primarily used in your watershed?
- Is water derived from a groundwater or surface-water source?
- What type of storage has been constructed in the basin?
- Are there any withdrawals of water for use in another basin (interbasin transfers)? Is any water being imported for use in the basin?
- Are there any illegal uses of water occurring in the basin?
- Do water uses in the basin have an effect on peak flows?
- Do water uses in the basin have an effect on low flows?

Assumptions

- Water use most significantly impacts low flows, with the exception of storage, which can reduce peak flows downstream of the structure.

Materials Needed

- Tabulation of water rights information from the Oregon Water Resources Department (OWRD; see contact information in the Water Rights Information sidebar)

- Map of surface and groundwater right locations, amounts, and priorities (from the OWRD)

Final Products of the Water Use Section

- Form WU-1: Water Rights Summary
- Form WU-2: Water Availability Summary
- Form WU-3: Consumptive Use Summary
- Map WU-1: Water Rights and In-Stream Flow Rights

WATER RIGHTS INFORMATION

Oregon Water Resources Department (OWRD)
158 12th Street NE
Salem, OR 97310
(503) 378-8455 phone
(503) 378-2496 fax

Internet address:
http://www.wrd.state.or.us

For assistance with access to the Water Rights Information System (WRIS) or the Water Availability Reports System (WARS), contact:

Manager of Information Systems
Oregon Water Resources Department
158 12th Street, NE
Salem, OR 97310
(800) 624-3100
(503) 378-8455 phone
(503) 378-2496 fax

Water Use Characterization

Step 1. Summarize Surface- and Groundwater Rights (Form WU-1 and Map WU-1)

The best way to characterize water use in your watershed is to tabulate both the surface-water and groundwater rights that are on file with OWRD. This can be accomplished by either (1) contacting your local Watermaster, or (2) using the OWRD Web page (see Water Rights Information sidebar) to download the data.

Tabulate water rights on Form WU-1 (or use printout from OWRD), and obtain a map showing the points of diversion of the water rights from OWRD. Also, identify where in-stream flow rights exist. Label this Map WU-1.

Water Use Assessment

Potential channel dewatering (zero flow in the channel) can present problems for spawning and fish passage. Typically, the spawning period that coincides with the lowest flow begins on approximately September 1 and extends through October. Rearing habitat in the summer also requires flow levels to be maintained. While these are the critical times of year, flow levels throughout the year need to be maintained to cover all life stages of all species present in a watershed.

The basis for the water use assessment will be the output from the Water Availability Reports System (WARS) and other data provided by the OWRD. Their system has accounted for **consumptive use** and presents the best available information at this time. You will assess the data and gain an understanding of the location and magnitude of low-flow problems in the watershed.

Step 2. Determine Water Availability (Form WU-2)

Task 1: Obtain the water availability reports at the 50% exceedance level for each month for each water availability basin (WAB) in your watershed. These will correspond to the 5th and/or 6th field **Hydrologic Unit Codes** (HUCs). However, not all subwatersheds will be a designated WAB, so use the WABs rather than the subwatersheds in this task.

The water availability reports can be obtained directly from the OWRD via your local Watermaster or can be retrieved from the OWRD Web site on the Internet (http://www.wrd.state.or.us). Select Water Availability Reports System (WARS) and when a login ID is requested, type “wars.” Follow the menu to acquire the information desired. Select the 50% exceedance streamflow from this database/model for review of water availability at this level.

Task 2: Identify on your map the WABs for which water availability has been calculated. Determine which subwatersheds coincide with or are situated within the WABs.

Task 3: Column 8 of the WARS report lists the net available flow. Enter the net water available for each month onto Form WU-2 for each WAB and highlight the WABs that do not have water available. If the “net water available” column is negative or zero, water is not available at this exceedance level. The streamflow in these WABs is insufficient to meet the demand for all in-stream and out-of-stream uses; conservation measures may help mitigate low-flow problems.

Task 4: Compute the percentage of consumptive use (CU) for each monthly natural streamflow and enter the result onto Form WU-3. From the Water Availability Reports System, Columns 3 and 5, report consumptive use before and after 1993. Column 2 of WARS reports the natural streamflow. Use the following formula to compute %CU:

$$\%CU = \frac{(\text{Column 3} + \text{Column 5})}{\text{Column 2}} \times 100$$

Task 5: Highlight the CU values on Form WU-3 that are greater than 10%.

Step 3. Flow-Restoration Priority Areas

If your watershed is not located in one of the following five regions: North Coast, Mid Coast, South Coast, Umpqua, or Rogue, call OWRD to determine if the flow restoration prioritization has been completed.

Task 1: Determine if any of the subwatersheds are within priority WABs for flow restoration. The information can be found through ODFW's Web page. Look for the box entitled "Streamflow Restoration Priorities." Find the location of your watershed: North Coast, South Coast, Mid Coast, Umpqua or Rogue.

Task 2: Highlight the WABs on Form WU-3 that are designated flow-restoration priority basins.

Task 3: Of the WABs that are designated as flow-restoration priorities, the ones with the highest consumptive use (>10%) present the greatest opportunity for flow restoration through conservation measures, increased efficiency of use, and/or best management practices. Based on this information, rank the WABs from greatest to least flow-restoration potential.

CONFIDENCE IN ASSESSMENTS

The confidence in the work performed up to this point will be largely a function of the data limitations and/or your confidence in the methods used. For example, were difficulties encountered when estimating the acreage within each land use or clearcut? Was the type of urban land use and associated percent imperviousness difficult to determine?

You must assess the data limitations associated with the work performed up to this point (complete form HW-1). The most obvious data limitation will arise if a stream gage is not located in the basin. Using streamflow records from a nearby similar gage, while appropriate in the absence of basin-specific data, does incorporate error.

The assessment approach was designed to be conservative in that a referral for further analysis would ideally be triggered before the existence of significant hydrologic impacts. Hydrologic processes are complex, and the interaction of several variables makes assigning screening thresholds difficult. You can gain more confidence that your assessment has identified the problematic subwatersheds if you sought technical assistance as questions arose, and if you obtained corroborative evidence from other components of this process.

FURTHER ANALYSES

If the qualitative assessment identified that a specific land use or uses are potentially problematic in some subwatersheds, further study is warranted. All of the compilation of data you have done up to this point will provide the basic building blocks for any additional analyses. Although it is fairly straightforward to identify the potential existence of a problem, attempting to quantitatively assess the magnitude of the problem or the change in streamflow is complex. Technical users of this manual understand the myriad of hydrologic techniques available for use. The following list attempts to identify a few techniques appropriate for analyzing the issues at hand; it by no means constitutes a definitive list, because many options exist.

- **Washington State Forest Practices Board Watershed Analysis Methods**
  Washington Forest Practices Board Manual: Standard Methodology for Conducting Watershed Analysis Under Chapter 222-22 WAC, Version 4.0, November 1997.
- **Antecedent Precipitation Index (API) Model**
  Fedora, M.A. 1987. Simulation of Storm Runoff in the Oregon Coast Range. BLM Technical Note 378, US Department of the Interior, Bureau of Land Management.
- **Continuous models (Hydrologic Simulation Program in Fortran [HSPF], Distributed Hydrologic Soil and Vegetation Model [DHSVM], etc.)**
  Bicknell, B.R., J.C. Imhoff, J.L. Kittle, A.S. Donigian Jr., and R.C. Johanson. 1993. Hydrological Simulation Program FORTRAN (HSPF): User's Manual for Release 10. EPA-600/R-93/174. US Environmental Protection Agency, Athens, GA.
  DHSVM – Dennis Littenmeier, University of Washington
- **Water Resources Evaluation of Nonpoint Silvicultural Sources Model**
  US Department of Agriculture, Forest Service. 1980. An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources (A Procedural Handbook). Published by EPA: EPA-600/8/80-012, August 1980.
- **Kendall Trend Analysis**
  Maidment, D.R. 1993. Handbook of Hydrology. McGraw-Hill, New York.
- **Double Mass Analysis**
  Linsley, R.K. Jr., M.A. Kohler, and J.L.H. Paulhus. 1975. Hydrology for Engineers. McGraw-Hill, Inc.
- **Gage Correlation Analysis**
  Robison, E.G. 1991. Methods for Determining Streamflows and Water Availability in Oregon. Hydrology Report #2, Oregon Water Resources Department, October 1991.
- **TR55 Methods (USDA 1986)**
  United States Department of Agriculture, Natural Resources Conservation Service. 1986. Urban Hydrology for Small Watersheds. Technical Release-55, June 1986.
- **Santa Barbara Unit Hydrograph Methods**
- Oregon Departments of Environmental Quality and Land Conservation and Development. Nonpoint Source Pollution Control Guidebook for Local Government. 1994. Available from ODEQ: (503) 229-6893.

REFERENCES

Agee, J.K. 1994. Fire and Weather Disturbances in Terrestrial Ecosystems of the Eastern Cascades. US Department of Agriculture Forest Service, Pacific Northwest Research Station, General Technical Report PNW-GTR-320, Portland, Oregon.

Belt, G.H. 1995. Recovery of Enhanced Rain-On-Snow Melt Caused By Harvesting: A Review of Scientific Literature. Professor of Forest Resources, College of Forestry, Wildlife, and Range Sciences, University of Idaho.

Black, P.E. 1991. Watershed Hydrology. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Bowling, L.C., and D.P. Lettenmaier. 1997. Evaluation of the Effects of Forest Roads on Streamflow in Hard and Ware Creeks, Washington. TFW-SH20-97-001, Water Resources Series Technical Report No. 155, University of Washington, Seattle.

Branson, F.A., G.F. Gifford, K.G. Renard, and R.F. Hadley. 1981. Rangeland Hydrology. Range Science Series No. 1, October 1972, Second Edition 1981. Society for Range Management, Denver Colorado. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Coastal Salmon Restoration Initiative. 1997. The Oregon Plan, Restoring an Oregon legacy through cooperative efforts. Submitted to National Marine Fisheries Services. 160 State Capitol, Salem, Oregon. March 1997.

Chow, V.T., D.R. Maidment, and L.W. Mays. 1988. Applied Hydrology. McGraw-Hill Inc., New York.

Coffin, B.A. and R.D. Harr, 1992. Effects of forest cover on volume of water delivery to soil during rain-on-snow. Timber/Fish/Wildlife Report No. SH1-92-001. Washington Department of Natural Resources. 118 pp.

Dunne, T., and L.B. Leopold. 1978. Water in Environmental Planning. W.H. Freeman and Co., New York.

Gifford, G.F., and R.H. Hawkins. 1979. Deterministic Hydrologic Modeling of Grazing System Impacts on Infiltration Rates. Water Resources Bulletin 15(4):924-934.

Gilmor Cooper, C. 1996. Hydrology Effects of Urbanization on Puget Sound Lowland Streams. A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Civil Engineering, University of Washington, Seattle.

Greenberg, J. and K.F. Welch. 1998. Hydrologic Process Identification for Western Oregon. Prepared for Boise Cascade Corp., Boise, Idaho.

Harr, D.R., W.C. Harper, J.T. Krygier, and F.S. Hsieh. 1975. Changes in Storm Hydrographs After Road Building and Clear-Cutting in the Oregon Coast Range. Water Resources Research 11(3).

Harr, R.D., R.L. Fredriksen and J. Rothacher. 1979. Changes in streamflow following timber harvest in southwestern Oregon. USDA Forest Service Research Paper PNW-249, Pacific Northwest Forest and Range Experiment Station, Portland, Oregon, 22pp.

Harr, R.D. 1981. Some characteristics and consequences of snowmelt during rainfall in Western Oregon. Journal of Hydrology 53:277-304.

Harr, R.D. 1983. Potential for Augmenting Water Yield Through Forest Practices in Western Washington and Western Oregon. Water Resources Bulletin 19(3):383.

Harr, R.D. 1986. Effects of clearcutting on rain-on-snow runoff in western Oregon: A new look at old studies. Water Resources Research 22(7): 1095-2000.

Jones, J.A. and G.E. Grant. 1996. Peak Flow Responses to Clear-Cutting and Roads in Small and Large Basins, Western Cascades, Oregon. Water Resources Research, Volume 32, Number 4, pp 959-974.

Kattelmann, R.C., N.H. Berg, and R. Rector. 1983. The Potential for Increasing Streamflow from Sierra Nevada Watersheds. Water Resources Bulletin 19(3):395.

MacDonald, L.H., with A.W. Smart and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. EPA 910/9-91-001. Published jointly by the US Environmental Protection Agency, Seattle, Washington and the Center for Streamside Studies in Forestry, Fisheries, and Wildlife, University of Washington, Seattle.

Maidment, D.R. 1993. Handbook of Hydrology. McGraw-Hill, New York.

May, C.W., E.B. Welch, R.R. Horner, J.R. Karr, and B.W. Mar. 1997. Quality Indices for Urbanization Effects in Puget Sound Lowland Streams. Final Report Prepared for Washington Department of Ecology, Centennial Clean Water Fund Grant, Water Resources Series Technical Report No. 154.

May, C.W., R.R. Horner, J. Karr, B.W. Mar, and E.B. Welch. 1997. Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion. Watershed Protection Techniques 2(4):483-493.

Miller, J.F., R.H. Frederick, and R.J. Tracey. 1973. Precipitation-Frequency Atlas of the Western United States, Volume X – Oregon. National Oceanic and Atmospheric Administration, NOAA Atlas 2.

Robison, E.G. 1991. Water Availability for Oregon's Rivers and Streams: Volume 1 – Overview. Oregon Water Resources Department. Hydrology Report #1.

Robison, E.G. 1991. Water Availability for Oregon's Rivers and Streams: Volume 2 – Technical Guide and Appendices. Oregon Water Resources Department. Hydrology Report #1.

Robison, E.G. 1991. Methods for Determining Streamflows and Water Availability in Oregon. Oregon Water Resources Department. Hydrology Report #2.

Schueler, T. 1994. The Importance of Imperviousness. Watershed Protection Techniques 1(3):100-111.

Schwab, G.O., D.D. Fangmeier, W.J. Elliot, R.K. Frevert. 1993. Soil and Water Conservation Engineering. John Wiley & Sons, Inc., New York.

Thomas, R.B. and W.F. Megahan. In press. Peak Flow Responses to Clear-Cutting and Roads in Small and Large Basins, Western Cascades, Oregon: A Second Opinion. Water Resources

Troendle, C.A., 1983. The Potential for Water Yield Augmentation from Forest Management in the Rocky Mountain Region. Water Resources Bulletin 19(3):359.

Troendle, C.A., and R.M. King. 1985. The Effect of Timber Harvest on the Fool Creek Watershed, 30 Years Later. Water Resources Research 21(12):1915-1922.

USDA (US Department of Agriculture) Natural Resources Conservation Service. Oregon Annual Data Summary, Water Year 19xx.

USDA (US Department of Agriculture) Soil Conservation Service. 1985. National Engineering Handbook, Section 4, Hydrology.

USDA (US Department of Agriculture) Soil Conservation Service. 1986. Urban Hydrology for Small Watersheds. Technical Release 55.

USGS (US Geological Survey). 1979. Magnitude and Frequency of Floods in Western Oregon. Open-File Report 79-553. Prepared in cooperation with the Oregon Department of Transportation, Highway Division, Portland, Oregon.

USGS (US Geological Survey). 1990. Statistical Summaries of Streamflow Data in Oregon: Volume 1: Monthly and Annual Streamflow, and Flow-Duration Values. Open-File Report 90-118. Prepared in cooperation with the Oregon Water Resources Department.

USGS (US Geological Survey). 1993. Statistical Summaries of Streamflow Data in Oregon: Volume 2: Annual Low and High Flow, and Instantaneous Peak Flow. Open-File Report 93-63. Prepared in cooperation with the Oregon Water Resources Department.

USGS (US Geological Survey). Water Resources Data-Oregon, Water Year 1997.

Viessman, W., Jr., and G.L. Lewis. 1996. Introduction to Hydrology. Harper Collins College Publishers, New York.

Washington State Forest Practices Board. 1997. Standard Methodology for Conducting Watershed Analysis Under Chapter 222-22 WAC. Version 4.0. Olympia, Washington.

Washington State Department of Natural Resources. 1991. Implementation of Rain-on-Snow Emergency Rule WAC 222-16-046 (7). Unpublished interorganizational memorandum from Jack Hulsey to regional managers.

GLOSSARY

adjudication: A court proceeding to determine all rights to the use of water on a particular stream system or groundwater basin.

annual maximum 24-hour precipitation: The largest amount of precipitation that has occurred in a 24-hour period over the course of 1 year.

annual minimum flows: The lowest daily flows that have occurred within a given water year.

annual peak flow: The highest streamflow or discharge recorded at a stream gage during each water year. Annual peak flows are reported on a water-year basis, defined as October 1 through September 30.

aspect: Aspect of a slope is the direction toward which the slope faces.

best management practice (BMP): Structural, nonstructural, and managerial techniques recognized to be the most effective and practical means to reduce surface- and groundwater contamination while still allowing the productive use of resources.

canopy cover: The overhanging vegetation in a given area.

Channel Habitat Type (CHT): Groups of stream channels with similar gradient, channel pattern, and confinement. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

consumptive use: The quantity of water absorbed by the crop and transpired or used directly in the building of plant tissue, together with the water evaporated from the cropped area.

crown closure: The amount of canopy cover in a given area.

discharge: Outflow; the flow of a stream, canal, or aquifer.

elevation: The vertical reference of a site location above mean sea level, measured in feet or meters.

ephemeral: A stream that is dry for a portion of the year and most often contains water during and immediately after a rainfall event.

evaporation: As water is heated by the sun, its surface molecules become sufficiently energized to break free of the attractive force binding them together; they evaporate and rise as invisible vapor in the atmosphere.

evapotranspiration: The amount of water leaving to the atmosphere through both evaporation and transpiration.

gaging station: A selected section of a stream channel equipped with a gage, recorder, or other equipment for determining stream discharge.

Geographic Information System (GIS): A set of tools for modeling virtually all physical and biological components of natural or cultural resources. A system that can integrate information from diverse sources. Comprised of four subsystems 1) data input subsystems; 2) data storage and retrieval; 3) data manipulation and analysis and; 4) data reporting system. GIS databases can usually have a spatial component in the storage of the data; potential to store and create map-like products; and potential for performing multiple analyses or evaluations of scenarios of model simulations.

groundwater: Water stored in the earth that occupies pores, cavities, cracks, and other spaces in the crustal rocks and soil.

hydraulic continuity: The connection between groundwater and surface water such that withdrawal from an underground aquifer affects the streamflow level in the channel (surface water).

hydrograph: A graph of runoff rate, inflow rate, or discharge rate, past a specific point of a river plotted over a predefined time period (annual, storm, etc.).

hydrologic soil group (HSG): Soil classification to describe the minimum rate of infiltration obtained for bare soil after prolonged wetting.

Hydrologic Unit Code (HUC): US Geological Survey designations that correspond to specific watersheds, and are expressed in a hierarchical scale.

hydrology: The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

impervious surface: An area that is made impenetrable by water, such as paved roads, rooftops, and parking lots.

infiltration: The rate of movement of water from the atmosphere into the soil.

lag time: The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff. It is the delay between upstream production of flow and its arrival at a downstream location.

low flow: The minimum rate of flow for a given period of time.

nonpoint source pollution: Variable, unpredictable, and dispersed pollution sources from agriculture, silviculture, mining, construction, saltwater intrusion, waste disposition and disposal, and pollution from urban-industrial development areas. ("Point sources" are steady, predictable, and concentrated through "end of pipe" discharges from manufacturing or water treatment plants.)

orthophotograph: A combined aerial photograph and planimetric (no indications of contour) map without image displacements and distortions.

peak flow: The maximum instantaneous rate of flow during a storm or other period of time.

percolation: The act of **s**urface water moving downwards, or percolating, through cracks, joints, and pores in soils and rocks.

planimeter: An instrument for measuring the area of a plane (2-dimensional) figure by tracing its boundary line.

precipitation: The liquid equivalent (inches) of rainfall, snow, sleet, or hail, collected by precipitation storage gages.

Prior Appropriation Doctrine: A water law based on the principle of prior appropriation, which means the first person to obtain a water right on a stream is the last to be shut off in times of low streamflows.

rain-on-snow event: When snowpacks are melted by warm rains, causing peak-flow events where the melted snow augments the runoff derived from rainfall. Rain-on-snow events usually occur within an elevation zone in which transient snowpacks occur.

recurrence interval: The frequency of hydrologic events can be discussed in terms of either probability or recurrence interval (also called the return period or frequency of occurrence). Exceedance probability refers to the chance that the annual-maximum event of any year will equal or exceed some given value.

return flow: The portion of a diversion that returns to the river system via subsurface pathways. The rest of the diversion is lost to crop consumptive use.

runoff: Surface runoff is water that moves overland across the surface into creeks, ponds, lakes, and rivers that eventually take the water back to the ocean.

runoff curve number: An empirical rating of the hydrologic performance of a large number of soils, vegetative covers, and land use practices throughout the United States.

spring snowmelt: The time in spring when the seasonal snowpack melts out.

transpiration: The process by which water vapor is emitted from plant leaves. Every day, an actively growing plant transpires 5 to 10 times as much water as it can hold at once.

water table: The water table marks the change in the groundwater zone between the zone of aeration, where some pores are open, and the underlying zone of saturation, in which water fills all the spaces in the soil and rocks.

water year: The water year in North America is referred to as the 12-month period beginning October 1 in one year and ending September 30 of the following year. The water year is designated by the calendar year in which it ends. For instance, the annual peak flow for water year 1996 would be the highest flow recorded from October 1, 1995, through September 30, 1996.

Appendix IV-A
Forms and Worksheets

FORM H-1: GENERAL WATERSHED CHARACTERISTICS

Name of Analyst:____ Date:___________________
Watershed Name:____

Subwatershed information:

Subwatershed Name	Subwatershed Area (mi^2)	Mean Elevation (feet)	Minimum Elevation (feet)	Maximum Elevation (feet)	Mean Annual Precipitation (inches)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total Watershed					

- Mean Annual Precipitation can be estimated from the Mean Annual Precipitation Map (from NOAA)
- Minimum and Maximum Elevations can be estimated from the Base Map or USGS quad maps.
- The State Service Center for GIS may also be able to provide the above information.

Describe the type and extent of natural storage (lakes, wetlands, etc.) in the watershed:

____
____
____
____

What watershed changes have occurred that will affect streamflows (i.e., dams, major diversions for urban water supply, irrigation diversions, industrial use etc.)?

____
____
____
____

Information on stream gages in basin: (Note: if more than one gage, fill out additional forms.)
Gage #:______________________
Gage Name:____
Gage Elevation:_______________________
Drainage Area to Gage:___________________________________
Storage or regulation upstream of gage (yes or no)? ___________ If yes, describe on back of sheet

Form H-2: Land Use Summary Form

Name of Analyst:____ Date:__________________
Watershed Name:____
Subwatershed information:

Subwatershed Name	Area (acres)	Forestry		Agriculture and/or Range Land		Urban		Other	
		Acres	%	Acres	%	Acres	%	Acres	%
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
Total Watershed									

Columns 3 through 10: If this information is not available from previous documents or agencies, it can be estimated from recent aerial photographs or orthophotographs.

640 acres = 1 square mile

Form H-3: Annual Peak Flow Summary Form

Name of Analyst:____ Date:____________________
Watershed Name:____

Subwatershed information:

Subwatershed Name	Area (acres)	Rain		Rain-on-Snow		Spring Snowmelt	
		Acres	%	Acres	%	Acres	%
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Total Watershed							

Peak flows by water year (use additional sheets if more than one gage in watershed):

Station Name: ________________________________ Station #:____________________________
Drainage Area = ______________________________ Period of Record: ______________________
Gage is in watershed? (circle one): Yes No

Water Year (10/1-9/30)	Peak flow amount (cfs)	Date of Peak Flow	Rank or Recurr. interval

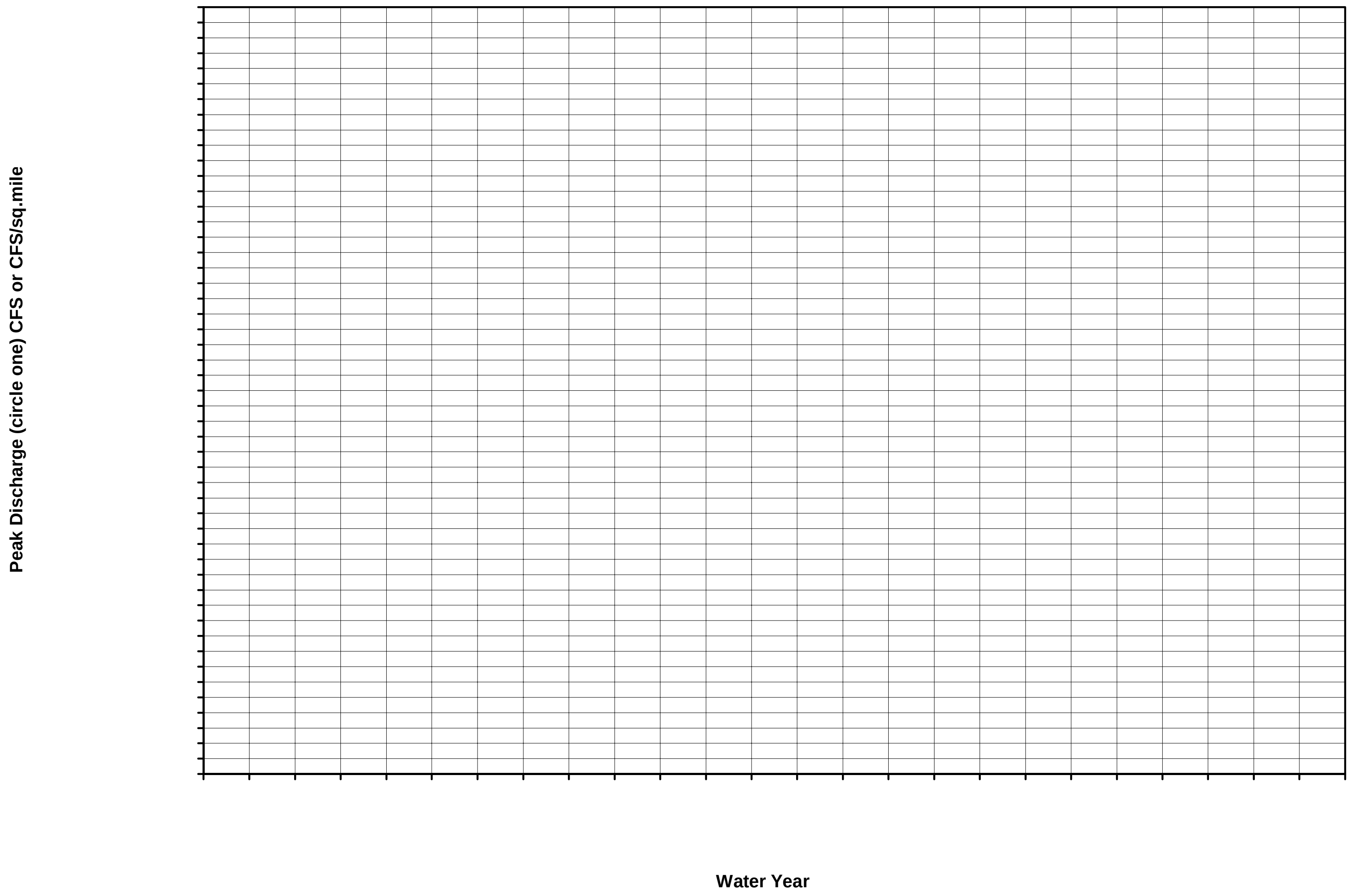
(Continue from Column to left)

Water Year (10/1-9/30)	Peak low amount (cfs)	Date of Peak Flow	Rank or Recurr. Interval

(Continue from Column to left)

Water Year (10/1-9/30)	Peak low amount (cfs)	Date of Peak Flow	Rank or Recurr. Interval

Form H-3: page 2.



Form H-4: Forestry Worksheet

Name of Analyst:____ Date:____________________
Watershed Name:____

1 **Subwatershed Name or Number**	**2** **Historic Crown Closure in Rain-on-Snow Areas (%)**	**3** **Percent of subwatershed in Rain-on-Snow Areas (%)**	**4** **Percent of Rain-on-Snow areas with <30% Current Crown Closure (%)**	**5** **Risk of Peak-Flow Enhancement (either "Potential," "Low," or "Unknown")**
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Entire Watershed				

Form H-5: Agriculture and Range-Land Worksheet

Name of Analyst:_______________________________________ Date:__________________

Watershed Name:____

Table 1. Agricultural Land Use and Range-Land Use Summary

1 Subwatershed Name	2 Area of Subwatershed in Agriculture or Range-Land Use	3 Hydrologic Soil Groups in Agricultural Lands or Grazed Range Lands (by approximate percentage)			
		A	B	C	D
Entire Watershed					

Form H-5: page 2.

Table 2. Curve Number and Runoff-Depth Summary Table for Primary Hydrologic Soil Group

Subwatershed Name:				**Primary Hydrologic Soil Group:**			
1 **Cover Type/Treatment**	**2** **Hydrologic Condition**	**3** **Curve Number**	**4** **Background Curve Number**	**5** **Rainfall Depth (in)**	**6** **Current Runoff Depth (in)**	**7** **Background Runoff Depth (in)**	**8** **Change from Background Col. 6 - 7**
				Subwatershed average change from background:			

Form H-5: page 3.

Table 3. Agricultural/Range-Land Summary

1 Subwatershed Name or Number	2 Percent of Agric./Range Area in 1st Hydrologic Soil Group Table 1 Col. 3 A,B,C, or D	3 Average Change from Background Table 2 Col. 8	4 Percent of Agric./Range Area in 2nd Hydrologic Soil Group Table 1 Col. 3 A,B,C, or D	5 Average Change from Background Table 2, Col. 8	6[1] Weighted Average Change from Background [Cols. 2x3 + 4x5]	7 Potential Risk of Peak-Flow Enhancement
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Entire Watershed						

1 If one hydrologic soil group is dominant, only Columns 2, 3, and 7 will be used. If two hydrologic soil groups are dominant, all seven columns will be used. If more than two hydrologic soil groups are dominant, add two columns per hydrologic soil group to table.

Form H-6: Forest and Rural Road Worksheet

Name of Analyst:______________________________ Date:______________

Watershed Name:____

Table 1. Forest Road Area Summary

1 Subwatershed Name	2 Area (mi^2)	3 Area Forested (mi^2)	4 Total Linear Distance of Forest Roads (miles)	5 Roaded Area Column 4 x std. width (ft^2) std. width = 25 feet = .0047 miles	6 Percent Area in Roads Col. 5/3	7 Relative Potential for Impact
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Entire Watershed						

Table 2. Rural Road Area Summary

1 Subwatershed Name	2 Area (mi^2)	3 Rural Area (Agric. + Range) (mi^2)	4 Total Linear Distance of Rural Roads (miles)	5 Roaded Area Column 4 x std. width (ft^2) std. width = 35 feet = .0066 miles	6 Percent Area in Roads Col. 5/3	7 Relative Potential for Peak-Flow Enhancement
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Entire Watershed						

Form H-7: Urban and Residential Area Worksheet

Name of Analyst:________________________________ Date:______________
Watershed Name:____

Table 1. Method 1: Urban and Rural Residential Land Use Summary

1 Subwatershed Name	2 Percent of Area Urbanized/ Rural Residential	3 Dominant Type of Urban Land Use	4 Average Percent Impervious	5 Estimate of Percent Total Impervious Area Col. 2 x Col. 4	6 Relative Potential for Peak-Flow Enhancement

Table 2. Method 2: Urban Road Density Summary

1 Subwatershed Name	2 Area (mi^2)	3 Area Urban (mi^2)	4 Total Linear Distance of Roads (miles)	5 Road Density Col. 4/3 (mi/mi^2)	6 Relative Potential for Peak-Flow Enhancement
Entire Watershed					

Form H-8: Hydrologic Issue Identification Summary

Name of Analyst:_______________________________________ Date:__________________
Watershed Name:____

Summary of Potential Risks from Land Use Impacts on Hydrology

1	2 Timber Harvest Form H-4 Table		3 Agriculture Form H-5 Table 3		4 Range Lands Form H-5 Table 3		5 Forest Roads Form H-6 Table 1		6 Rural Roads Form H-6 Table 2		7 Urban Impervious or Urban Roads* Form H-7 Table 1 or Table 2	
Subwatershed Name or Number	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Entire Watershed												

* Circle the method used.

Form WU-1. Water Rights Summary

Name of Analyst:____ Date:____________________
Watershed Name:____

Water Rights on Record with OWRD

Watershed Name: ____________________________ **County:**							
Permit or Certificate #	**Status**	**Priority Date**	**Flow Rate (cfs)**	**Time of Diversion**	**Type of Use (Irrigation Stock Watering Domestic)**	**Location**	**WAB #**

Form WU-2: Water Availability Summary

Name of Analyst:______________________________ Date:______________
Watershed Name:______________________ County:______________________

Monthly Net Water Available by Water Availability Basin (cfs)

Water Availability Basins	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Form WU-3. Consumptive Use Summary

Name of Analyst:______________________________ Date:________________
Watershed Name:________________________ County:________________________

Consumptive Use as a Percentage of 50% Exceedance Streamflow

Water Availability Basins	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Form HW-1. Confidence Evaluation

Name of Analyst:_______________________________________ **Date:**__________________
Watershed:_____________________________ **Area:**_________________________________

Technical expertise or relevant experience:____
____
____

Resources used:

USGS Web site
Hydrodata or Earthinfo CD-ROM
USGS Open File Report 90-118
USGS personnel
NRCS personnel
OWRD regional personnel
Oregon Climate Service Web site
NRCS Web site
USGS Water Supply Papers, Oregon
OWRD Web site
OWRD local Watermaster

Confidence in hydrology assessment

Low: Unsure of procedures and/or used minimal resources.
Low to moderate: Understood and followed most of the procedures, but minimal resources available and/or used.
Moderate: Understood and followed procedures, and used adequate number of resources, but had moderate understanding of outcome.
Moderate to high: Understood and followed procedures, used adequate number of resources, and had high understanding of outcome.
High: Understood and followed procedures, used numerous resources, and had high understanding of outcome.
If none of the above categories fit, describe your own confidence level and rationale:

Recommendations for further assessment or analysis:

Appendix IV-B
Reference Tables

Table B-1. Runoff Curve Numbers for Cultivated Agricultural Lands[1]

Cover Type	Treatment[2]	Hydrologic Condition[3]	Curve Numbers for Hydrologic Soil Group A	B	C	D
Fallow	Bare Soil	---	77	86	91	94
	Crop Residue Cover	Poor	76	85	90	93
		Good	74	83	88	90
Row Crops	Straight Row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight Row + Crop Residue Cover	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + Crop Residue Cover	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured and Terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured and Terraced + Crop Residue Cover	Poor	65	73	79	81
		Good	61	70	77	80
Small Grain	Straight Row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight Row + Crop Residue Cover	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + Crop Residue Cover	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured and Terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured and Terraced + Crop Residue Cover	Poor	60	71	78	81
		Good	58	69	77	80
Close-Seeded or Broadcast Legumes Rotation Meadow	Straight Row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and Terraced	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition and $I_a = 0.2$ S
2 Crop Residue Cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good > 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better-than-average infiltration and tend to decrease runoff.

From USDA Soil Conservation Service, TR55 (2nd edition, June 1986); Table 2-2a, page 2-5.

Table B-2: Runoff Curve Numbers for Other Agricultural Lands[1]

Cover Type	Hydrologic Condition	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Pasture, grassland, or range – continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass; protected from grazing and generally mowed for hay	---	30	58	71	78
Brush – brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods – grass combination (orchard or tree farm)[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6] Shaded area can be used as background if the land was originally wooded	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads – buildings, lanes, driveways, and surrounding lots	---	59	74	82	86

1 Average runoff condition and $I_a = 0.2$ S

2 **Poor:** <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

3 **Poor:** <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use curve number = 30 for runoff computations.

5 Curve numbers shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the curve numbers for woods and pasture.

6 **Poor:** Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

From USDA Soil Conservation Service, TR55 (2nd edition, June 1986); Table 2-2b, page 2-6.

Table B-3: Runoff Curve Numbers for Arid and Semiarid Range Lands

Cover Type	Hydrologic Condition	Curve Numbers for Hydrologic Soil Group			
		A[3]	B	C	D
Herbaceous – mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen – mountain-brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper – pinyon, juniper or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub – major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition and I_a = 0.2 S.

2 **Poor:** <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good:>70% ground cover.

3 Curve numbers for Group A have been developed only for desert shrub.

From USDA Soil Conservation Service, TR55 (2nd edition, June 1986); Table 2-2c, page 2-7. For range in humid regions, use table 2-2c of TR55.

Table B-4: Runoff Depth for Selected Curve Numbers and Rainfall Amounts[1]

	Runoff Depth for Curve Number of…												
Rainfall	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**98**
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.15	0.27	0.46	0.74	0.99
1.4	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.13	0.24	0.39	0.61	0.92	1.18
1.6	0.00	0.00	0.00	0.00	0.01	0.05	0.11	0.20	0.34	0.52	0.76	1.11	1.38
1.8	0.00	0.00	0.00	0.00	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.29	1.58
2.0	0.00	0.00	0.00	0.02	0.06	0.14	0.24	0.38	0.56	0.80	1.09	1.48	1.77
2.5	0.00	0.00	0.02	0.08	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.96	2.27
3.0	0.00	0.02	0.09	0.19	0.33	0.51	0.71	0.96	1.25	1.59	1.98	2.45	2.77
3.5	0.02	0.08	0.20	0.35	0.53	0.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	0.06	0.18	0.33	0.53	0.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	0.14	0.30	0.50	0.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	0.24	0.44	0.69	0.98	1.30	1.65	2.04	2.45	2.89	3.37	3.8 8	4.42	4.76
6.0	0.50	0.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	0.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

1 Interpolate the values shown to obtain runoff depths for curve numbers or rainfall amounts not shown.

From USDA Soil Conservation Service, TR55 (2nd edition, June 1986); Table 2-1, page 2-3.

Appendix IV-C
Resources for Data Acquisition

RESOURCES FOR DATA ACQUISITION

USGS

Contact Information

Information Officer
US Department of the Interior, Geological Survey
10615 SE Cherry Blossom Drive
Portland, OR 97216
Telephone: (503) 251-3201
Fax: (503) 251-3470
Office hours: 7:30 a.m. to 4:30 p.m. Pacific Time
Internet address: http://waterdata.usgs.gov/nwis-w/OR

Internet Instructions

Access the Internet site referenced above. When you enter the State Surface Water Data Retrieval Page for Oregon, select the gage for which you want information, or, if you don't yet know the gage number, select the county list or the map from which to select the county. Select the gage from the county list. Summary information will appear and below that *Data Types Available*. Select *Peak Flow Data*; then select *Annual Peaks* and *Tab-Delimited Text Data File*. The largest instantaneous streamflow recorded for each year will be displayed along with the date of that peak flow. This data can be downloaded into a spreadsheet by saving it as a text file. The most recent peak flows will not be on the Internet and must be requested from the state USGS office.

CD-ROM

Hydrosphere and Earthinfo, both located in Boulder, Colorado, produce and distribute CD-ROMs containing USGS streamflow data. These CD-ROMs can be found in some libraries, especially at universities. If you wish to purchase a CD for use with your computer, you can order one directly from either of the above-mentioned businesses.

Publications

Frank, F.J., and A. Laenen. 1977. Water Resources of Lincoln County Coastal Area, Oregon. Prepared in cooperation with the Oregon Water Resources Department. US Geological Survey, Water Resources Investigations 76-90, Portland, Oregon.

Greenberg, J. and K.F. Welch. 1998. Hydrologic Process Identification for Western Oregon. Prepared for Boise Cascade Corp., Boise, Idaho.

Harris, D.D., L.L. Hubbard, and L.E. Hubbard. 1979. Magnitude and Frequency of Floods in Western Oregon. Prepared in cooperation with the Oregon Department of Transportation, Highway Division. US Geological Survey, Open File Report 79-553, Portland, Oregon.

Harris D.D., and L.E. Hubbard. 1983. Magnitude And Frequency Of Floods In Eastern Oregon. US Geological Survey WRIR 82-4078.

Moffatt, R.L., R.E. Wellman, and J.M. Gordon. 1990. Statistical Summaries of Streamflow Data in Oregon: Volume 1: Monthly and Annual Streamflow, and Flow-Duration Values. Prepared in cooperation with the Oregon Water Resources Department. US Geological Survey, Open-File Report 90-118, Portland, Oregon. Maps are located in the appendix of this document showing the location of streamflow gaging sites.

Wellman, R.E., J.M. Gordon, and R.L. Moffatt. 1993. A Statistical Summaries of Streamflow Data in Oregon: Volume 2: Annual Low and High Flow, and Instantaneous Peak Flow. Prepared in cooperation with the Oregon Water Resources Department. US Geological Survey, Open-File Report 93-63, Portland, Oregon.

Regional Offices of Oregon Water Resources Department (OWRD)

Northwest Region
158th 12th Street, NE
Salem, OR 97310
(503) 378-8455, ext. 281
Fax: (503) 378-8130

North Central Region
3920 Westgate
Pendleton, OR 97801
(541) 278-5456
Fax: (541) 278-0287

Southwest Region
Grants Pass Municipal Building
942 SW 6th Street Suite E
Grants Pass, OR 97526
(541) 471-2886; ext. 86
Fax: (541) 471-2876

Eastern Region
Baker County Courthouse
1995 3rd Street
Baker City, OR 97814
(541) 523-8224
Fax: (541) 523-7866

South Central Region
1340 NW Wall Street, Suite 100
Bend, OR 97701
(541) 388-6669
Fax: (541) 388-5101

Oregon State Department of Forestry
2600 State Street
Salem, OR 97301
(503) 945-7469
Fax: (503) 945-7490

Appendix IV-D
Background Hydrologic Information

BACKGROUND HYDROLOGIC INFORMATION

Land Use Impacts on Hydrology

Land use practices can modify the amount of water available for runoff, the routing of water to the streams, the **lag time** [1] (delay between rainfall and peak streamflow), the flow velocity, or the travel distance to the stream. Figure D-1 demonstrates how urbanization causes the peak flow (highest point on the curve) to increase and to occur sooner (the lag time has decreased). The same concepts are shown in Figure D-2, in which two streams respond differently to the same rainstorm: One stream drains a forested watershed and the other drains an urbanized watershed. Agricultural land would produce a similar but less pronounced response than the urban response shown in both Figures D-1 and D-2.

Land use practices that affect the rate of infiltration and/or the ability of the soil surface to store water are typically most influential in affecting the watershed's hydrology. Using this as an indicator for comparison among the land uses, forest harvesting produces the smallest change in the infiltration rate, thereby producing the smallest impacts to the hydrologic regime of a basin. Forest harvest practices have evolved such that land compaction can be minimized; however, roads and grazing in these watersheds decrease the infiltration rate. In contrast to forest harvest, agricultural practices, range-land utilization for grazing purposes, and urban development can all involve compaction of the soils and/or paved surfaces, resulting in substantial alteration of the infiltration rate. Agricultural practices and urban development directly involve altering the shape of the drainage system by ditching, channelizing, or using piped stormwater networks which decrease the infiltration and the travel time of subsurface flow to reach the channel. This effect can be exacerbated in high-flow conditions. Forest harvest, although not always practiced at a sustainable rate, is a temporary conversion of the vegetation, and the hydrologic effects diminish as vegetative

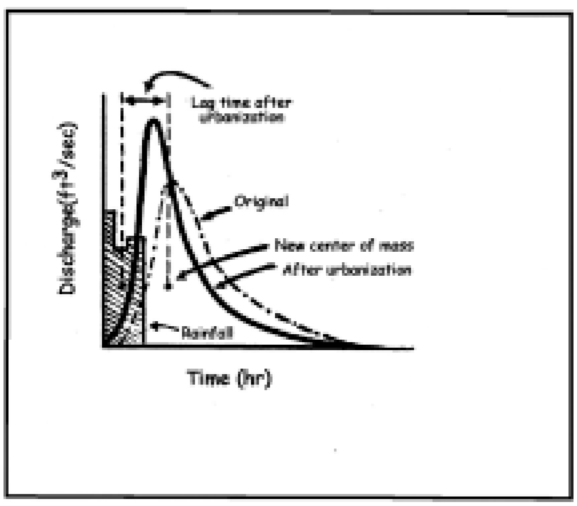


Figure D-1. Hypothetical unit hydrographs illustrating urbanization impacts on peak flows.

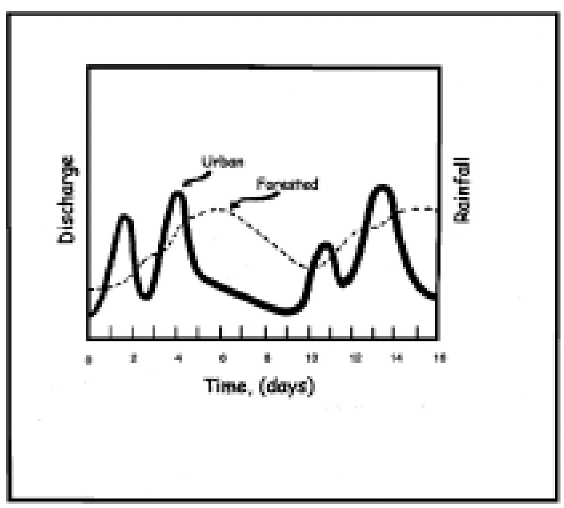


Figure D-2. Streamflow comparison of urban versus forested watersheds.

[1] Terms that appear in bold italic in this appendix are defined in the Glossary of the main text of this component.

regrowth occurs. Conversion of lands to agriculture or urbanization produces generally longer-lasting effects. Road construction, associated with all land uses, alters the rate of infiltration on the road surface and replaces subsurface flow pathways with surface pathways resulting in quicker travel time to the channel network.

Forestry

The potential effects of forest practices on hydrology include changes in peak flows, water yield, and low flows. There are two primary mechanisms by which forest practices in Pacific Northwest watersheds impact hydrologic processes: (1) the removal and disturbance of vegetation, and (2) the road network and related harvesting systems.

Removal of vegetation reduces interception and **evapotranspiration**, both of which allow additional water to reach the soil surface during rainstorms. Additionally, open areas accumulate more snowpack. The additional snowpack can potentially produce an increase in water yield (volume of water) that, in arid and semiarid regions, is viewed as a net benefit for water supply. The area with a decrease in **canopy cover** due to tree removal is subject to increased exposure to solar radiation and wind that can cause faster melting rates, potentially causing an increase in peak flows occurring earlier in the melt season. Harvest practices can also affect low flows, especially in spring snowmelt regimes. The quicker melting of the snowpack reduces the opportunities for groundwater recharge, the primary supply for baseflow conditions (streamflow during the driest part of the year). However, this decrease may be offset by the decreased evapotranspiration resulting from the reduction in canopy cover.

The size and structure of forest vegetation varies throughout the state primarily as a function of climatic variables, **aspect**, and elevation. In the eastern regions of the state, crown closure or vegetative cover was historically less dense than the thick forests of western Oregon. In some areas in eastern Oregon, the once-sparse forests now tend to be denser due to the prevention and control of forest fires. The suppression of fire on the landscape, in areas that historically experienced frequent fire, has led to the following general conditions: increased stand densities and canopy closure, smaller average stand diameter, changes in vegetative composition (i.e., fir or juniper invasion), decreased shrub/herb growth, increased litter/duff layer, and increased large woody debris and overall fuel loading (Agee 1994). Consequently, peak flows produced from undisturbed historic forests may have been higher compared to forests in which fires have been controlled. Due to this probable condition, potential hydrologic impacts in these regions may be minor.

The forestry-related effects on peak flows may be a function not only of harvest and vegetative cover issues, but also of the type of hydrologic process that occurs in a basin (MacDonald and Hoffman 1995). The greatest likelihood of causing problems from timber harvest is through increases in peak flows associated with rain-on-snow events (Harr 1981, 1986; Coffin and Harr 1992; and Washington Forest Practices Board 1997). While rain-on-snow conditions can occur at almost any elevation, given a specific combination of climatic variables, the probability of rain-on-snow enhancement of peak flows differs with elevation and, to a lesser degree, aspect. The highest probability of encountering rain-on-snow conditions occurs at mid-elevations where transient snowpacks develop but do not get too deep. The lowest probability occurs in the lowlands, where snowpack rarely occurs and, at the higher elevations, where winter temperatures are too cold to melt the snow. The elevation of the lower boundary of the rain-on-snow zone will vary geographically and often by ecoregion. For some portions of Oregon, the boundary has been defined systematically (Greenberg and Welch 1998), whereas for other portions of the state, you will need to contact a local hydrologist.

Agriculture

Agricultural practices have most often been implemented along valley bottoms, floodplains, and other adjacent low-gradient lands. An often long-lasting change in the vegetative cover has occurred from the conversion of the landscape from forested woodlands, prairie grasslands, or other natural environs. Clearing for pasture or crop production has also entailed landleveling or topographic changes of the landscape. Leveling and field drainage has resulted in the elimination of many wetlands and depressions that previously attenuated flood peaks by providing detention storage. Without wetlands and depressions, surface and subsurface runoff move more quickly to the channel network. In addition, extensive **nonpoint source pollution** often accompanies agricultural land use practices (see Water Quality component).

Ditches have been constructed to drain the land and streams have been channelized to maximize agricultural land use. These practices result in increased velocities of surface and subsurface flows that correspondingly decrease infiltration opportunities. Decreased infiltration produces increased runoff and subsequent decreased baseflows during the low-flow season.

The impact of agriculture on hydrology is dependent on specific practices such as the type of cover and management treatments, as well as the characteristics of the soil being farmed. The practices that alter the rate of infiltration are most influential in causing a change in the hydrologic regime. The infiltration rates of undisturbed soils vary widely. Agriculture has a greater affect on runoff in areas where soils have a high infiltration rate compared to areas where soils are relatively impermeable in their natural state (USDA 1986).

The Natural Resources Conservation Service (NRCS) has characterized and mapped the soils throughout the state. As part of the mapping process, soils are classified into one of four hydrologic soil groups (Table D-1) primarily as a function of their minimum infiltration rate on wetted bare soil. As part of the NRCS methods (USDA 1986), runoff curve numbers are assigned to areas for each of the combination of three parameters: (1) soil group, (2) cover type, and (3) treatment or farming practice.

Runoff curve numbers are used as part of a simplified procedure for estimating runoff in small agricultural and urban watersheds (USDA 1986). Curve numbers are assigned based on factors such as soils, plant cover, and impervious area. Rainfall is converted to runoff using Curve numbers.

Certain soil conditions can make farming difficult, so amending the soil structure by adding organic matter becomes a way in which farmers can maximize the use of their land. This practice can actually change the hydrologic soil group from, say, a C to a B. In this example, it is possible to reduce the runoff rather than increase it. To detect these changes at this screening level of assessment will be difficult. Voluntary actions and implementation of best management practices to improve soil texture and water holding capacity can be a benefit to the farmer as well as to the hydrology of the watershed.

Table D-1. NRCS hydrologic soil group classification (USDA 1986).

Hydrologic Soil Group	Characteristics of Soils	Minimum Infiltration Rate (mm/hr)
Low Runoff Potential A	High infiltration rates even when thoroughly wetted. Deep, well-drained sands or gravels with a high rate of water transmission. Sand, loamy sand, or sandy loam.	8 - 12
B	Moderate infiltration rates when thoroughly wetted. Moderately deep to deep, moderately well-drained to well-drained, moderately fine to moderately coarse textures. Silt loam or loam.	4 – 8
C	Slow infiltration rates when thoroughly wetted. Usually has a layer that impedes downward movement of water or has moderately fine to fine textured soils. Sand clay loam.	1 – 4
D High Runoff Potential	Very low infiltration rate when thoroughly wetted. Chiefly clay soils with a high swelling potential; soils with a high permanent water table; soils with a clay layer near the surface; shallow soils over near-impervious materials. Clay loam, silty clay loam, sandy clay, silty clay, or clay.	0 – 1

Range Lands

Grazing animals impact range lands in two ways: (1) removal of protective plant material, and (2) compaction of the soil surface. Both of these actions affect the infiltration rate (Branson et al. 1981). Cattle grazing on sparsely forested lands can have similar impacts and should be considered under this heading. In general, moderate or light grazing reduces the infiltration capacity to 75% of the ungrazed condition and heavy grazing reduces the infiltration by 50% (Gifford and Hawkins 1979). Soil compaction, which decreases the infiltration rate, correspondingly increases the overland flow or surface runoff. Surface runoff is the most common kind of runoff on range lands. This is evidenced in that most range-land stream channels are **ephemeral**. In other words, these channels flow with water only during the snowmelt season or after a high-intensity or long-duration rainfall (Branson et al. 1981).

Impacts associated with the use of range lands can be assessed in a similar manner as agricultural lands. There is no statistical distinction between the impact of light and moderate grazing intensities on infiltration rates. Therefore, they may be combined for purposes of assessment. (Gifford and Hawkins 1979).

Forest and Rural Roads

Road networks associated with forestry can alter the rate of infiltration on the road surface and potentially change the shape of the natural drainage. The surface of most forest roads is compacted soil that prevents infiltration of precipitation. Forest road networks primarily increase streamflow by replacing subsurface with surface runoff pathways (e.g., roadside ditches) (Bowling and Lettenmaier 1997). Roads can also intercept and divert overland flow and shallow subsurface flow, potentially rerouting the runoff from one small sub-basin to an entirely different subbasin (Harr et al. 1975 and 1979). Roads can potentially impact peak flows during rainfall events, rain-on-snow events, or spring snowmelt; therefore, the determination of percent of basin occupied by roads provides useful information regardless of the way in which peak flows are generated.

Rural roads associated with either agriculture or range lands can also affect streamflow and will be characterized in a similar manner as forest roads. Roadside ditches are more structured and maintained along rural roads and can significantly extend the stream network density, because their presence is additional to the natural channel. However, if natural channels are altered through straightening or channelizing, the stream network length may decrease. Channelizing streams results in increased velocities and potentially increases erosion rates of the banks and bed.

Roads along stream channels restrict lateral movement and can cause a disconnection between the stream or river and its floodplain. Restricting lateral movement can result in downcutting of the channel and decreased accessibility of flood waters to overbank storage, resulting in decreased flood peak attenuation.

Urban and Rural Residential

Urbanization has the highest impact on hydrology of the land uses addressed. In urban settings, a large portion of the land surface becomes impervious from roads, parking lots, shopping malls, buildings, sidewalks, etc. The streamflow regime is significantly altered from decreases in infiltration rates and recharge rates, corresponding increases in peak flows and volume of runoff, and a decrease in watershed response time (time to peak). Rainfall striking the ground surface moves more quickly from streets and roofs than from naturally vegetated areas; conveyance systems such as storm sewers and lined open channels increase the flow velocities, thereby decreasing the lag time or the time it takes for water to enter the stream channel. Low flows are affected by reduced groundwater recharge resulting from the increase in impervious surfaces. In addition, pervasive nonpoint source pollution often accompanies stormwater runoff in urbanized areas (see Water Quality component). As with agriculture, urbanization has a greater affect on runoff where soils have a high infiltration rate than in areas where soils are relatively impermeable in their natural state (USDA 1986).

Water Law and Water Use Background

Water law in the State of Oregon is based on the **prior appropriation doctrine** or "first in time, first in right," subject to the physical availability of water and the ability to put it to beneficial use without waste. The most senior appropriator (the right with earliest date) has a right to divert water prior to any junior water right (a later date). The most senior right is the last one to be shut off from diverting water during low streamflows. Any person or entity withdrawing water from a stream or river must have a water right from the Oregon Water Resources Department (OWRD). These water rights are in various levels of use and certification or **adjudication**. For example, there are certificates, applications for certificates, water rights on record and not being used, and rights not using their full entitlement. Each water right has an instantaneous flow amount (the maximum rate at which water can be withdrawn at any point in time), an annual volume restriction (water duty), and a designated beneficial use, including agriculture, domestic, urban, industrial, commercial, fish and wildlife, power, recreation, etc.

In general, agriculture places the greatest demand on our water resources compared to other uses. Water is required for irrigation of crop lands, pasture, stock watering, and/or washdown. In most cases, the period of high demand for irrigation coincides with the period of low streamflow; crop water requirements tend to peak in August, when streamflows are usually the lowest. Water withdrawals are applied to the crop lands for irrigation, and part of that water is used by the crop (evapotranspiration), a portion **percolates** to deep groundwater, and a portion may be returned to another watershed; the total portion not returned to the river is called **consumptive use**. The portion of the diversion that returns to the stream system through subsurface avenues at points downstream is called the **return flow**.

Urban water supply can provide for residential, commercial, and some industrial uses. Water is diverted, treated, and then distributed throughout a municipality. Subsequently, the wastewater is delivered to a sewage treatment facility where it is treated to a "primary" or "secondary" level and discharged to a stream or bay at a distinct location. Much of the residential urban water is nonconsumptive, with the exception of lawn watering, and is returned to the stream network from the wastewater facilities. Lawn-irrigation return flow occurs through subsurface avenues.

Stormwater runoff from urban areas is generally not treated and discharged directly to the stormwater conveyance facilities that often deliver directly to the stream channel.

Industrial water uses can demand large quantities of water for operation of their facilities. Some have on-site treatment facilities and all are subject to discharge quantity and quality restrictions through National Pollution Discharge Elimination System (NPDES) permits.

National forests, national parks, US Bureau of Land Management lands, Indian reservations, etc., are federal reservations. These entities maintain federal reserved rights for the purposes for which the reservations were established. Their priority date is the date the reservation was created. In many cases, reservations were established in the mid- to latter part of the 19th century. Many of the federal reservation water rights have been tried in the courts of law, and, more often than not, case law has set the precedent of adjudicating federally reserved water rights (Winters Doctrine).

Water Rights

There are three primary types of surface water rights: (1) out-of-stream rights, (2) storage rights, and (3) in-stream rights. Out-of-stream rights are also called "direct flow" or "run of the river" diversions. These rights entail withdrawing water directly from the channel with subsequent application for a specific beneficial use such as irrigation, domestic or urban water supply, industrial use, etc. Storage rights can be for on-stream or off-stream reservoirs. On-stream reservoirs capture water as it flows into the reservoir. Water is stored until it is needed for the specified beneficial use, at which time it is released either into the channel and withdrawn downstream or released into conveyance facilities for delivery to the point of use. Off-stream reservoirs require diversion from the river to the storage site, and subsequent release and conveyance to the point of use. In-stream rights are those that require a designated quantity of water to remain in the stream or river for a specific beneficial use, most often for aquatic resources, wildlife, or aesthetics.

Water withdrawals reduce streamflows, potentially resulting in a negative impact on the biologic resources, particularly during the low-flow season. In recent years, in-stream rights have become more common as a means of protecting the biologic resources. In-stream water rights did not exist in Oregon prior to 1955. **Minimum flows** were established by administrative rule in 1955, but they did not carry the full weight of a water right. Between 1955 and 1980, the Oregon Department of Fish and Wildlife (ODFW) conducted basin investigations from which minimum flows were recommended and adopted by rule. In 1987, the legislature changed the administrative rulemaking into an application process for a water right. OWRD holds the water right, but ODFW, Department of Environmental Quality, and State Parks can apply for an in-stream right. Minimum flows were changed into in-stream rights, and the date minimum flows were adopted became the priority date. The in-stream rights can have the value up to but not exceeding the median flow. In-stream rights tend to be junior to the majority of the out-of-stream water rights; this reduces their ability to maintain effective streamflows in the channel. If federal reserved rights for in-stream flows have been adjudicated, they would usually have the most senior right in the basin, because federal reservations were established before the implementation of the Prior Appropriation Doctrine.

Water users with large demands generally have storage rights, because reservoirs provide more certainty of supply during low-streamflow conditions. The ability to capture streamflow during the high flows and use it during low flows can be a significant benefit to water users. In some instances, reservoirs are constructed as flood control facilities to provide attenuation of the peak flows and reduce downstream flooding and damage.

Groundwater rights are those attached to the withdrawal of water from a well. With some exceptions, all water users extracting groundwater as the source of supply must have a water right for the legal use of the water. There are exempt uses that do not require a right. The most significant of these is rural residential water users; these users are limited to 15,000 gallons per day for noncommercial use and irrigation of less than 0.5 acres.

Groundwater has the potential to influence surface water by what is called **hydraulic continuity**. Depending on the location of the well and the geology in the area, water withdrawn can have a corresponding effect on the streamflow. In other words, it is possible for the extraction of groundwater to dry up a nearby stream during low flows. Consequently, the State of Oregon manages surface- and groundwater rights conjunctively, which means there are times at which groundwater withdrawals will be shut down due to low flows in the channel.

Storage

Man-made storage facilities such as water supply reservoirs, flood control reservoirs, or multipurpose reservoirs impact the peak flows downstream of the impoundment. Each reservoir has its unique operating scheme, and therefore will requires more detailed hydrologic investigations, often including release schedules, reservoir routing, etc. If you have a reservoir in your watershed, further technical analyses will be required for the portion of your basin below the dam, while some of these exercises can be completed for the portion of the basin above the dam.

Water Availability

The OWRD has developed a computer model, Water Availability Reports System (WARS), which calculates water availability for any of their designated water availability basins (WABs) in the state. Water availability, as defined by the OWRD, refers to the natural streamflow minus the consumptive use from existing rights. If water is available, additional in-stream or out-of-stream rights may be issued. This value is dynamic and is often updated to account for issuance of new water rights. The *80% level of exceedance* is that which OWRD uses to determine whether additional water rights can be issued in a basin. The 80% exceedance flow is the streamflow that is in the river 80% of the time over a designated 30-year period, which accounts for wet- and dry-year cycles. In other words, that amount of water is in the channel for a given month at least 80% of the time (4 out of 5 years on average).

The following list is an outline of information provided by WARS.

- Month (1 = January, 2 = February, etc.)
- Natural streamflow
- Consumptive use and storage with dates before January 1, 1993
- Amount of water that is physically in the system after uses with priority dates before January 1, 1993
- Consumptive use and storage with dates after January 1, 1993
- Amount of water that is physically in the system after uses with priority dates after January 1, 1993
- Flow rate of any existing in-stream water rights
- Net water available for any potential water right

The WARS program produces both the 80% exceedance and the 50% exceedance flows, along with the associated water availability under each condition. The 50% exceedance flow is the same as the median flow value. The median flow value means half the time the natural flows are above this value and half the time flows are below this value. The 50% exceedance flows were those used as an upper limit in developing in-stream rights for aquatic species and other in-stream beneficial uses. Water rights for out-of-stream uses are issued only when water is available at the 80% exceedance level.

Water availability is the amount of water that is physically **and** legally available for future appropriation, and is determined by the following equation:

$$\mathbf{Q_a = Q_{80} - Q_{cu} - Q_{ir}}$$

where

Q_a = water available
Q_{80} = natural streamflow at the 80% exceedance level
Q_{cu} = consumptive use of diverted water
Q_{ir} = in-stream rights.

Streamflow Restoration Priority Areas

Oregon's Departments of Fish and Wildlife and Water Resources collaborated to develop the Streamflow Restoration Priority Areas (SRPA). This effort was an outcome of the Oregon Plan (1997), which is the broader framework for the Coastal Salmon Restoration Initiative (CSRI). The

CSRI mission is to restore coastal salmon populations and fisheries to sustainable levels. Three major factors were identified in CSRI as exacerbating the loss of fish populations: (1) fish resources, (2) fish habitat, and (3) loss of streamflow. The loss of streamflow is the focus of the SRPA analysis.

The identification of priority areas was based on a combination of biological factors and water use. ODFW identified priority areas to enhance fish populations. A rank was assigned to three categories under fisheries: (1) fish resources; (2) habitat integrity; and (3) risk factors such as a listing under the Endangered Species Act, in-stream flow protection, or natural low-flow problems. OWRD identified areas in which an opportunity existed to enhance in-channel flows. Concurrently, OWRD identified areas in which an opportunity existed to enhance in-channel flows, situations under which water could be saved through conservation, efficiency of use, etc. The criteria for water resources was assigned to two categories: (1) consumptive use by percentage of the median (50% exceedance) streamflow, and (2) number of months an in-stream water right is not met. A priority was established based on the combination of the two resulting factors: "need" (fisheries) and "optimism" (water resources). For example, in the Mid Coast Region (Table D-2), if the need is given a rank of 2 by ODFW and the optimism is given a rank of 1 by OWRD, the basin would not be selected as a priority for flow restoration. In the need and optimism column, 1 is the lowest rank and 4 is the highest.

Table D-2. Initial state restoration priority.

Basin	Flow-Restoration		
	Need	**Optimism**	**Priority**
North Coast and Rogue	1 or 2 3 or 4	1 or 2 3 or 4	No Yes
Umpqua	Any	1 2, 3, 4	No Yes
South Coast	1 or 2 3 or 4	1 2, 3, 4	No Yes
Mid Coast	1 2, 3, 4	1 2, 3, 4	No Yes

References

Bowling, L.C., and D.P. Lettenmaier. 1997. Evaluation of the Effects of Forest Roads on Streamflow in Hard and Ware Creeks, Washington. TFW-SH20-97-001, Water Resources Series Technical Report No. 155, University of Washington, Seattle.

Branson, F.A., G.F. Gifford, K.G. Renard, and R.F. Hadley. 1981. Rangeland Hydrology. Range Science Series No. 1, October 1972, Second Edition 1981. Society for Range Management, Denver Colorado. Kendall/Hunt Publishing Co., Dubuque, Iowa.

Coffin, B.A.. and R.D. Harr. 1992. Effects of Forest Cover on Volume of Water Delivery to Soil During Rain on Snow. Final Report TFW-Sh1-92-001.

Gifford, G.F., and R.H. Hawkins. 1979. Deterministic Hydrologic Modeling of Grazing System Impacts on Infiltration Rates. Water Resources Bulletin 15(4):924-934.

Greenberg, J. and K.F. Welch. 1998. Hydrologic Process Identification for Western Oregon. Prepared for Boise Cascade Corp., Boise, Idaho.

Harr, R.D. 1981. Some Characteristics and Consequences of Snowmelt During Rainfall in Western Oregon. Journal of Hydrology 53:277-304.

Harr, R.D. 1986. Effects of Clearcutting on Rain-on-Snow Runoff in Western Oregon: A New Look at Old Studies. Water Resources Research 22 (7):1095-1100.

Harr, D.R., W.C. Harper, J.T. Krygier, and F.S. Hsieh. 1975. Changes in Storm Hydrographs After Road Building and Clear-Cutting in the Oregon Coast Range. Water Resources Research 11(3).

Harr, R.D., R.L. Fredriksen, and J. Rothacher. 1979. Changes in Streamflow Following Timber Harvest in Southwestern Oregon. Research Paper PNW-249. February 1979. Pacific Northwest Forest and Range Experiment Station, U.S. Department of Agriculture, Forest Service, Portland, Oregon.

Logan, R.S. and R.A. Fletcher. 1996. Forest Ecosystem Stewardship. Montana State University Publications, Bozeman, Montana.

MacDonald, L.H. and J.A. Hoffman. 1995. Causes of Peak Flows in Northwestern Montana and Northeastern Idaho. American Water Resources Association, Water Resources Bulletin 31 (1):79-95.

Oregon, State of. 1996. Oregon Plan for Salmon and Watersheds including Oregon's Coastal Salmon Restoration Initiative (OCSRI) and Steelhead Supplement. http://www.oregon-plan.org/

USDA (US Department of Agriculture) Soil Conservation Service. 1986. Urban Hydrology for Small Watersheds. Technical Release 55.

Washington State Forest Practices Board. 1997. Standard Methodology for Conducting Watershed Analysis Under Chapter 222-22 WAC. Version 4.0. Olympia, Washington.

WATERSHED CHARACTERIZATION OF TEMPERATURE – UMPQUA BASIN[1]

The screening procedure described in the Water Quality Assessment component will often raise further questions about the spatial distribution of temperature exceedances in the watershed. A more detailed watershed characterization, such as described here, can be used to answer these questions. The Elk Creek Temperature Study (Umpqua Basin Watershed Council 1998) provides a good example of how to conduct and interpret data from a more comprehensive study.

The Oregon temperature criteria is measured as the 7-day moving average of the maximum daily temperatures. The reason for using a moving average in the water quality standards is to decrease the effect of a single peak temperature on data interpretation. Aquatic organisms are affected more by exposure to high temperature over an extended period than to a single excursion over the criteria. As noted in this study, the seasonal maximum temperature was, for this particular watershed and season, consistently about 3°F higher than the 7-day moving average. This finding shows the utility of using the simpler daily maximum of 64°F as a screening tool, as described in the watershed assessment manual.

Study Area

The Elk Creek Watershed is located in southwestern Oregon in Douglas County. The watershed is approximately 350 square miles in size and is primarily in private ownership: 40% private ownership, 40 % private commercial forestland, and 20% federal. Elevation ranges from 90 feet at the mouth to 2,000 feet at the top of the watershed. The vegetation is typical of southwest Oregon: the forest lands are dominantly Douglas fir; the riparian areas contain alder, willow, and cottonwood. Vegetative recovery of disturbed areas is relatively rapid in the form of woody brush and grass.

Objectives

The objectives of the study were to provide an understanding of how temperature varies spatially throughout the watershed, provide data for the evaluation of aquatic habitat, and develop a database for development of a Temperature Management Plan for the watershed.

Methods

The Elk Creek study used an intensive monitoring approach during one field season to eliminate the between-year variability. Twenty-eight sites were chosen to obtain a representative sample of various stream types and conditions throughout the watershed. Continuous temperature data loggers were set to record data every 20 minutes from July 1 through the end of September. Quality control procedures included the following: (1) calibration of each unit against a reference thermometer at two different temperatures both before deployment and after retrieval of the units, (2) photo documentation of each site saved in digital format, (3) standardized field data sheets, and (4) field verification of data logger temperature against the reference thermometer. The accuracy assessments indicated that all data loggers remained within 0.3°F of the reference temperature during the study period.

[1] Elk Cr. Temperature Study. Courtesy of Umpqua Basin Watershed Council and Insight Consultants, Roseburg, Oregon.

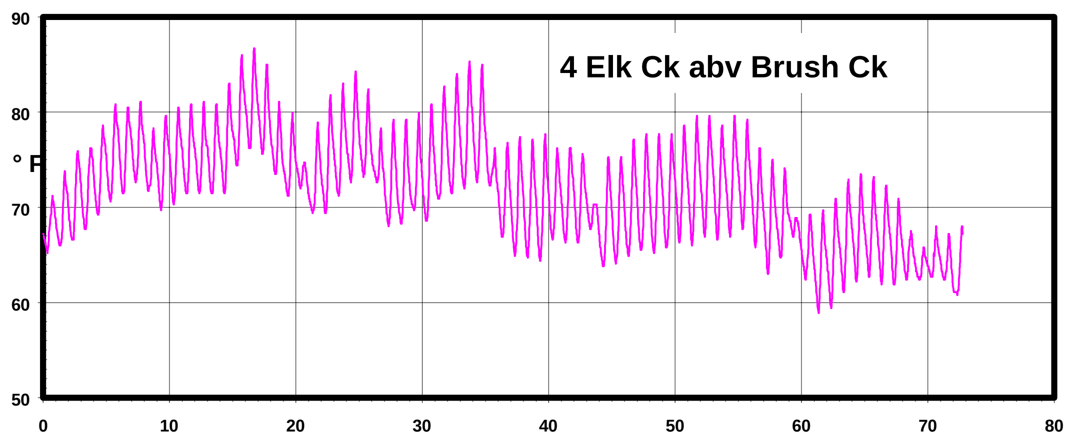
Results

Figure 1 is an example monitoring site data sheet from the report. It contains relevant information about the site as well as a chart of the raw temperature data. These charts are useful in finding anomalies in the data and making general comparisons between stations.

The second chart (Figure 2) shows a summary of some useful statistics for all the stations which includes the seasonal maximum temperature, the 7-day average maximum temperature, and the daily change in temperature.

Project Name: ELK CREEK TEMPERATURE 1998

Temperature Logger ID:	6048	Site Name:	4 Elk Ck abv Brush Ck
Logger Type:	Vemco	River Basin:	Umpqua - Main Stem
Data File Name:	Elk Creek 98	Watershed:	Elk Creek
Deployment Date:	7/8/98	Site Latitude:	43° 39.698
Sample Interval:	20 Minutes	Site Longitude:	123° 29.463
Unit Retrieval Date:	9/22/98	Elevation:	178 ft
		Distance to Mouth:	11.90 Miles
		Distance to Headwater:	32.7 Miles
		Collected by:	InSight



Start Date: 7/11/1998 **Day #** **Stop Date: 9/21/1998**

Key Statistics: [Produced by DEQ "Tempture" Program]

	Date	Day #	Value
Seasonal Maximum:	7/27/98	16	86.7
Seasonal Minimum:	9/10/98	61	58.9
Maximum ΔT:	8/31/98	51	13.6
Max 7-Day Average:	7/26/98	15	83.4

Checks:	Date	Status
Pre-deployment:	7/3/98	OK
Audit:	8/15/98	OK
Post-deployment:	9/25/98	OK

Location Details:

Channel width about 60 feet
cobble /gravel channel bed
continuous riffle
Unit depth 1 ft.

Figure 1. Example data sheet and chart of temperature in degrees Fahrenheit.

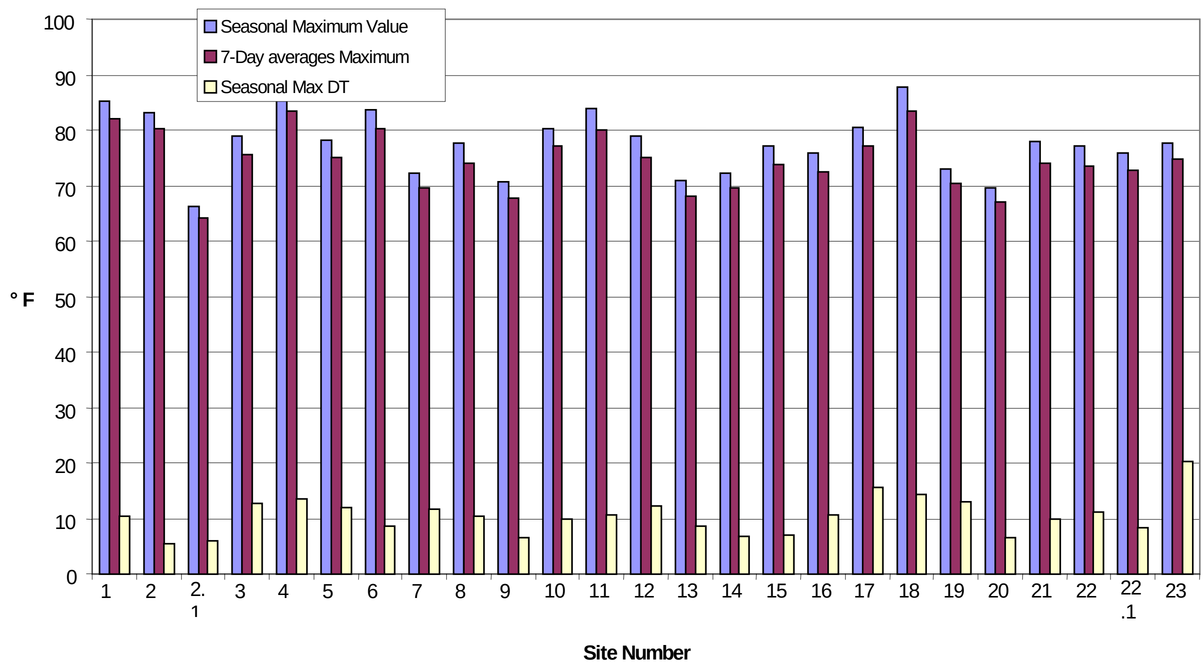


Figure 2. Station summary of maximum seasonal temperature, 7-day moving average of maximum daily temperatures, and maximum daily change in temperature.

Discussion

This study provides data to better understand how stream temperature varies both seasonally and daily at various points within a watershed. This information, when tied to observations on channel conditions, shade, canopy, and riparian vegetation, can be used to make viable recommendations for developing a temperature management strategy. The study identified tributaries that consistently contributed cooler water to Elk Creek: These tributaries may be important in moderating temperature and providing cool water refuges for fish. The downstream change in temperature also showed areas of significant heating or cooling. Areas with temperature gain can be further investigated to identify the specific reason for higher temperatures (e.g., wide shallow channels, reduced canopy) and potential site-specific solutions. The areas of cool water may serve as important holding areas for juvenile and adult fish, and can be identified for protection as part of the watershed restoration plan.

The database associated with this project provides an opportunity to develop other statistics and test stream temperature modeling efforts. For example, there may be an interest in the average daily temperature for a site. This statistic could be calculated from the data and used to calibrate temperature models such as SSTEMP, which predicts mean daily temperature for different conditions.

Component IX
Fish and Fish Habitat Assessment

Table of Contents

Table of Contents (continued)

Component IX
Fish and Fish Habitat Assessment

INTRODUCTION

This component of the Oregon Watershed Assessment Manual helps the user compile and evaluate available information on fish populations, in-stream habitat, and migration barriers through the following four-step process:

1. Document the temporal distribution and abundance of fish species within the watershed.

2. Identify potential interactions between species of concern, such as those species listed under the Endangered Species Act (ESA).

3. Compile existing Oregon Department of Fish and Wildlife (ODFW) and other habitat data that have been collected on the watershed, and compare them with established ODFW benchmarks to provide an evaluation of in-stream habitat conditions.

4. Identify and prioritize human-caused barriers to fish passage in the watershed.

The information gathered in this component is then integrated into the Watershed Condition Evaluation, where users evaluate impacts to important areas of current fish use and habitat.

Critical Questions

1. What fish species are documented in the watershed? Are any of these currently state- or federally listed as endangered or candidate species? Are there any fish species that historically occurred in the watershed which no longer occur there?

2. What is the distribution, relative abundance, and population status of **salmonid** [1]species in the watershed?

3. Which salmonid species are native to the watershed, and which have been introduced to the watershed?

4. Are there potential interactions between native and introduced species?

5. What is the condition of fish habitat in the watershed (by sub-basin) according to existing habitat data?

6. Where are potential barriers to fish migration?

[1] Terms found in bold italic throughout the text are defined in the Glossary at the end of this component.

Assumptions

- Salmonid fish are typically the most sensitive fish species occurring within a stream network. If habitat conditions are suitable for salmonid fish, then they reflect “good” habitat conditions for the watershed.

- Fish distribution is a function of the quantity and quality of habitat types available in the watershed. **Channel Habitat Types** (CHTs) have predictable habitat conditions that influence the potential fish use within a **stream reach**. The distribution of fish species in a watershed is a function of the distribution and condition of the CHTs found there.

Materials Needed

This assessment relies on finding and compiling existing information to develop distribution maps for **resident** and **anadromous** salmonid fish. You will need to have the following items handy:

- Any available fisheries information for the watershed, including basin plans, data reports, etc.

- A copy of historical fish information from the Historical Conditions Assessment component

- Forms found in Appendix IX-D

- A copy of the CHT map (from the Channel Habitat Type Classification component)

- Two or three copies of watershed base maps (from Start-Up and Identification of Issues component) (two copies for watersheds with only resident fish, three copies if watershed has resident and anadromous fish)

- Habitat survey data from ODFW, US Forest Service (USFS), Bureau of Land Management (BLM), Oregon Forest Industry Council (OFIC) or others

The Fish Information sidebars on this page and the next will help you gather information.

FISH INFORMATION CONTACTS

Oregon Department of Fish and Wildlife

General Information:
(503) 229-5222

Home Page:
http://www.dfw.state.or.us

Regional Offices:
Northwest Region, Corvallis
(541) 757-4186

Southwest Region, Roseburg
(541) 440-3353

Central Region, Bend
(503) 388-6363

Northeast Region, LaGrande
(541) 963-2138

Southwest Region, Ontario
(541) 573-6582

Marine Region, Newport
(541) 867-4741

Columbia Region, Clackamas
(503) 657-2000

Oregon Department of Forestry

Northwest Area, Forest Grove
(503) 357-2192

Southern Area, Roseburg
(541) 440-3412

Eastern Area, Prineville
(541) 447-5658

Necessary Skills

This assessment does not require any specialized skills. It is helpful to have a persistent nature to track down and sort through information from a wide variety of sources.

Field evaluations of road crossings require the physical ability to scramble down potentially steep road embankments and take measurements. Field work also will require use of a level and **stadia rod** to measure culvert elevations.

Final Products of the Fish and Fish Habitat Component

This assessment will result in the following completed forms and maps:

- Form F-1: Fisheries Information Summary
- Form F-2: Habitat Condition Summary
- Form F-3: Fish Passage Evaluation
- Form F-4: Fish Passage Field Assessment (optional)
- Form F-5: Confidence Evaluation
- Map F-1a: Resident Fish Distribution (current and historical)
- Map F-1b: Anadromous Fish Distribution (current and historical)
- Map F-2: Migration Barrier Identification

ASSESSMENT METHODOLOGY

Step 1: Identify Fish Species and Populations (Form F-1)

The goal of this step is to compile all available information on fish that are documented to occur in the watershed, and to evaluate the status of the fish populations. With this information, you can start thinking about the habitat needs of the watershed's fish species, document when anadromous fish occur in the watershed, and help identify which species have the lowest population

FISH POPULATION AND DISTRIBUTION INFORMATION

- **Oregon Plan**: Anadromous fish core area and distribution information is available in the Oregon Plan (Chapter 15). This can be accessed through the ODFW Web site. http://www.dfw.state.or.us/
- **ODFW Basin Plans**: These reports are in various stages of completion and some plans may be outdated. Nevertheless, these are often the most accessible source of information relevant to fish management. ODFW District Offices should have copies of the plans as appropriate to their basins, or contact ODFW, Basin Planning Coordinator at (503) 872-5252, x 5421.
- **Biennial Report on the Status of Wild Fish in Oregon**: This report includes information on all wild freshwater and estuarine fish species in Oregon. Most of the report comes from ODFW files, particularly annual reports filed by ODFW district biologists or from research projects. This report can be accessed through the ODFW home page at http://www.dfw.state.or.us under Research and Reports. These reports also contain some information on historic abundance and distribution.
- **Bull Trout Distribution**: This information is available on GIS and can be accessed through the ODFW Web site. This information will not apply to coastal watersheds or private lands. Contact ODFW at (503) 872-5252 x 5602.
- **Other Trout and Steelhead Distribution**: Contact ODFW at (503) 872-5252, x 5412.
- **Stocking History**: The records from 1983 are in a database. The codes they used to identify the location of stocking are unique to the hatchery; it may be difficult to access all information specific to your watershed. Contact ODFW at (503) 872-5252, x 5415.
- **Migration Barriers and Culverts**: This data is in several places and you will have to make multiple phone calls to locate what if anything is available for your watershed. For fish passage information, contact (503) 872-5252 x 5582; for culvert information, (503) 872-5252 x 5590; for ODFW Coho Spawning Project, (541) 737-7636.

numbers or may be the most sensitive.

The sources listed in the sidebar on page 5 will provide a good start toward compiling the information you need. They may also be able to point you to other sources. Find as much information as you can, then sit down and complete Form F-1 with as much detail as possible. The form may collect duplicate information, so be sure to note if the information recorded on the form can be found in multiple sources. Make notes of any conflicting information. Where you do not have any information, you may need to interview local OFDW and other agency (i.e., USFS, BLM, etc.) fish biologists.

Form F-1: Species of Concern, Fish Presence, and Population Status

Item 1 in Form F-1 asks for information on species of concern, including ESA and ODFW status, and population trends. Item 2 documents whether any species that historically occurred in the watershed are no longer found. Various sources listed in the sidebar contain current and historic fish distribution information. Usually, ODFW basin plans are the best source of this information. Your local ODFW fish biologist should able to help acquire and sort through the data.

Consult with the assessment team member performing the Start-Up and Identification of Watershed Issues component for a list of species in the watershed compiled using the Natural Heritage Database. In addition, look for the ODFW's comprehensive review of threatened, endangered, and sensitive (TES) species (terrestrial and aquatic). This ODFW project is no longer active, but copies of the report are available from the ODFW's Fish Conservation Program Leader, (503) 872-5242, extension 5405.

Form F-1: Stocking History

The goal of Item 3, Form 1 is to summarize what species have been stocked in the watershed and how extensive the stocking efforts were/are. This information will help identify potential interactions between native and stocked species, and help you understand if hatchery fish have an influence on current population trends. ODFW basin plans are usually the best source for this type of summary information, although such information may not be up-to-date. Table 1 provides an example of a completed stocking history summary.

Form F-1: Life History Patterns, Important Habitat Areas

Items 4 and 5 of Form 1 ask for information about the timing of anadromous and resident fish spawning and migration. Again, this information can be found in the local basin plan or other ODFW documents. This information will help you understand how and when fish use specific portions of the watershed. This knowledge may be important when planning the timing of specific development or enhancement activities. Table 2 provides an example record of fish life history patterns from Big Elk Watershed in the Yaquina Basin.

Table 1. Example of a completed stocking history summary.

Species	Stocking Notes	Native or Exotic?	Source
Chinook	Historically 1902–1990		Yaquina River Basin Plan
Coho	Historically 1902–1990		Yaquina River Basin Plan
Steelhead	1905–1939 Average 31,000 smolts/year since 1978		Yaquina River Basin Plan
Cutthroat	Historically 1925-1960		Yaquina River Basin Plan
Pink Salmon	Historically 1977–1982 (OSU Experiment)	Exotic	Yaquina River Basin Plan
Rainbow Trout	Historically 1950– 58, no resident rainbows present		Yaquina River Basin Plan
Brook Trout	Historically stocked in 1904, no longer present	Exotic	Yaquina River Basin Plan
American Shad	Stocked in Columbia 1800s, later became established in Yaquina	Exotic	Yaquina River Basin Plan

Notes: Hatchery at Elk City 1902–1950, OreAqua Hatchery 1974 – 1990

Table 2. Example summary of fish life history patterns.

Species	A-Anadromous R-Resident	Location	Spawning	Outmigration
Chinook	A – fall	Mainstem, lower reaches of large tributaries	Oct. to Jan., peak in Nov.	June/July to estuary Summer/fall to ocean as under-yearling smolts
Coho	A – fall	Low-gradient tributaries	Nov. to Feb.	2nd spring after hatching, peak in May; limited estuary time
Steelhead	A – winter	Low-/moderate-gradient tributaries	Oct. to March, peak Dec. and Jan.	2 to 3 years in freshwater, outmigrate in March to June*
Cutthroat	A – summer/fall R Fluvial	1st and 2nd order tributaries	Dec., peaks in Feb.*	Age 1+ and 2+ fish outmigrate April or May to estuary/tidewater Age 3 fish go to ocean in May Adults overwinter in estuaries of origin*

* Based on information from Alsea Watershed; local data not available.

Form F-1: Known Migration Barriers

The initial data compilation and search will likely turn up some information on known migration barriers. Indicate these in item 7 of Form F-1 and mark them on the draft fish distribution maps.

During the assessment of potential migration barriers, you will work with the Sediment Sources analyst to map and identify potential fish passage barriers.

Form F-1: Species Interactions

Did you answer yes to question 7 on Form F-1? If so the following species interactions may be occurring. Consult with the regional ODFW fisheries biologist to determine the potential extent of the following species interactions.

- Brook trout/bull trout (competition, interbreeding)
- Rainbow/cutthroat (competition/ interbreeding)
- Hatchery/wild-stock interactions

Step 2: Create Fish Distribution Maps

After you've collected all the pertinent information for Form F-1, you are ready to create the fish distribution maps. These color-coded maps will visually document where fish are known to occur in the watershed and where areas of important habitat occur. This information will help the watershed council evaluate how potential impacts may or may not affect fish habitat, and will help visually illustrate where enhancement activities may have the greatest benefit. If your watershed has anadromous and more than one species of resident fish, you may want to make one map for anadromous fish distributions (Map F-1a) and one for resident fish (Map F-1b). Typically, the base map you are using will be the Oregon Department of Forestry (ODF) stream classification maps, which show the upstream extent of fish utilization. Be aware that these maps are not always based on current data, and you may want to ask local ODFW or ODF staff if any recent data collection has been performed to validate the mapped information. In addition, these maps do not identify fish species; look for fish species information in the raw data or talk to local fish biologists and make an educated guess about which fish species potentially occur.

Not only may data sources be outdated or inaccurate, you may find that specific distribution information is simply not available. Creating a fish distribution map will help you identify such data gaps. As a first cut, look at all available information and indicate what is known on the draft maps. It is often useful to take a copy of the map to local fish biologists and ask them to indicate what they know about the fish distributions. Typically, the upstream extent of fish utilization by species has not been identified or mapped, but you can make an educated guess at where these fish may occur in the watershed by using the CHT map and general information about the species occurring in the watershed (see Introduction). Table 3 summarizes potential fish use within each CHT. This information can help you make decisions on potential fish distributions within the watershed.

Once you have developed a draft map you will probably have numerous questions to ask local ODFW, USFS, or other agency fish biologists who have worked in the watershed. They can help review the data you have compiled, and make the necessary judgment calls in developing the fish distribution maps. They can also provide insight on locations of important spawning and rearing areas. Usually it is more effective to develop a draft map before asking for help; it is easier to discuss key locations with a map in front of you. If the information on current and historical fish distributions is significantly different, place a footnote on the map explaining the reasons. Figure 1 shows an example of a completed map from a coastal watershed.

Table 3. Potential fish utilization of Channel Habitat Types.

Channel Habitat Type	Gradient Range	Oregon Stream Size	Additional Description	Fish Use
Low gradient large floodplain (FP1)	1%	Large	Lowland and valley bottom channels; can include small adjacent wetlands	**Anadromous**[1]: Important[2] spawning, rearing, and migration corridor **Resident:**[3]: Important spawning, rearing, and overwintering
Low gradient medium floodplain (FP2)	<u><</u>2%	Large to medium	Mainstem streams in broad valley bottoms	**Anadromous**: Important spawning, rearing, and migration corridor **Resident**: Important spawning, rearing, and overwintering
Low gradient small floodplain (FP3)	<u><</u>2%	Small to medium	Low-gradient floodplain channels occupy the floodplains of larger streams	**Anadromous**: Important spawning, rearing, and migration corridor **Resident**: Important spawning, rearing, and overwintering
Alluvial fan (AF)	1-12%	Small to medium	Transition from steep mountain slopes to valley floor	**Anadromous**: Important rearing, migration corridor; potential[4] spawning in lower gradients **Resident**: Important spawning and rearing
Low gradient moderately confined (LM)	<2%	Usually medium to large	Alternating hillslopes and terraces limit floodplain	**Anadromous**: Potential spawning and rearing **Resident**: Potential spawning, rearing, and overwintering
Low gradient confined (LC)	<2%	Usually medium to large	Relatively straight channel, limited floodplain; partial or complete barriers may occur at bedrock knickpoints	**Anadromous**: Potential spawning and rearing **Resident**: Potential spawning, rearing, and overwintering
Moderate gradient moderately confined (MM)	2-4%	Usually medium to large	Limited floodplain; bedrock steps with cascades may form partial or complete barriers	**Anadromous**: Potential steelhead and coho spawning and rearing; limited[5] chinook **Resident**: Potential spawning, rearing, and overwintering
Moderate gradient confined (MC)	2-4, 6%	Variable	Narrow open to moderate V-shaped valley; hillslope or terrace confined	**Anadromous**: Potential steelhead and coho spawning and rearing; limited chinook **Resident**: Potential spawning, rearing, and overwintering
Moderate gradient headwater (MH)	1-6%	Small	Common to plateaus or broad drainage divides; sites of headwater beaver ponds	**Anadromous**: Potential steelhead and coho spawning and rearing; limited chinook **Resident**: Potential spawning, rearing, and overwintering
Moderately steep narrow valley (MV)	4-8%	Small to medium	Narrow valley	**Anadromous**: Potential steelhead, coho, sea-run cut spawning and rearing **Resident**: Potential spawning, rearing, and overwintering
Bedrock canyon (BC)	>4%	Variable	Very narrow V-shaped channel; migration barriers, may be anywhere	**Anadromous**: Lower-gradient areas provide limited rearing (if accessible) **Resident**: Limited resident spawning and rearing
Steep narrow valley (SV)	8-16%	Small		**Anadromous**: Lower-gradient areas provide limited rearing (if accessible) **Resident**: Limited resident spawning and rearing
Very steep headwater tributaries (VH)	>16%	Small		**Resident**: Very limited rearing

1 **Anadromous** refers to chinook, coho, steelhead, and sea-run cutthroat trout unless specifically stated.
2 **Important** designates CHTs that potentially contain large areas of preferred habitat conditions.
3 **Resident** refers to native redband, cutthroat trout and/or bull trout.
4 **Potential** designates CHTs that may have suitable habitat conditions depending on site-specific factors.
5 **Limited** designated CHTs that may have pockets of suitable habitat conditions depending on site-specific factors.

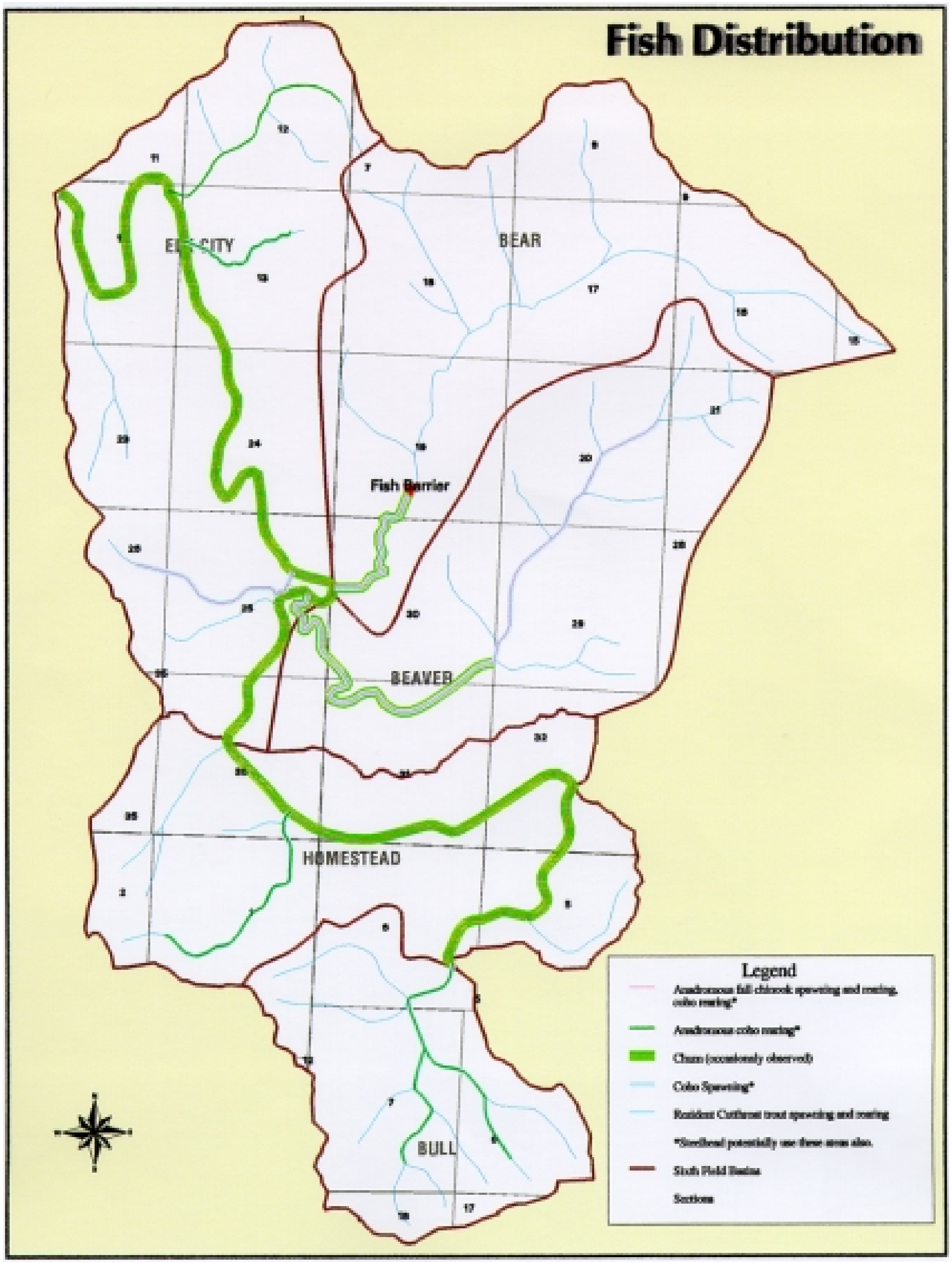


Figure 1. An example of a completed map from a coastal watershed.

Step 3: Complete Habitat Condition Summary (Form F-2)

In this step, you will compile existing ODFW fish habitat data. The ODFW has developed a standard stream habitat survey methodology (Moore et al. 1997). ODFW, ODF, and large private landowners have used this methodology to collect extensive amounts of fish habitat data. Data collected in cooperation with ODFW is available in **Geographic Information Systems** (GIS) format from the ODFW Web site, or can be obtained in a spreadsheet format by calling the Habitat Division of ODFW at (541) 757-4263. The assessment will be most straightforward if you request the data summary files, and the maps showing the locations of sampled segments.

The approach presented here provides a format for organizing the data and determining how habitat conditions vary throughout the watershed, and for comparing watershed conditions with "benchmark" conditions for the State of Oregon. This comparison allows you to look for patterns in habitat conditions throughout the watershed or to identify specific portions of the watershed where problems may exist. For example, in the Big Elk watershed habitat condition summary (Appendix IX-B) there are low numbers of large wood throughout the watershed, a condition which also appears to contribute to a lack of **complex pools**. In addition, in the Wolf Creek sub-watershed reach #4 pool conditions ranked as undesirable conditions, indicating a need to revisit that stream reach and determine if there are site-specific conditions to explain this data.

> CAUTION: Stream survey data is like a single photograph of a dynamic system. Stream channel conditions may change drastically between years, especially if there has been a high-flow flood event. Also, the survey methodology has evolved, and older data may have been collected using slightly different methodologies. It is important to be aware of changes that may have occurred in the stream system; the analysts of the Hydrology and Water Use, Riparian/Wetlands, and Sediment Sources assessment components can provide insights. In addition, some surveyed stream reaches have been found to be inconsistently sampled, and the summary data do not necessarily reflect actual conditions. If the condition evaluations based on comparisons to benchmark conditions do not seem to fit with observed conditions, then those reaches and parameters should be identified for field verification.
>
> Also remember that the CHT breaks may not correspond with ODFW reaches. If a reach includes more than one of your preliminary segment breaks, or extends beyond an obvious change in channel gradient or **confinement**, then you can report the summary information for the combined CHT classifications. If you are comfortable with doing spreadsheet analyses, you can consult the line-by-line field data for the stream and break it at the CHT breaks, then resummarize the data.

Forms F-2a, b, and c are organized to follow the general format of the ODFW data summary files and use the same column headings as you will find in the ODFW files. Form F-2a summarizes pool conditions, F-2b summarizes **riffle** and woody debris conditions, and Form F-2c summarizes **riparian** conditions. If you collect extensive data, you may wish to fill out a separate set of forms for each subwatershed. You will need to provide an overall pool rating: Using the most current benchmark values for your area, indicate whether the sampled conditions fall into the undesirable (U), desirable (D), or in-between range (B) (Appendix IX-A). The overall condition rating is developed using the following criteria:

- **Desirable (D)**: All parameters rated desirable or in-between
- **Between (B)**: Parameter ratings were mixed
- **Undesirable (U)**: Most of the parameters rated undesirable
- **ND**: No data

After you have completed a summary for a watershed or subwatershed, you can examine the data for trends. Is there one parameter that consistently rates undesirable or desirable? Is there one reach that has consistently good or bad conditions? Make notes of any general trends or conclusions you see in the data (see guidelines in ODFW Habitat Benchmarks sidebar). This summary will be used in the Watershed Condition Evaluation. Appendix IX-B provides examples of completed summary forms and illustrates the types of general conclusions that can be drawn from the data.

If you use data that was not collected using the ODFW protocol (i.e., from USFS or BLM), you will need to look at the collection methods and decide if the parameters are comparable. You may need to enlist the local ODFW fish biologist for assistance in determining how to complete an evaluation of habitat conditions for other data sets.

ODFW HABITAT BENCHMARKS

The ODFW habitat benchmark values (Appendix IX-A) are designed to provide an initial context for evaluating measures of habitat quality. While the natural regime of a stream depends on climate, geology, vegetation, and disturbance history, it is useful to know whether a value of a habitat feature in a reach of stream is high or low. For example, knowing whether a reach has a lot of large woody debris (LWD) or fine sediments is useful for understanding the condition of aquatic habitat and its influence on the life history of fishes. The determination of whether the "value" of a habitat feature is "good" or "bad" depends on the natural regime of the stream and the fish species of interest. The habitat benchmark values for desirable and undesirable conditions are derived from a variety of sources. Values for specific parameters were derived for appropriate stream gradient, and regional and geologic groupings of reach data (see Moore et al. 1997). This assessment is designed to look at combinations of features rather than to single out individual values. This approach should help identify patterns within these features that can then be interpreted in a broader watershed context.

The benchmark values of habitat features are listed as desirable or undesirable, but we emphasize that the values should be viewed on a sliding scale, and that the watershed context should be considered. For example, eight pieces of LWD per 100 meters may be very low for a stream in the Cascade Mountains, but extremely high for a stream in the high desert of southeast Oregon. The stream must be viewed within its natural environment. Similarly, a reach in the Cascade Mountains may have eight pieces of LWD per 100 meters, but neighboring reaches may have 25 pieces of LWD per 100 meters. Variability within a watershed may reflect normal disturbance and hydrologic cycles in addition to management history. The assessment of habitat conditions should look to other components of the watershed assessment to find if there are historic or current activities influencing these measures. This provides the basis for linking the findings from the broader assessments of upslope and upstream activities and impacts to actual in-channel conditions.

Step 4: Migration Barrier Identification (Forms F-3 and F-4)

Stream channel crossings by roads have been the cause of serious losses of fish habitat due to improperly designed culverts. Assessment of migration barriers is important, because anadromous salmonids migrate upstream and downstream during their lifecycles; in addition, many resident salmonids and other fish move extensively upstream and downstream to seek food, shelter, better water quality, and spawning areas. Where these barriers occur, fish can no longer reach suitable habitats. By reducing the amount of accessible habitat in a watershed, fish populations may be limited.

Culvert road crossings can create barriers to fish migration in the following ways (Figure 2):

- Culvert is too high for the fish to jump into.
- The water velocity in the culvert is too fast for the fish to swim against.
- The water in the culvert is not deep enough for the fish to swim, or has a disorienting turbulent flow pattern, making it difficult for fish to find their way through.
- There is no pool below the culvert for the fish to use for jumping and resting, so they cannot make it into the culvert, or there are no resting pools above the culvert, so the fish are washed back downstream.

A combination of these conditions may also impede fish passage. It is not always clear when a culvert blocks fish passage. Some culverts may be velocity barriers during high flows but pass fish successfully during low flows. Other culverts may not be deep enough during summer low flows to pass fish, but fish can pass successfully during higher flows. Large, adult anadromous fish may be able to pass through culverts that are total barriers to smaller juvenile or resident fish. For these reasons it is important to understand what fish species occur in the watershed and when they will be migrating.

In this step of the fish assessment, you will map and document what is known about the road crossings in the watershed. This information will provide the basis for evaluating where fish passage barriers potentially occur, and will help prioritize efforts to survey and/or replace problem culverts.

Create Stream Crossing Map

The Sediment Sources Assessment component will create an updated road map that identifies all known road crossings of streams. Obtain a copy of the this map from the Sediment Sources analyst and label is Map F-2: Migration Barriers. The Sediment Sources analyst also may have developed a spreadsheet numbering system for all road crossings. This spreadsheet will be a good tool to help consistently compile data on road crossings. All road crossings should be considered potential fish passage barriers until field-verified. Develop a color-coding system to identify bridges and culverts, and then classify the culvert crossings as definitive barriers, potential barriers, passable, or unknown.

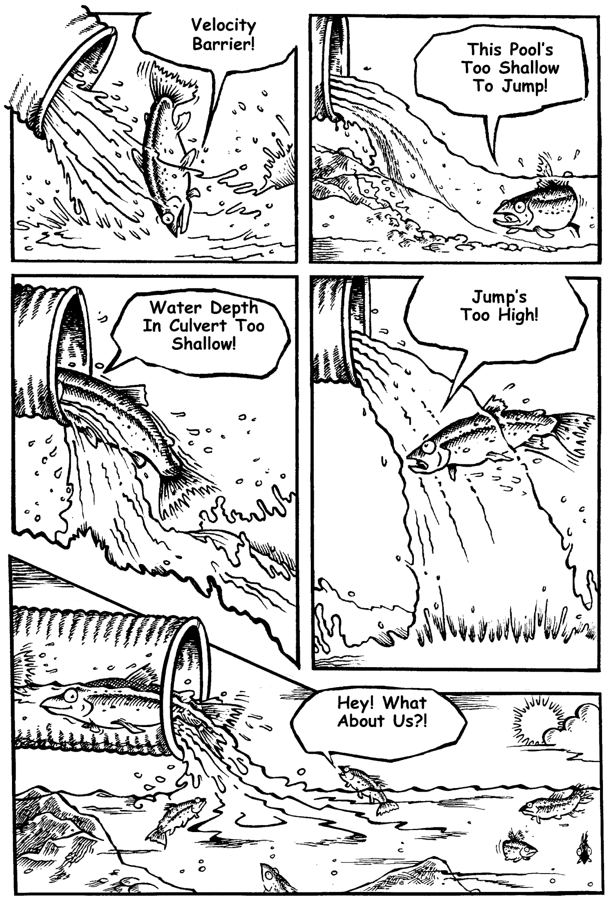


Figure 2. Culverts under roads can block fish passage through a number of factors, including excessive water velocity, insufficient depth, excessively high jumps, or a combination of these factors.

The ODFW data on stream crossings and culverts may note which crossings have been field-verified; however, these data are not typically available for an entire watershed. The Sediment Sources analyst may have compiled information from private landowners or other sources on the condition of road crossings. Check with other analysts to see what they have found on the condition of road crossings. From the information summarized on Form F-1 and compiled from other analysts, mark the locations of all known fish passage barriers (natural and man-made) and all crossings that have been checked and are passable on Map F-2. Incorporate this information into your crossing summary database on Form F-3, Fish Passage Evaluation.

Determine Crossing Status

Culverts come in round, square, elliptical, and other shapes. Culverts can be made of various materials, including concrete, but metal pipe is the most common material. Because of the variability in culvert type and design, it is often difficult to definitively determine if a culvert blocks fish passage. Table 4 summarizes basic criteria for determining fish passage based on ODF guidance (Robison 1997). Table 4a lists the culvert conditions that would block passage of juvenile salmonid fish, defined by ODF as "impeding fish passage." Table 4b lists the culvert conditions that would block passage of most adult fish. It is important to remember that these criteria are not minimum values; they describe the conditions in which passage of most fish is blocked. Other conditions may still prevent some fish from passing through a specific culvert.

Comparing these criteria to culvert conditions summarized on Form F-3 and using the fish distribution map, rate each road crossing as a juvenile barrier (JB), adult barrier (AB), potential partial/seasonal barrier (PB), passable (P), or unknown (U). You will also list on Form F-3 which species are blocked.

If time allows, you may field-verify those road crossings for which no data exist. Form F-4 provides a form for field verification of road crossings; this form is based on the ODFW Culvert Evaluation Form. Any field effort should start with a check of road crossings that are in the lower portion of the stream network, and then continue upstream.

Table 4. Criteria for determining fish passage through culverts.

a. Impeding Fish Passage Criteria (blocking juvenile salmonid fish passage)

- Velocity ≤ 2 feet per second
- Outlet perching ≤ 6 inches with little or no inlet constriction or drop
- Flow depth ≥ 12 inches, or streambed conditions similar to the natural channel
- Free from debris that may concentrate flows and increase velocities

	Bare (nonembedded culverts)	**Embedded Culverts**	**Baffled Culverts**
Slope	< 0.5% (unless backwatered – see Robison 1997).	At grade – with material simulating natural channel. Material should be > 1 foot deep.	See Robison 1997 for specific design criteria.
Outlet Drop	< 6 inches, with residual pool 1.5 times deeper than the jump.	None.	< 6 inches, with residual pool 1.5 times deeper than the jump.
Inlet Condition	Diameter >1/2 bankfull channel width; no inlet drop.	Width 2/3 bankfull channel width, with tapering material, not a sudden drop.	Little or no inlet drop. Top wier should backwater into upstream natural channel.
Length	< 100 feet long.		
Outlet Backwatering	Minimum 8 inches deep at baseflows.		

b. Fish-Blockage Criteria

- Velocity ≤ 10 feet per second
- Outlet perching ≤ 4 feet with adequate jump pool
- Outlet perching ≤ 1 foot without adequate jump pool
- Severe inlet constriction or drop
- Flow depth ≥ 8 inches, or streambed conditions similar to the natural channel

	Bare (nonembedded culverts)	**Embedded Culverts**	**Baffled Culverts**
Slope	< 4% (unless backwatered or less than 50 ft long–see Robison 1997).	At grade – with material simulating natural channel. Material should be > 1 foot deep.	See Robison 1997 for specific design criteria.
Outlet Drop	< 4 feet, with residual pool 1.5 times deeper than the jump or 2 feet deep.	None.	< 4 feet, with residual pool 1.5 times deeper than the jump.
Inlet Condition		Width 2/3 bankfull channel width.	Little or no inlet drop. Top wier should backwater into upstream natural channel.
Length	< 200 feet long.		

The final task in the assessment will be to estimate the length of potential fish habitat upstream of the barriers. You can use a map wheel to measure the upstream extent of potential fish habitat; record this in the last column of Form F-3 (see example of completed form in Appendix IX-C). If you have been working with a spreadsheet program, it will be simple to sort the road crossings identified as barriers by the amount of habitat blocked. Prioritize remediation opportunities by listing those barriers that block the largest areas of fish habitat, and incorporate this priority list into the Watershed Condition Evaluation

Step 5: Evaluate Confidence in the Assessment (Form F-5)

You can evaluate the strength of your fish use and habitat assessment by considering the resources used, whether information was field-verified, and so on. Form F-5 provides criteria for the evaluation. If the type or quality of information used to map the fish distributions differs significantly from area to area, fill out one form for each general area.

REFERENCES

Moore, K.M.S., K.K. Jones, and J.M. Dambacher. 1997. Methods for stream habitat surveys. Oregon Department of Fish and Wildlife, Portland, Oregon.

Robison, G.E. 1997. Interim fish passage and culvert/bridge sizing guidance for road crossings. Oregon Department of Forestry Memorandum, Salem, Oregon.

GLOSSARY

anadromous fish: Fish that move from the sea to fresh water for reproduction.

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, **channel pattern**, and **confinement**. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

complex pool: Portion of stream with reduced velocity, a smooth surface, and deeper water; usually with undercut banks, thick bank vegetation and/or associated with large woody debris.

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

Geographic Information System (GIS): A computer system designed for storage, manipulation, and presentation of geographical information such as topography, elevation, geology etc.

resident fish: Nonmigratory fish that remain in the same stream network their entire lives.

riffle: Shallow section of stream or river with rapid current and a surface broken by gravel, rubble, or boulders.

riparian vegetation: Vegetation growing on or near the banks of a stream or other body of water in soils that are wet during some portion of the growing season. Includes areas in and near wetlands, floodplains, and valley bottoms. (from Meehan 1991)

salmonid: Fish of the family *Salmonidae*, including salmon, trout, char, whitefish, ciscoes, and grayling. Generally, the term refers mostly to salmon, trout, and char.

stadia rod: Surveying rod used for measuring changed in elevation from one point to another.

stream reach: A section of stream possessing similar physical features such as gradient and confinement; usually the length of stream between two tributaries.

Appendix IX-A
ODFW Habitat Benchmarks

APPENDIX IX-A: ODFW HABITAT BENCHMARKS

	UNDESIRABLE	DESIRABLE
POOLS		
Pool Area (% total stream area)	<10	>35
Pool Frequency (channel widths between pools)	>20	5-8
Residual Pool Depth		
Small Streams (<7-m width)	<0.2	>0.5
Medium Streams (≥7-m & <15-m width)		
Low Gradient (slope <3%)	<0.3	>0.6
High Gradient (slope >3%)	<0.5	>1.0
Large Streams (≥15-m width)	<0.8	>1.5
Complex Pools (pools w/wood complexity >3 km)	<1.0	>2.5
RIFFLES		
Width/Depth Ratio (active-channel based)		
East Side	>30	<10
West Side	>30	<15
Gravel (% area)	<15	≥35
Silt-Sand-Organics (% area)		
Volcanic Parent Material	>15	<8
Sedimentary Parent Material	>20	<10
Channel Gradient <1.5%	>25	<12
SHADE (reach average %)		
Stream Width <12 m		
West Side	<60	>70
Northeast	<50	>60
Central-Southwest	<40	>50
Stream Width >12 m		
West Side	<50	>60
Northeast	<40	>50
Central-Southeast	<30	>40
LARGE WOODY DEBRIS* (15 cm X 3 m min. size)		
Pieces/100-m Stream Length	<10	>20
Volume/100-m Stream Length	<20	>30
"Key" Pieces (>60-cm and 10-m long)/100 m	<1	>3
RIPARIAN CONIFERS (30 m from both sides)		
Number >20-in dbh/1,000-ft Stream Length	<150	>300
Number >35-in dbh/1,000-ft Stream Length	<75	>200

* Values for streams in forested basins

Appendix IX-B
Example Habitat Condition Summary Forms

Example Form F-2a: Pool Habitat Condition Summary Big Elk Watershed

Name: Karen Kuzis **Date:** September 1998 **Data Sources:** ODFW

Data Dates: Elk Creek & Spout Creek 1992, Devils Well 1995, Wolf Creek 1994

Rating Codes: D: Desirable**, U:** Undesirable**, B:** Between

Site	Length Sampled (Prichnll)	Lane Use (Luse1)	Gradient	CHT	Width	Pool Area		Pool Frequency		Residual Pool Depth		Complex Pools		Overall Pool Rating
						Pctpool	Bench-mark	CWpool	Bench-mark	Residpd	Bench-mark	Compool_km	Bench-mark	
Elk Creek 1	5687	ST	0.8	LC	18.7	16.2	B	16.2	B	1.6	D	0	U	B
Elk Creek 2	2420	ST	0.3	LC	12.6	75.8	D	15.7	B	1.3	D	0	U	D
Elk Creek 3	7719	MT	0.4	LC	15.6	57.7	D	8.4	B	1.2	B	0	U	B
Elk Creek 4	4082	HG	0.3	LC	16.7	47.7	D	9.1	B	1.3	B	0	U	B
Elk Creek 5	7628	MT	0.3	LC	15	56.2	D	6.2	D	1.3	B	0	U	D
Elk Creek 6	9861	LG	0.2	LC/LM	11	53	D	7.2	D	1.1	D	0	U	D
Spout Creek 1	2945	TH	1.3	LC	6.2	60.7	D	4.4	D	0.4	B	0	U	D
Spout Creek 2	1161	TH	0.8	LC	4.8	68.8	D	4.2	D	0.4	B	0	U	D
Spout Creek 3	1279	ST	1.1	LM	4.1	62.8	D	5.6	D	0.3	B	0	U	D
Spout Creek 4	1509	AG	0.5	LM	4.2	88.6	D	10.4	B	0.3	B	0	U	B
Spout Creek 5	1056	MT	1.8	LM	4.2	55.6	D	5.4	D	0.3	B	0	U	D
Spout Creek 6	1152	MT	0.4	LM/MV	5.4	92.4	D	5	D	0.2	B	0	U	D
Devils Well	1081	ST	4.1	MV	1.3	30.2	B	40.9	U	0.5	D	0	U	B
Wolf Creek 1	412	ST	1.1	LM/FP3	4.4	26	B	4.3	D	0.4	B	0	U	B
Wolf Creek 2	1060	LT	1.4	FP3	4.7	32.4	B	5.1	D	0.5	D	0	U	B
Wolf Creek 3	1059	OG	1.8	FP3	6.2	73.7	D	3.2	D	0.5	D	0	U	D
Wolf Creek 4	678	OG	3.1	FP3/LM	1.7	1.6	U	78.8	U	0.3	B	0	U	U
Wolf Creek Trib a 1	590	ST	3.3	LM	2.7	37.8	D	9.1	B	0.4	B	0	U	B
Wolf Creek Trib a 2	1716	ST	5.6	MC/MV	2.2	25.8	B	36.3	U	0.5	D	0	U	B

Conclusions:

- 60% of the sampled reaches are in the LC category.
- 54% of the sampled reaches have desirable pool conditions.
- 45% of the sampled reaches have in-between conditions.
- Complex pools were low in all reaches– related to general lack of large woody debris.
- Wolf Creek #4 is the only reach with undesirable conditions– may want to revisit data or field-verify site.

Example Form F-2b: Riffle and Woody Debris Habitat Condition Summary

Site	Width/Depth Ratio		Gravel (% area)		Silt-sand-organics (% area)		Overall Riffle Rating	LWD Pieces/100 m		Volume LWD/100m		Key Pieces/100 m		Overall LWD Rating
	WDratio	Bench-mark	Pctgravel	Bench-mark	Pctsndoc	Bench-mark		LWDpiece1	Bench-mark	LWDvol1	Bench-mark	KeyLWD 1	Bench -mark	
Elk Creek 1	90.5	U	15	B	22	B	B	4.1	U	2.8	U	0	U	U
Elk Creek 2	52.5	U	17	B	27	U	U	4	U	1.8	U	0	U	U
Elk Creek 3	45	U	9	U	12	D	U	3.1	U	2.7	U	0	U	U
Elk Creek 4	67.5	U	8	U	9	D	U	3.6	U	1.4	U	0	U	U
Elk Creek 5	78.5	U	8	U	11	D	U	5.4	U	2.9	U	0	U	U
Elk Creek 6	54	U	16	B	22	B	B	5.8	U	3.1	U	0	U	U
Spout Creek 1	51	U	10	U	16	B	U	7.7	U	4	U	0	U	U
Spout Creek 2	48	U	22	B	33	U	U	9	U	11.4	U	0	U	U
Spout Creek 3	31	U	14	U	29	U	U	7.2	U	3	U	0	U	U
Spout creek 4	22	B	26	B	53	U	B	4.3	U	2.3	U	0	U	U
Spout Creek 5	32	U	17	B	28	U	U	12.3	B	7.1	U	0	U	U
Spout Creek 6	11	B	18	B	74	U	B	8	U	5.8	U	0	U	U
Devils Well	32.2	U	27	B	51	U	U	6.8	U	8.4	U	0.2	U	U
Wolf Creek 1	20.9	B	34	B	44	U	B	7.5	U	5.8	U	0	U	U
Wolf Creek 2	0	?	21	B	37	U	U	15.5	B	9.8	U	0	U	U
Wolf Creek 3	24.8	B	15	U	82	U	U	9.5	U	7.8	U	0	U	U
Wolf Creek 4	0	?	48	D	18	B	B	4.9	U	8.2	U	0	U	U
Wolf Creek Trib a 1	28.4	B	18.0	B	23.0	U	B	5.8	U	3.7	U	0.00	U	U
Wolf Creek Trib a 2	20.2	B	29.0	B	42.0	U	B	7.4	U	7.1	U	0.20	U	U

Conclusions:

- All sampled reaches in all CHTs are deficient in LWD.
- Width:depth ratios are higher than anticipated throughout the watershed.
- The percent area of gravel is low everywhere except Wolf Creek #4 (which was the site deficient in pools). *High flow event in 1996 may have cleaned gravel – may want to spot-check*.
- The percent of sand-silt-organics is higher than desirable in all reaches.

Example Form F-2c: Riparian Habitat Condition Summary.

Site	CHT	Width	Conifers # >20-in dbh Con_20plus	Conifers # > 35-in dbh Con_36plus	Bench-mark	Opensky	Shade = 180-Open sky	Benchmark	Overall Riparian Benchmark	Bank Erosion Bankerosi*	Percent Secondary Channels Pctscchnls*
Elk Creek 1	LC	18.7	0	0	U	49	131	D	*	5.3	0
Elk Creek 2	LC	12.6	0	0	U	35	145	D	*	14	1.3
Elk Creek 3	LC	15.6	0	0	U	30	150	D	*	11.3	0.1
Elk Creek 4	LC	16.7	0	0	U	35	145	D	*	12.3	12.9
Elk Creek 5	LC	15	0	0	U	30	150	D	*	7.2	0.5
Elk Creek 6	LC/LM	11	0	0	U	30	150	D	*	45.7	1.4
Spout Creek 1	LC	6.2	0	0	U	9	171	D	*	28.8	0.7
Spout Creek 2	LC	4.8	0	0	U	12	168	D	*	38.8	0.5
Spout Creek 3	LM	4.1	0	0	U	3	177	D	*	54.6	2.1
Spout creek 4	LM	4.2	0	0	U	7	173	D	*	76.3	0.3
Spout Creek 5	LM	4.2	0	0	U	5	175	D	*	24.1	1
Spout Creek 6	LM/MV	5.4	0	0	U	11	169	D	*	5.7	33.5
Devils Well	MV	1.3	0	0	U	26	154	D	*	0	0
Wolf Creek 1	LM/FP3	4.4	0	0	U	31	149	D	*	37.6	0.6
Wolf Creek 2	FP3	4.7	42	0	U	14	166	D	*	17.4	1.1
Wolf Creek 3	FP3	6.2	30.1	30.1	U	33	147	D	*	4.3	9
Wolf Creek 4	FP3/LM	1.7	121	181	U	1	179	D	*	5.2	0.4
Wolf Creek Trib a 1	LM	2.7	0.0	0	U	3.0	177	D	*	22.3	1.6
Wolf Creek Trib a 2	MC/MV	2.2	0.0	0	U	15.0	165	D	*	1.1	0.5

* Benchmarks do not exist for these parameters; however they provide some interesting information on general observed conditions.

Conclusions:

- Low numbers of riparian conifers – check Riparian assessment to verify.
- Plenty of shade in all sampled reaches – check Riparian map.
- Spout Creek reaches have high bank erosion, Elk Creek #6 and Wolf Creek #1 (USFS notes recent bank erosion Elk Creek 1995, Lower Savage with high proportion of unstable banks).
- Spout Creek #6 and Elk Creek #4 have >10% secondary channels, indicating good complex habitat.

Appendix IX-C
Example Fish Passage Evaluation

Example Form F-3: Fish Passage Evaluation

Road Crossing Number	Crossing Type[1]	Crossing Slope	Outlet Drop	Outlet Pool Residual Depth	Inlet Drop	Inlet Diameter	Stream Bankfull Width	Crossing Length	Crossing Rating[2]	Species Blocked	Estimated Habitat Blocked
LBC01	B	na	na	na	na	na	40'	na	P	0	0
LBC 02	A	na	na	na	na	na	38'	na	P	0	0
LBC03	C	1%	10'	1.8'	0	72"	8'	50'	AB	Coho	2 miles
CC01	EC	4%	0	10"	0	18'	21'	60'	P	0	0
CC02	C	1%	3'	0	0	72"	7.5'	40'	AB	Cutthroat	0.25 miles
CC003	C	2%	1'	1'7"	0	8'	8'	15'	JB	Cutthroat	0.2 miles

1 Crossing Types: B-Bridge, A- Arch, BC-Bare Culvert, EC-Embedded Culvert, BC-Baffled Culvert

2 Crossing Ratings: JB-Juvenile Barrier, AB-Adult Barrier, PB-Potential Partial/Seasonal Barrier, P-Passable, U-Unknown

Appendix IX-D
Blank Forms

Form F-1: Fisheries Information Summary

Analyst's Name: **Date:**

This sheet summarizes key information about fish populations, important habitat areas, and the locations of known barriers. This information will provide the basic information needed for mapping fish distributions in the watershed.

1) List all salmonid or other fish species of concern occurring in the watershed:

Species	ESA Status	ODFW Status and Population Trends	Source (data quality)

Make notes on any documented or anecdotal changes in historic fish distribution (cite your sources):

____

____

____

____

____

____

2) List fish species that occurred historically in the watershed and are no longer present:

Species	Source

Form F-1: page 2

3) List species that have been or are currently stocked in the watershed:

Species	Stocking Notes	Native or Exotic?	Source

4) Identify life history patterns of key fish species:

Species	A-Anadromous R-Resident	Location	Spawning Timing	Outmigration Timing

Notes:

5) Identify important locations for adult holding, spawning, summer, and winter rearing:

Location	Species/Purpose	Source

Form F-1: page 3

6) Identify locations of known migration barriers:

Location (subwatershed, trib., site)	Barrier: Type: C- culvert, N-natural, D-dam	Source

7) Does the watershed contain the following combinations of fish?

- Brook trout/bull trout (competition, interbreeding) **YES NO**
- Rainbow/cutthroat (competition/ interbreeding) **YES NO**
- Hatchery/wild-stock interactions ? **YES NO**

If you answered yes to any of these items consult with a local ODFW fisheries biologist to determine the extent of the potential interactions. If this is unknown, more analysis may be warranted.

Notes:

____

____

____

____

____

____

Form F-2a: Pool Habitat Condition Summary

This form will be filled out for each subwatershed where ODFW or other comparable habitat data exist. Measured values are recorded and compared to rating criteria.

Analyst's Name: **Date** **Page** **of**

Subwatershed: **Data Sources:** **Data Dates:**

Site	Length Sampled (Prichnll)	Land Use (Luse1)	Gradient	CHT	Width	Pool Area		Pool Frequency		Residual Pool Depth		Complex Pools		Overall Pool Rating
						Pctpool	Bench-mark	CWpool	Bench-mark	Resid pd	Bench-mark	Compool _km	Bench-mark	

Conclusions:

Form F-2b: Riffle and Woody Debris Habitat Condition Summary

This form will be filled out for each subwatershed where ODFW or other comparable habitat data exist. Measured values are recorded and compared to rating criteria.

Analyst's Name: **Date** **Page of**

Subwatershed: **Data Sources:** **Data Dates:**

Site	Width/Depth Ratio		Gravel (% area)		Silt-sand-organics (% area)		Overall Riffle Rating	LWD Pieces/100 m		Volume LWD/100 m		Key Pieces/100 m		Overall LWD Rating
	WDratio	Bench-mark	Pctgravel	Bench-mark	Pctsndor	Bench-mark		LWDpiece1	Bench-mark	LWDvol1	Bench-mark	KeyLWD1	Bench-mark	

Conclusions:

Form F-2c: Riparian Habitat Condition Summary

This form will be filled out for each subwatershed where ODFW or other comparable habitat data exist. Measured values are recorded and compared to rating criteria.

Analyst's Name: **Date** **Page** **of**

Subwatershed: **Data Sources:** **Data Dates:**

Site	CHT	Width	Conifers # >20-in dbh Con_20plus	Conifers # >35- in dbh Con_35plus	Benchmark	Opensky	Shade = 180- Opensky	Benchmark	Overall Riparian Benchmark	Bank Erosion Bankerosi*	Percent Secondary Channels Pctscchnls*

* Benchmarks do not exist for these parameters; however, they provide some interesting information on general observed conditions.

Conclusions:

Form F-3: Fish Passage Evaluation

Analysts Name:

Date: **Page** **of**

Subwatershed:

Road Crossing Number	Crossing Type[1]	Crossing Slope	Outlet Drop	Outlet Pool Residual Depth	Inlet Drop	Inlet Diameter	Stream Bankfull Width	Crossing Length	Crossing Rating[2]	Species Blocked	Estimated Habitat Blocked

1- Crossing Types: B-Bridge, A- Arch, BC-Bare Culvert, EC-Embedded Culvert, BC-Baffled Culvert

2- Crossing Ratings: JB-Juvenile Barrier, AB-Adult Barrier, PB- Potential Partial/Seasonal Barrier, P-Passable, U-Unknown

Form F-4: Fish Passage Field Assessment.

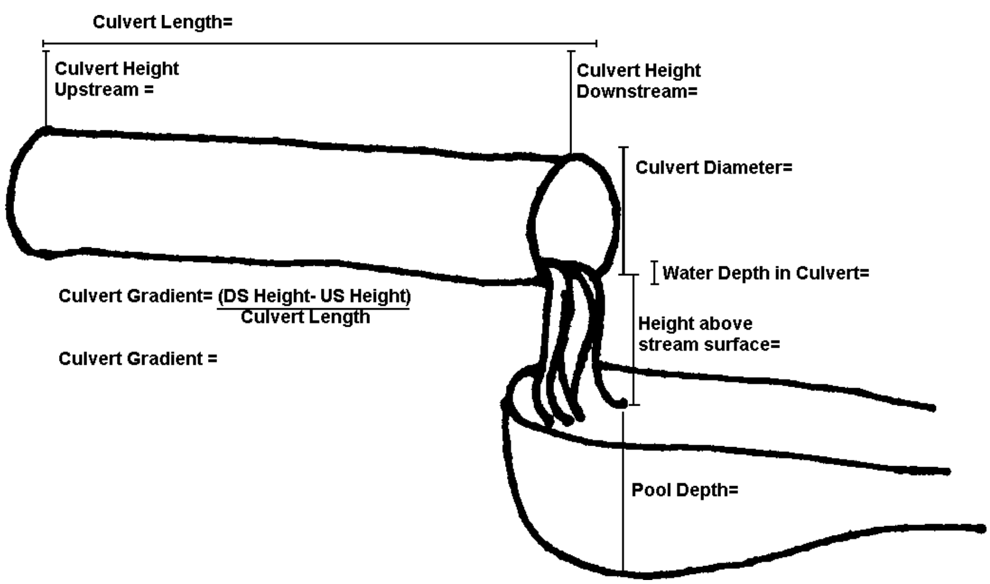
Watershed:

Analyst's Name: **Date:**

Crossing Number:

The culvert height measurements are taken to calculate culvert slope. These measurements require that a level be set up on the road crossing between the upstream and downstream end of the culvert. The upstream and downstream measurements are made by placing a stadia rod on the end of the culvert and reading the measurement through the level. As an alternative, culvert slope can be measured using a string attached to the culvert inlet. Level the string and measure the height of the string above the outlet (rise). The culvert slope can be calculated by dividing the rise by the length of the culvert (run).

Hike down to the culvert and take the illustrated measurements and fill in the measured values:



	Measurement	Units
Length of Culvert		Feet
Culvert Diameter		Inches
Outlet Drop (height above stream surface)		Inches
Pool Depth (outlet pool residual depth)		Feet
Culvert Gradient/Crossing Slope		Drop in inches or % slope
Culvert Inlet Width		Inches
Culvert Inlet Drop		inches
Stream Gradient Above Culvert		% slope
Stream Gradient Below Culvert		% slope
Stream Bankfull Width Above the Culvert		feet

Form F-4: page 2

Culvert Material (circle one):

galvanized steel   tarred galvanized steel   concrete

wood   aluminum   other

Describe any internal baffles, weirs, or bedload materials:

Who owns/maintains the culvert?

Is the culvert in good physical condition?

Fish species present above culvert?

Fish species present below culvert?

Describe upstream adult or juvenile passage problems, if any:

In your opinion, what improvements may be needed:

Form F-4: page 3

Other comments, observations:

Photo:

Form F-5: Fish Assessment Confidence Evaluation

Watershed:

Analyst's Name:

Technical expertise or relevant experience:

Resources used:

- ☐ ODFW personnel (list):
- ☐ ODF personnel (list):
- ☐ federal (USFS, BLM, NMFS) (list):
- ☐ stream surveys (list):
- ☐ newspaper archives
- ☐ private landowners (list):
- ☐ others (list):

Published surveys or reports: *(examples: ODFW stream surveys for ___ miles of stream in the ([sub]watershed, or USFS/BLM watershed analysis report for [sub]watershed):*

Confidence in distribution maps:

- ☐ Local expert says high / low (circle one) degree of accuracy based on field experience (provide name of local expert):
- ☐ High degree of accuracy as field verification of fish presence/absence were available (provide source of info/mapping):
- ☐ No verification; map based on recommendations of local professional (provide name):
- ☐ No verification; map based on personal judgement
- ☐ Additional criteria/relevent information (describe):

Form F-5: page 2

Confidence in habitat assessment:

- ☐ **Low:** Unsure of procedures; didn't consult expert; no field verification
- ☐ **Low to moderate:** Understood and followed procedures; no field verification
- ☐ **Moderate:** Some field verification and found field conditions different from data descriptions
- ☐ **Moderate to high:** Field surveys available and useful for many streams; no field verification
- ☐ **Moderate to high:** Some field verification on questionable segments only
- ☐ **High:** Used field surveys and field-verified many segments
- ☐ **If none of above** categories fits, describe your own confidence level and rationale:

Confidence in barrier identification:

- ☐ **Low:** Unsure of procedures; didn't consult expert; no field verification
- ☐ **Low to moderate:** Understood and followed procedures; no field verification
- ☐ **Moderate:** Some field verification
- ☐ **Moderate to high:** Some field verification; few unknowns
- ☐ **High:** Field-verified most crossings or good data available
- ☐ **If none of above** categories fits, describe your own confidence level and rationale:

Recommendations for additional field verification, or habitat or fish population surveys, if any, and why:

Component V Riparian/Wetlands Assessment

Table of Contents

Component V
Riparian/Wetlands Assessment

INTRODUCTION

The interactions between **riparian/wetland** [1] areas, streams, and fisheries habitats are discussed in the Introduction section of this manual. The focus of this Riparian/Wetlands component is to describe the assessment techniques for these areas. This portion of the manual is broken into two assessment sections. Section I describes the methods to assess current riparian vegetation conditions, and their impacts on **recruitment** of large wood and shade. Section II describes the methods to characterize wetland conditions in the analysis area. After the wetland section is a list of references for further reading and background information on riparian/wetland characterization. In Appendix A are all of the necessary forms for completing each of these assessments.

SECTION I: RIPARIAN ZONE CONDITION

Critical Questions

1. What are the current conditions of riparian areas in the watershed?

    - To determine conditions, users will examine riparian area width, vegetation types, and vegetation density, stream shading, and the continuity or interruption of the riparian zone from road crossings, streamside roads, and other land uses.

2. How do the current conditions compare to those potentially present or typically present for this **ecoregion**?

    - Users will use Level IV ecoregion vegetation descriptions to complete this comparison.

3. How can the current riparian areas be grouped within the watershed to increase our understanding of what areas need protection and what the appropriate restoration/enhancement opportunities might be?

    - Using information from the riparian evaluation, users will group riparian areas by sources of impact.

Assumptions

1. The riparian vegetation descriptions developed for Level IV ecoregions will provide insight on the most likely vegetation found in riparian zones, and vegetation types with the highest potential to become established in a riparian zone.

2. The vegetation likely to occur in a given riparian zone can be defined by the **Channel Habitat Type** (CHT) and ecoregion, which together integrate important site characteristics i.e., moisture, disturbance, influence of beavers, etc.).

---

[1] Terms that appear in bold italic are defined in the Glossary at the end of this component.

3. Large wood (sometimes referred to as **large woody debris**) is an important component of in-stream habitat in ecoregions that historically were forested, or had forested riparian areas. The importance of large wood for in-stream habitat will vary in ecoregions with sparsely forested riparian areas, and those where trees do not naturally occur.

4. Well-stocked riparian stands, often dominated by **conifers**, will provide adequate long-term supplies of large wood to a stream channel. In some situations, riparian stands dominated by hardwoods will contribute important amounts of large wood.

5. Recruitment distance of in-channel large wood will vary by ecoregion, and is a function of potential tree height. The majority of wood recruitment will come from riparian forests within 100 feet of the stream (horizontal distance) or less.

Materials Needed

- 1:24,000-scale Oregon Department of Forestry (ODF) base maps (from Start-Up and Identification of Watershed Issues component).

- CHT maps from the Channel Habitat Type Classification analyst

- Recent **stereo aerial photographs** covering the entire assessment area (from Start-Up and Identification of Watershed Issues component).

- Stereoscope for 3-D viewing of aerial photographs. Although a mirrored stereoscope (with magnification) is preferable, a simple lens stereoscope is adequate.

- Aerial photo scale for measuring riparian area widths, etc. Scale should be the same as the aerial photographs used.

- Map wheel for measuring lengths of riparian areas.

- Land use maps (optional). May be useful in determining land use associated with riparian disturbance.

- Level IV ecoregion map and descriptions of ecoregions occurring in the watershed.

- Stream survey summaries from the Fish and Fish Habitat Assessment that describe riparian vegetation composition and shade summaries (if available).

- Paper copies of Riparian Assessment Forms **or** a spreadsheet set up in the same format. (Note: spreadsheet templates for the various forms needed for the assessment may be available on the Internet; check http://www.state.or.us/agencies.ns/69000/00070/)

Time Needed

Aerial photo assessment time will vary depending on the size of the assessment area, the type of vegetation present, the amount of disturbance in riparian areas, and, most importantly, the skill of the person doing the interpretation. In a test of the methodology, a skilled assessment person was able to interpret riparian conditions at the rate of approximately 11 minutes/mile of stream, or 18 hours/100 miles of stream. The use of a computer spreadsheet rather than paper forms will greatly speed up summarizing and analyzing riparian conditions.

Necessary Skills

Ability to interpret vegetation type, size and density are the most important skills needed for this portion of the assessment. Although a person with no prior experience in aerial photo interpretation could complete this assessment, they should plan on spending considerable time learning the skills needed, and allow ample time to field-verify their initial estimates of riparian conditions (see Start-Up and Identification of Watershed Issues component for listing of references on aerial photo interpretation). Many watershed councils have members or land owners in the watershed with staff who are skilled in aerial photo interpretation, and who should be contacted to either perform the assessment or assist in training others to perform the assessment. Other skills needed include the ability to make measurements from aerial photographs, the ability to read and interpret topographic maps, and the ability to use a computer spreadsheet.

Final Products of the Riparian Zone Condition Section

This assessment will result in the following forms (Appendix A) and maps:

- Form R-1: Riparian Condition Unit Information
- Form R-2: Riparian Recruitment Situation Description
- Form R-3: Riparian Conditions Confidence Evaluation
- Map R-1: Riparian Condition Unit Map
- Map R-2: Riparian Recruitment Situations Map
- Map R-3: Riparian Shade Map

Methods

Overview

This portion of the assessment is conducted using aerial photographs—with field verification as time and interest permits—and produces a database and maps of riparian characteristics. The fundamental mapping unit, for which all information in this portion of the assessment is collected, is defined here as the **Riparian Condition Unit** or RCU. An RCU is a portion of the riparian area for which riparian vegetation type, size, and density remain approximately the same. When riparian characteristics change a new RCU is defined. Each RCU occurs on only one side of the stream (i.e., riparian areas on the opposite side of the stream are separate RCUs).

Information for each RCU is collected on Form R-1 (a separate row for each RCU), and mapped on Map R-1. As a rule of thumb, the minimum length for an RCU should be approximately 1,000 feet; however, there will be situations where a shorter length may be required. Information from Form R-1 will be used to group RCUs into similar **Riparian Recruitment Situations** (i.e., groups of RCUs that have similar characteristics and that may be treated similarly for the purposes of restoration/enhancement) on Map R-2. Finally, information from Form R-1 will be used to group RCUs into similar shade categories and mapped on Map R-2. Use of a computer spreadsheet will greatly facilitate these summaries and groupings.

Step 1: Prepare

All of the items listed in the Materials section should first be gathered. The boundaries of the watershed and subwatersheds should be drawn on the base maps that were completed in the Start-Up and Identification of Watershed Issues component. Consult the Ecoregions appendix of this manual for a listing of potential streamside vegetation types found within the ecoregion(s) within this watershed. The Ecoregions appendix will list potential streamside vegetation by three channel constraint groups: constrained, semiconstrained, and unconstrained. Keep this table handy.

Step 2: Map Riparian Condition Units

Choose a Starting Point

As mentioned previously, the fundamental mapping unit, for which all information in this portion of the assessment is collected, is the Riparian Condition Unit (RCU). Beginning at a logical starting point on the aerial photographs (see Where to Begin sidebar for suggestions), follow along the stream until you encounter changes in any of the following characteristics:

- Vegetation (type, size, density)
- Stream size or other changes
- CHT
- Ecoregion
- Subwatershed

Mark each end of the RCU with a pencil mark perpendicular to the stream, and assign it a number (see Note RCU Number subsection below for suggestions on developing a numbering system). Try to keep each RCU no less than 1,000 feet in length. Remember that each RCU occurs on only one side of the stream (i.e., riparian areas on the opposite side of the stream are separate RCUs).

> **WHERE TO BEGIN**
>
> All of the materials have been gathered together, a base map is laid out on a large table, aerial photos are close at hand, and the daunting task of looking at each stream in the watershed is ahead of you. Where to begin! Although there is no "rule" about where to start or which order to proceed, it is suggested that you begin at the outlet of a small subwatershed and move upstream along the primary stream, picking up each tributary as you go. From there, try looking at a few miles of the largest river in the watershed. Try to pick some areas that are easily accessible from a road so that you can go out and field-check your initial work.

Note Which CHT the RCU is in

Note on Form R-1 what CHT the RCU is in. If the RCU boundaries that you have tentatively selected overlap more than one CHT, than split the RCU into two (or more) RCUs at the CHT boundary(ies). Information about CHTs is necessary to estimate potential vegetation condition (which varies by CHT), as well as to prioritize restoration efforts when completing the Watershed Condition Evaluation component (some CHTs are more responsive to large wood than others).

Note Riparian Assessment Width(s)

The Ecoregion appendix contains tables of Potential Streamside Vegetation for each ecoregion. Although recruitment has the potential to come from as far away from the stream as the site potential tree height, the majority of functional wood is recruited within 100 feet (horizontal distance) or less (depending on ecoregion) of the stream's edge (e.g., McDade et al. 1990). Riparian areas in some ecoregions will have distinct characteristics within this normal zone of large wood recruitment (e.g., a band of red alder or other hardwoods from 0 to 25 feet [horizontal distance] from the stream edge, and conifers from 25 to 100 feet). Look-up the Potential Streamside Vegetation for ecoregion(s) your watershed is in to determine the assessment width of the riparian area closest to the stream (referred to in the table as Riparian Area 1 or RA1), and the distance for the remainder of the recruitment zone (RA2). The widths of RA1 and RA2 will also change depending on which Channel Constraint Group (Table 1) the RCU falls into. Write down the width of RA1 on Form R-1. Some ecoregions or CHTs will have only one assessment width.

Note Riparian Vegetation Characteristics

Locate RA1 and RA2 on the aerial photos, using an aerial photo scale to identify the widths of each RA if necessary. For both RA1 and RA2 note the riparian vegetation characteristics on Form R-1 using a three-letter code that describes vegetation type (first letter), vegetation size (second letter), and vegetation density (third letter). Choices are given in Table 2. For example, "CSD" would mean a riparian stand that is predominantly conifer, small in size, and dense.

Using the aerial photographs you will be able to detect the relative height of riparian stands, and the relative size of the tree crowns. Relating these characteristics to average stand size is a skill that can only be developed by field-verifying your initial estimates. If any survey information is available for streams in the assessment area, it may also be possible to find descriptions of riparian vegetation that may help to verify estimates that you have made from aerial photos.

Sometimes stand conditions will not be uniform with respect to tree size. An example would be situations where large individual trees (left from an earlier timber harvest) are interspersed within an otherwise small stand. This condition should be noted on Form R-1. If these anomalies occur frequently it may be desirable to define these stands as a separate Riparian Recruitment Situation (discussed below), because enhancement opportunities may be different for these stands.

Table 1. CHTs found in Channel Constraint Groups

Channel Constraint Group	Channel Habitat Types
Constrained channels	LC Low Gradient Confined MC Moderate Gradient Confined MH Moderate Gradient Headwater MV Moderately Steep Narrow Valley BC Bedrock Canyon SV Steep Narrow Valley VH Very Steep Headwater
Semiconstrained channels	ES Small Estuary EL Large Estuary AF Alluvial Fan LM Low Gradient Moderately Confined MM Moderate Gradient Moderately Confined
Unconstrained channels	FP1 Low Gradient Large Floodplain FP2 Low Gradient Medium Floodplain FP3 Low Gradient Small Floodplain

Table 2. Codes to describe vegetation type (modified from WFPB 1997).

Vegetation Type	
C	Mostly conifer trees (>70% of area)
H	Mostly hardwood trees (>70% of area)
M	Mixed conifer/hardwoods
B	Brush species
G	Grass/meadow
N	No riparian vegetation
Tree Size Classes	
R	Regeneration (<4-inch average diameter at breast height (DBH)
S	Small (4- to 12-inch average DBH)
M	Medium (>12- to 24-inch average DBH)
L	Large (>24-inch average DBH)
N	Nonforest (applies to vegetation Types B, G, and N)
Stand Density	
D	Dense (<1/3 ground exposed)
S	Sparse (>1/3 ground exposed)
N	Nonforest (applies to vegetation Types B, G, and N)

Note RCU Number

For each RCU recorded on Form R-1, assign a unique number (RCU#) that links it to the RCU mapped on Map R-1. Write the RCU number on Map R-1 as well.

Complicated systems to number RCUs can be devised; however, it is suggested to simply start with the number "1" and number RCUs sequentially from that point. The additional information collected for each RCU (described below), and the use of a computer spreadsheet to organize the data, will allow you to easily extract information about a particular stream, sub-basin, etc., and will eliminate the need for a complicated numbering system.

Note Stream Bank

On Form R-1 note which stream bank the RCU lies on (R for right bank looking downstream or L for left bank looking downstream). This information is useful for locating the RCU on the map or out in the field.

Measure and Note Length of RCU

Using a map wheel, measure the length of the RCU in feet and note it on Form R-1. This information will be used to summarize the various condition categories of riparian stands.

Note the Name of the Stream (or lake)

Find the name of the stream or lake on the base map and note it on Form R-1. Unnamed tributaries can be numbered sequentially staring with the first unnamed tributary working in an upstream direction. For example, the first unnamed tributary to "Madeline Creek" can be named "Madeline Ck Unn Trib #1," the second can be named "Madeline Ck Unn Trib #2," etc. Unnamed tributaries entering other unnamed streams can be named using the same convention (e.g., the first unnamed tributary entering Bear Creek can be named "Bear Ck Unn Trib #1," the first tributary entering that stream can be named "Bear Ck Unn Trib #1, Unn Trib #1", etc.). This information is useful for extracting data about a stream of interest.

Note the Name of the Subwatershed

Note the name of the subwatershed on Form R-1. This information is used to summarize riparian conditions by sub-basin.

Note the Ecoregion

Note on Form R-1 the ecoregion that the RCU is in. (If the entire watershed is in the same ecoregion, this column can be left blank).

Note the Stream Size

Note on Form R-1 the stream size (L-large, M-medium, S-small) from the ODF base map. Additionally, if a stream is noted on the ODF base map as being non-fish-bearing, note this on Form R-1 with an "N" suffix. (For example, a small stream that is non-fish-bearing would be noted as "SN"). All RCUs must be split at stream-size breaks. This information is used in the Watershed Condition Evaluation to prioritize restoration projects.

Note Permanent Discontinuities

In some situations the vegetation characteristics of an RCU may be broken up, and recruitment limited by permanent discontinuities. For example, there may be a road within the RCU along the entire length, severely limiting riparian recruitment. If any permanent discontinuity exists within the RCU, and it covers more than 30% of the total area of the RCU, the source of the discontinuity should be noted on Form R-1 (e.g., "Road"). This information will be used to define Riparian Recruitment Situations where permanent discontinuities exist, and will also be used in the Watershed Condition Evaluation to prioritize restoration projects.

Note Stream Shading

RCUs each occur on only one side of the stream, but the amount of shade that the stream experiences is a result of conditions on both sides of the stream. Nevertheless, it is reasonable for our purposes to estimate the amount of shade that each RCU provides independent of conditions on the opposite bank. Using the aerial photographs and Table 3, which provides indicators of stream shading, estimate the shade category (H, M, or L) for each RCU and record it on Form R-1. This information will be used to produce Map R-3, and in the Watershed Condition Evaluation.

Table 3. Shade estimation criteria (modified from WFPB 1997).

Indicator	Shade	Code
Stream surface not visible, slightly visible, or visible in patches	>70%	H
Stream surface visible but banks are not visible	40-70%	M
Stream surface visible; banks visible or visible at times	<40%	L

If any survey information is available for streams in the assessment area, it may be possible to find descriptions of stream shading that may help to verify estimates that you have made from aerial photos.

If you are unfamiliar with estimating shade from aerial photographs, you may wish to field-verify some of your initial estimates. A methodology for measuring shade in the field is given in Appendix B.

Additional Notes

The final item of information gathered for each RCU is any additional notes that might be helpful in defining the Riparian Recruitment Situations (described in Step 4). For example, you might consider recording information on types of land use associated with riparian disturbance, sources of discontinuity, presence of beaver ponds, etc.

At this point, Map R-1 is completed and shows all of the RCUs in the watershed. Form R-1 is also complete, with the exception of the Riparian Recruitment Situations column.

Step 3: Perform Field Verification

Field visits can greatly enhance the understanding of riparian conditions. However, it is understood that all watershed councils may not have the time or resources available to do this. It is possible to generate a basic RCU map without field visits, but the accuracy of the information will greatly improve with field verification. Field verification early in the process (i.e., after a few initial estimates of riparian conditions in a few parts of the watershed) may be the most useful, as it will help you “calibrate” your eye, and give you an understanding of what the aerial photos look like compared to on-the-ground conditions.

Visit a sampling of RCUs to evaluate conditions in the field. Use the following list to guide your field sample selection. Consider visiting those areas where you experienced one or more of the following situations:

- You were unable to determine information required to complete Form R-1 from the maps and photos.
- The information on the map did not match your recollection or data collected in the area.
- The information on different maps or photos conflict with each other.

In addition, sample a range of RCUs scattered throughout the watershed.

Based on the time available, determine a goal for the number of RCUs you will be able to visit. Make a list of areas to be visited using the guidelines above, and refine it to meet your goal. It is difficult to give useful estimates for the time a field visit will take, but be aware that in many watersheds, the travel time to an area will be the most time-consuming step of the field work. Once you are at the site, the RCU can usually be evaluated in less than an hour; sometimes substantially less.

Plan your field day and assemble your materials before visiting the field. The following steps will assist you in this process.

1. Plan an efficient route, and try to determine the most likely spots from which to access or at least view the area. If necessary, contact the property owner and request permission to visit the area. If you do not contact landowners ahead of time, you may wish to carry a letter of explanation to give to landowners. If gaining access to an area is a problem, it may be necessary to view the area from public roadways with binoculars.

2. Generate a field form by either printing the spreadsheet or photocopying Form R-1. Once in the field, evaluate the accuracy of each item in Form R-1.

3. For each area to be visited, assemble a packet that includes a photocopy of the relevant portion of the base map, field form, and aerial photograph.

In addition to field work, data collected from other sampling efforts can be used to validate the mapping. Stream surveys have been completed by a variety of agency and private entities (Oregon Department of Fish and Wildlife [ODFW], US Forest Service, US Bureau of Land Management, tribes, county or local municipalities, etc.). Depending on when the survey was completed and the protocol that was used, the survey may describe riparian vegetation composition and contain shade summaries. The Fish and Fish Habitat Assessment component will help you compile and summarize this survey data. The fisheries analyst will be able to provide available data and a copy of completed Form F-2, which summarizes riparian conditions in stream reaches that have been surveyed.

Step 4: Define and Map Riparian Recruitment Situations

Determining Where Current Recruitment Potential is Adequate

At this point you want to decide, for each RCU, if current riparian conditions provide adequate or inadequate recruitment potential. This task requires comparing current conditions to the potential vegetation descriptions for that ecoregion (see Ecoregions appendix for descriptions; note that potential vegetation descriptions vary by channel confinement classes), using the decision tree shown in Figure 1. If current conditions are as good or better (i.e., conifers are better than hardwoods; large trees are better than medium trees; dense stands are better than sparse stands) than the potential conditions for both RA1 **and** RA2, then current recruitment potential is considered to be adequate. If current conditions are not as good as potential conditions, then recruitment is considered to be inadequate. Note in the Riparian Recruitment Situations column on Form R-1 all the RCUs that have adequate current recruitment potential, and go on to the next step.

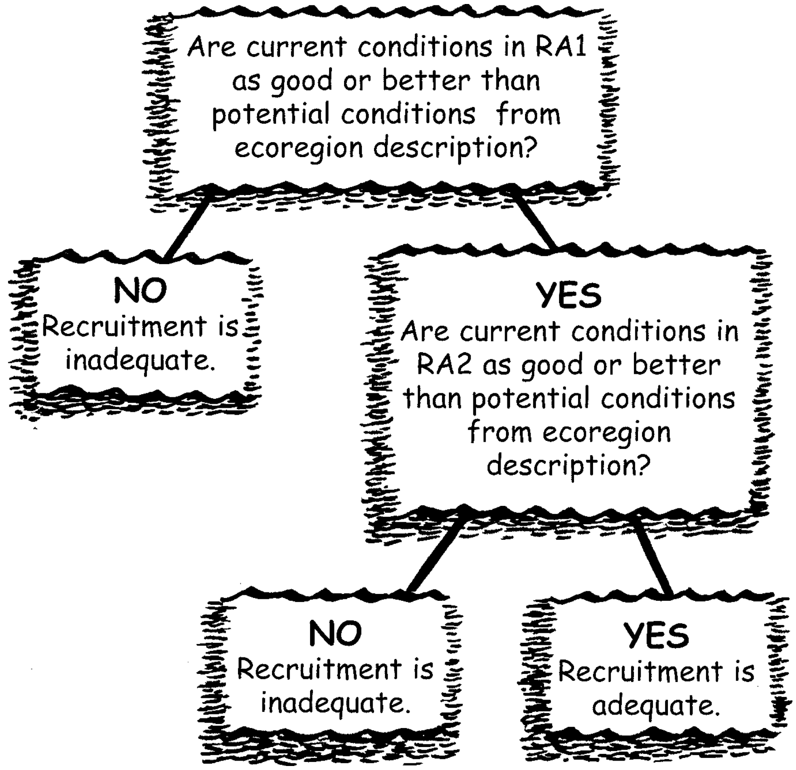


Figure 1. This decision tree will help you determine if current riparian conditions provide adequate or inadequate recruitment potential in a Riparian Condition Unit, by comparing current conditions to the potential vegetation descriptions for that ecoregion.

Defining Riparian Recruitment Situations

You have now determined which RCUs have adequate current recruitment potential, and which do not. You could simply stop at this point; however, you do not know the underlying reasons why recruitment is inadequate, nor do you have any way to logically group RCUs for restoration purposes. Riparian Recruitment Situations are a way to group the RCUs into several categories that may respond to similar restoration treatments, and to summarize the major riparian impacts in the watershed.

At this point you need to define a set of Riparian Recruitment Situations that are appropriate for the watershed in question. The first Situation will always be those stands where current recruitment potential is adequate (determined in the previous step). You now need to go through the notes collected during the aerial photo interpretation and decide on several Situations that make sense for the watershed. Questions to consider when developing Riparian Recruitment Situations for your watershed include the following: What are the land uses that limit recruitment potential? What are the primary stand types (e.g., small conifer plantations, stands of large hardwoods, narrow buffers of hardwoods between agricultural fields and the stream, etc.)? What are the areas where wetlands, residential development, etc., limit tree growth? What are the sources of permanent discontinuities in riparian areas (e.g., roads, power lines, etc.)?

A description of each Situation should be filled out on Form R-2 (one sheet for each Situation), and the Riparian Recruitment Situation noted for each RCU on Form R-1. Examples of Riparian Recruitment Situations from a Coast Range watershed assessment are provided in Table 4.

Mapping Riparian Recruitment Situations

Now all RCUs have been assigned a Riparian Recruitment Situation type on Form R-1, and each Situation has been described on Form R-2. The next step is to assign a mapping color to each Situation and map them on Map R-2. There are two possible approaches to take. The first approach is to overlay a large piece of drafting vellum (a semitransparent material, so the RCU boundaries and numbers can be viewed) on Map R-1 and color all RCUs that are in the same Riparian Recruitment Situation the same color. The second approach is to make a large photocopy of Map R-1 and color-code the Riparian Recruitment Situations. In either case, having Form R-1 in a computer spreadsheet will allow you to sort RCUs and create a list by Riparian Recruitment Situation. A wide felt-tip marking pen works well in coloring the Riparian Recruitment Situations (Figure 2, page V-12).

Step 5: Produce Shade Map

Assign a mapping color to each of the three shade categories described in Table 3. Then, using either a new piece of drafting vellum or a new photocopy of Map R-1, color-code all RCUs that are in the same shade category to produce Map R-3. Again, having Form R-1 in a computer spreadsheet will allow you to sort RCUs and create a list by shade categories.

Table 4. Riparian Recruitment Situations: An example from a Coast Range watershed.

Riparian Recruitment Situation	Description
Adequate	No enhancement needed (dense stands of large-sized conifers).
Small stands	Stands that are generally too small to provide recruitment under current conditions. The land use associated with these stands is forestry.
Large hardwood stands	These stands are also associated with forestry land use. These stands are primarily areas of large hardwoods.
Agriculture	The land use associated with these stands is agriculture. These areas that have no or very narrow buffers between agricultural land and the streams.
Development	The land use associated with these stands is residential development. Buffers are either absent, small hardwoods, or lawns.
Infrastructure	Areas where roads and power lines have created permanent discontinuities in riparian conditions.
Beaver	These are areas where beaver ponds are limiting riparian recruitment.
Wet/meadow	Wetland conditions limit riparian recruitment.

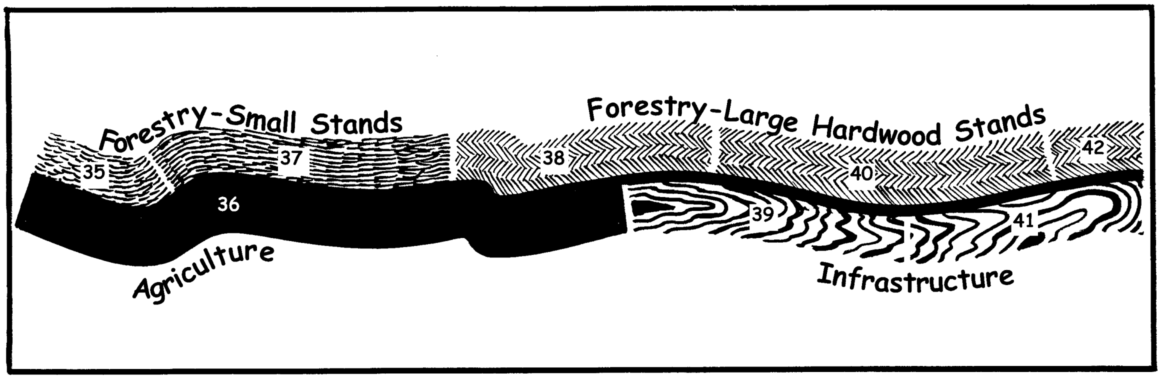


Figure 2. In this portion of a Riparian Recruitment Situation map, similar RCUs (numbered in the figure) are grouped by Riparian Recruitment Situation and color-coded on the map. (Colors are depicted with textures in the figure.)

Step 6: Evaluate Confidence in Riparian Assessment

Using the Riparian Conditions Confidence Evaluation Form (R-3), describe your level of confidence in this assessment. This can include a discussion of the limits of available information, of the amount of field verifying that was possible, and identification of areas where further investigation or data collection might yield either better results or more confidence in the assessment.

Review the critical questions. Are there any questions that it was not possible to answer, for any reason? Can the reason be identified? Does this affect your confidence in one of the areas of analysis? If so, and if the topic of concern has not already been identified on one of the evaluation forms, use the back of the form to describe the situation, and your resulting confidence level.

SECTION II: WETLAND CHARACTERIZATION AND FUNCTIONAL ASSESSMENT

Purpose

Wetlands are protected by federal, state, and local regulations. In order to plan for growth and development in a watershed, it is necessary to know where these resources are. In addition, wetlands can contribute to critical functions in the health of a watershed, as discussed in the Introduction section of this manual. Determining the approximate location and extent of wetlands may be essential in solving problems within the watershed.

The purpose of the wetland characterization is to gain specific information on the location and attributes of wetlands in the watershed, including (but not limited to) size, habitat type, surrounding land use, **connectivity**, and opportunities for restoration. This process will also assist in determining the relationship between wetlands and problems in the watershed that are identified through other assessments conducted in the watershed analysis process. In addition, the method will help watershed councils determine whether it is appropriate or necessary to collect additional data on wetland function.

Critical Questions

1. Where are the wetlands in this watershed?

    - Wetland locations will be identified and mapped using National Wetland Inventory (NWI) maps, aerial photos, and other resources.

2. What are the general characteristics of wetlands within the watershed?

    - The characteristics or attributes of known wetlands will be documented.

3. What opportunities exist to restore wetlands in the watershed?

    - Restoration opportunities that are obvious from aerial interpretation, such as presence of **fill**, clearing, grazing, or ditching in wetlands, are identified in the wetland characterization, which results in a list of possible restoration sites.

Assumptions

1. Wetlands are protected by federal, state, and local regulations. In order to plan for growth and development in a watershed, it is necessary to know where these resources are. In addition, wetlands can contribute to critical functions in the health of a watershed, as discussed in the Watershed Fundamentals component of this document. Determining the approximate location and extent of wetlands may be essential in solving problems within the watershed.
2. Although there is no definitive correlation between readily observable wetland conditions, such as size, habitat type, etc., and the functions the wetland provides, this information can offer some indications. As examples, a wetland connected to a stream has a high likelihood

of providing winter fish habitat, while a large wetland in the middle elevation of the watershed may contribute significantly to flood control.

3. Some restoration opportunities are obvious from aerial interpretation. However, wetland restoration is complex, and the process outlined in this document will only provide a first-cut at identifying restoration opportunities.

Materials Needed

A number of existing resources may be available to assist in identifying wetlands in the watershed. Although all of these may not be available, assemble as many of these as possible before beginning. The following list presents these resources in descending order of usefulness for this project.

- **Local wetland inventory.** Several (45 at the time of this printing) of the communities in Oregon have completed local wetland inventories. Most of these have focused on urban areas. To determine what is available for your watershed, contact the Oregon Division of State Lands at (503) 378-3805.

- **National Wetland Inventory (NWI) maps.** NWI maps are available for the most of Oregon. These maps are produced by the US Fish and Wildlife Service. Using US Geological Survey (USGS) quadrangle maps as a base, NWI maps indicate the location, size, and habitat type of wetlands. Maps may be purchased either through the Oregon Division of State Lands at (503) 378-3805, or from the USGS at (800) USA-MAPS.

  These maps are also available digitally, which will be extremely valuable if maps for the project will be produced on a **Geographic Information System** (GIS). NWI digital data can be purchased through the agencies listed above, and are also available free of charge via the Internet. The NWI's World Wide Web server can be accessed at http://www.nwi.fws.gov/. This web site is organized by 1:250,000-scale quadrangle maps. Each of the folders listed is the name of a 1:250,000-scale map. Determine the names of the 1:250,000-scale maps for your area, and look for that folder; within each folder is data for each 7.5-minute quadrangle map in that area. Figure 3 presents the status of NWI maps in Oregon.

- **Aerial photos.** Information on how to obtain aerial photographs for the project is provided in the Start-Up and Identification of Watershed Issues component of this manual. These photos can be invaluable at verifying and updating information from other resources, viewing the entire wetland when areas are not accessible, looking at how wetlands may be connected to streams, and determining the dominant vegetation type, surrounding land use, and disturbances.

- **Soil survey maps.** Soil survey maps are prepared by the Natural Resource Conservation Service (NRCS; formerly the Soil Conservation Service). In some instances, wetlands can be identified by comparing the mapped soil type with the list of **hydric soils** for the State of Oregon. However, in order to meet the federal and state wetland definitions, **wetland vegetation** and **hydrology** must also be present; hydric soils alone do not definitely indicate wetlands. Hydric soils can also be used to identify areas that were formerly wetlands—if an area is mapped as having hydric soils but is not currently a wetland, it may be that a wetland was present that has been drained or otherwise eliminated. Soil surveys are usually available free of charge. To order, contact NRCS at: State Conservationist, Federal Building, Room 1640, 1220 SW 3rd Avenue, Portland, OR 97204-3221; (503) 414-3201. The hydric soils list for the State of Oregon is available on the Internet at: http://www.statlab.iastate.edu/soils/hydric/sslists.html.

- **USGS topographic maps.** These maps will have been gathered for other portions of the assessment. These maps show lakes, ponds, and some wetlands, in addition to other helpful features such as topography, roads, and other landmarks.

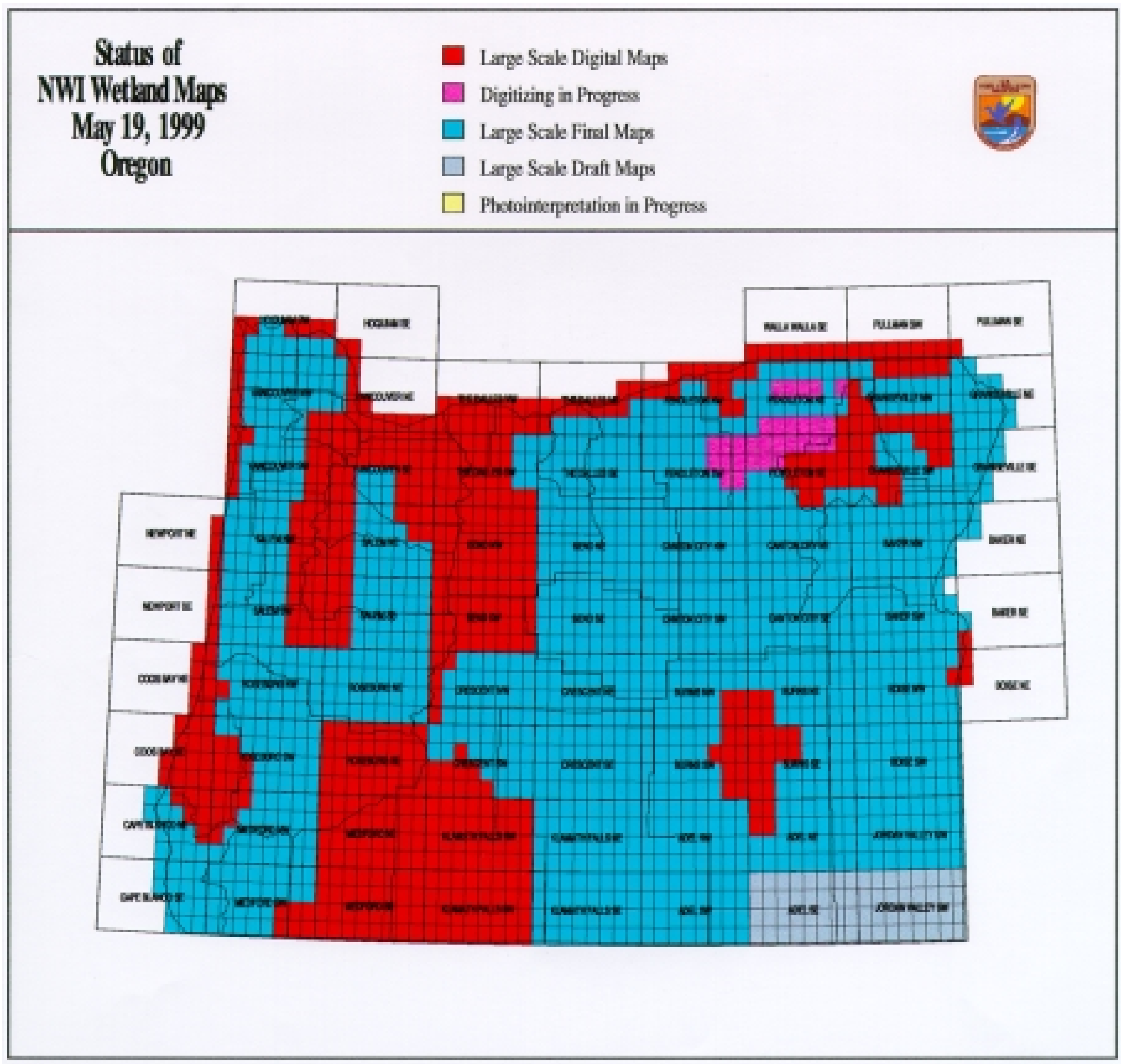


Figure 3. National Wetland Inventory (NWI) maps are available for the most all of Oregon. Produced by the US Fish and Wildlife Service, these maps indicate the location, size, and habitat type of wetlands.

Necessary Skills

The analyst for this assessment must be able to do the following:

1. Interpret aerial photographs.
2. Read maps.
3. Organize information in a spreadsheet (recommended but not required).

Final Products of the Wetland Characterization Section

- Map W-1: Wetland Locations
- Form W-1: Wetland Attributes
- Form W-2: Confidence Evaluation
- Form W-3: Wetland Functions Table (optional)

Wetland Characterization Methods

The flow chart provided in Figure 4 presents the general steps necessary to complete the wetland characterization and assessment. Each of those steps are explained in greater detail in the following pages. Before beginning this process, it is strongly urged that you read through each of the steps. Although each step is laid out in a separate, sequential fashion, it may be most efficient to be working various steps concurrently. For example, you may wish to be developing the Table of Wetland Attributes (Step 5) at the same time that you are creating the Wetland Locations Map (Step 2).

Step 1. Gather and Evaluate Existing Resources

Obtain as many of the maps identified in the Materials required section as are available. Review the maps you have gathered to identify which is the most complete starting point for the wetland inventory. Select the most detailed wetland map available to be the base map.

Step 2. Integrate Resources to Create Preliminary Wetland Map

If the project will not be using GIS, generate a wetland base map by using the most complete of the maps gathered in Step 1. If you will not be using GIS, and your area does not have a local wetland inventory for the entire watershed (this will be true in most cases), the most useful base map will be the NWI map(s). Draw the watershed boundary on the base map(s) using the startup map provided. (See the Start-Up and Identification of Watershed Issues component of this document for more information on how to generate a base map.) If a portion of the watershed has a wetland inventory, you can transfer that information to the NWI map, and consider it to be more accurate than the NWI maps.

Use personal knowledge, other maps, and aerial photographs to modify the base map with the addition of wetlands. If you will be using NWI maps as a base, look at only the area greater than 200 feet from the channel. This is to avoid having to examine the very complex NWI mapping that can occur near the channels. If the map for your area is not complex and difficult to interpret, you may choose to include the channel areas in the assessment at this time. Do not include NWI-mapped wetlands that begin with the letter “R” (for riverine). For the purpose of this project, the

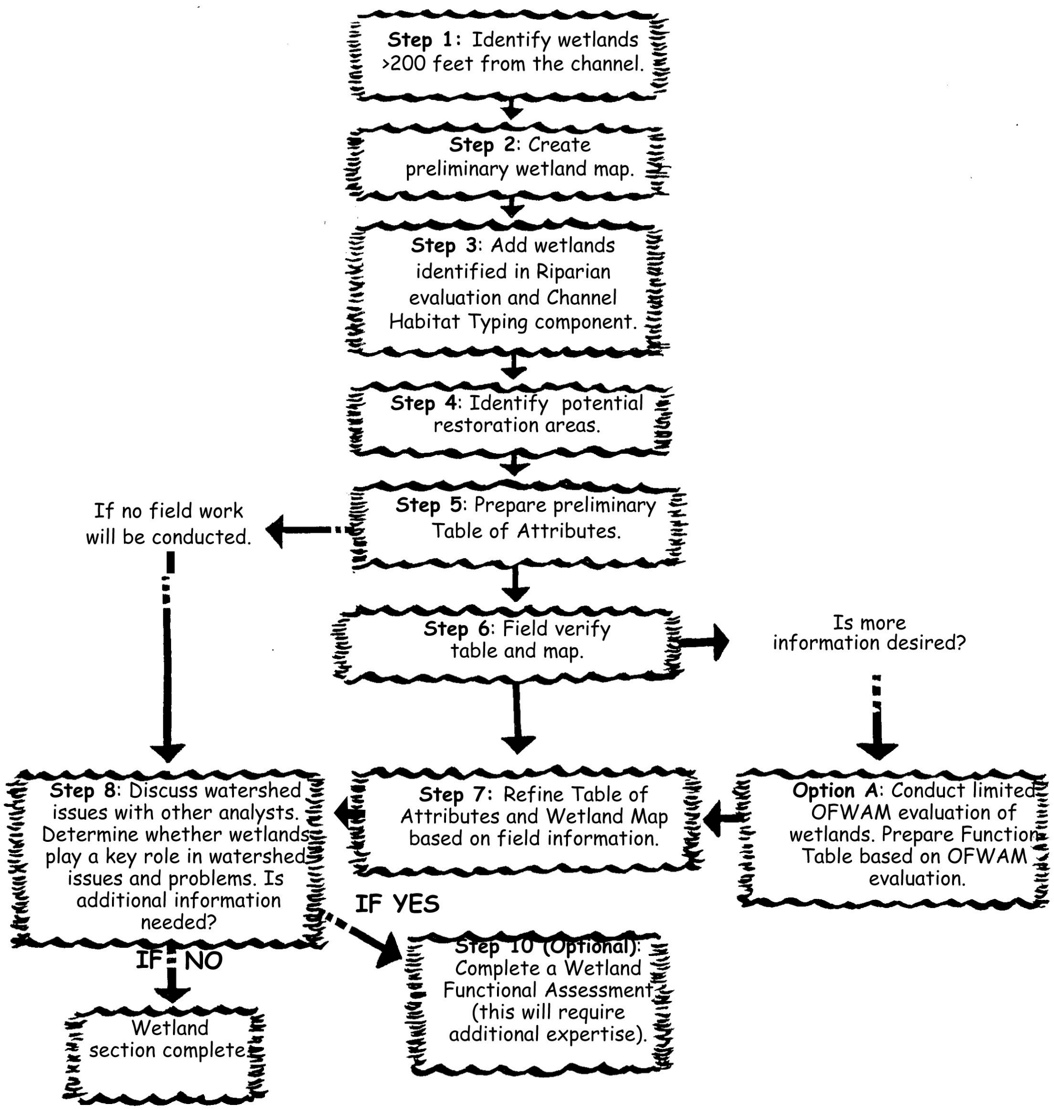


Figure 4. This flow chart presents the general steps necessary to complete the wetland characterization and assessment. Although each step is laid out in a sequential fashion, it may be most efficient to be working various steps concurrently.

characterization will not include most rivers as wetlands (with the exceptions identified in Step 3). If mapping near the channel is complex, ignore the channels at this time. Wetlands near the channel will be added during Step 3.

Step 3. Add Wetlands Identified in Riparian Evaluation and CHT Analyses

Interview the people doing the Riparian and Channel Habitat Type Classification evaluations to gather information about wetlands within 200 feet of the channel. Add any areas that they have identified in their work near the channel to your wetland base map.

Include anything identified by the riparian analyst as potentially wetland. This may include wet meadows, shrub areas, or forests. To confirm these wetlands, examine NWI maps, aerial photographs, and soil survey maps. If the area is indeed a wetland, the other sources should support that finding. If it is not clear, add it to the map, and tag it for field verification (Step 6).

Wetland areas may also be present in riparian areas mapped with the following channel habitat types:

- FP1—Low Gradient Large Floodplain
- FP2—Low Gradient Medium Floodplain
- FP3—Low Gradient Small Floodplain
- LM—Low Gradient Moderately Confined
- MM—Moderate Gradient Moderately Confined
- AF—Alluvial Fan
- ES—Estuary, Small
- EL—Estuary, Large

These areas should also be confirmed by examining maps and photos to determine whether or not they are wetlands. If they are or are likely to be wetland, they should be added to the map.

Step 4. Identify Restoration Opportunities

Add potential restoration areas to the map. Restoration areas would include disturbed wetlands or wetland buffers, or areas that were formerly wetland but have been converted to other land uses. These can be located on the maps and photos by looking for the following situations:

1. Areas show up as wetland in one source, but recent aerial photographs or personal knowledge indicate filling, clearing, grading, ditching/draining, or diking in the same area.

2. One of the following modifiers is indicated on the NWI map:
   d = partially drained/ditched
   f = farmed
   h = diked/impounded

3. The soil survey indicates hydric soils, but the area does not appear to be wetland currently, based on other sources.

NOTE: This is only a first-cut at identifying possibilities, and does not indicate that these areas are necessarily appropriate or feasible sites to restore. If, later on in this process, wetland restoration is identified as a goal, a more thorough analysis of restoration potential should be conducted by individuals with expertise in wetland restoration.

Step 5. Generate Preliminary Table of Wetland Attributes

Use Form W-1, or create a spreadsheet with similar columns. If you have more than a few wetlands, it may be extremely helpful to use a spreadsheet instead of the form provided, because it will allow you to tabulate summary information in various ways with ease, should you wish to do that in the future.

Gather and enter the following information into the form or spreadsheet:

> **HOW TO CALCULATE WETLAND ACREAGE**
>
> 1. Determine the scale of your map or photo (e.g., 1 inch = 2,000 feet)
> 2. Measure the approximate length and width of the subject wetland.
> 3. Multiply the length in inches times the scale of the map, and do the same for the width.
> 4. Multiply the resulting numbers by each other.
> 5. Divide the result by 43,560. The answer will be the wetland area, in acres, of the wetland.
>
> **Example:**
>
> Map scale: 1 inch = 2,000 feet
> Wetland on map = 0.5 inches by 1.0 inches.
> Formula: [(0.5 x 2000) x (1 x 2000)] ÷ 43560 = 45.9 acres

- Wetland ID: Assign an identifying number to each wetland. A suggested format for the ID number is Township, Range, Section, and then a consecutive number. For example, 13-20N-4E-1, 13-20N-4E-2, refer to two different wetlands within Section 13, Township 20 North, Range 4 East. Update your map and data form concurrently by adding the identifying number to the base map.

- Sub-basin. Enter the appropriate sub-basin. This can be useful later on if a particular sub-basin is identified as having a unique issue. Sub-basin information should be provided on the base map provided for the project.

- Size. Estimate the size of each wetland in acres (see the sidebar above). Sources for this information include NWI maps and aerial photographs. Use the source that offers the best (largest) scale on which to measure wetland size.

- Connected. If possible, determine whether there is a surface-water connection between the wetland and a stream. This is often difficult to do without field verification. A wetland is connected if some part of it has a surface-water connection to a **seasonal or perennial surface water**, including natural and man-made channels, lakes, or ponds. If there is an obvious stream inlet or outlet shown on the map, enter “Y” (yes) in this column. If the wetland appears to be isolated, (meaning no surface connection to a stream or ditch), enter “N” (no). If you are uncertain, enter “U” (unknown). If wetlands are connected, they are more likely to provide fish habitat. Sources for this information include NWI maps, aerials, and USGS topographic maps.

- Cowardin Classification Code: (From NWI map). Each wetland shown on the NWI map will have a code that provides some information about the wetland. Generally, the first three letters are the most important for this purpose. This will indicate the class (e.g. palustrine, riverine, etc.) and the subclass (e.g. forested, emergent, etc.). Use the legend provided on the map (Table 5 provides a summary) to interpret the remaining codes. If the NWI map indicates more than one code, list all codes in separate columns in the form or spreadsheet. Note that these NWI codes may be helpful in identifying restoration opportunities, as described in Step 4.

- Buffer: Using the aerial photographs, list the dominant land use within 500 feet of the wetland edge. Use the following codes: **Fo** = forest or open space, **Ag** = agriculture (pasture, crops, orchards, range land), **R** = rural (mix of small-scale agriculture, forest, and/or rural residential), or **D** = developed (residential, commercial, industrial). If more than one of these exists, list the dominant (>50% of the area) land use. If two land uses are fairly equally represented in the buffer, list them both.

Table 5. NWI map legend.

Letter Code	Definition	Comment	Subcategories
M = Marine	Consists of the open ocean overlying the continental shelf and its associated high-energy coastline. Marine habitats are exposed to the waves and currents of the open ocean and the water regimes are determined primarily by the ebb and flow of oceanic tides.	These will normally be outside of the watershed assessment areas.	1 = subtidal 2 = intertidal
E = Estuarine	Deepwater tidal habitats and adjacent tidal wetlands that are semi-enclosed by lands but have open, partially obstructed, or sporadic access to the open ocean, and in which open water is at least occasionally diluted by freshwater runoff from the land.	These areas are only along the coast.	1 = subtidal 2 = intertidal
R = Riverine	Includes all wetlands and deepwater habitats contained within a channel, except: (1) wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and (2) areas with water containing ocean-derived salts in excess of 0.5 parts per thousand.	Rivers will be addressed in the CHT component of this manual. Only map those CHTs listed in Step 3 as wetlands.	1 = tidal 2 = lower perennial 3 = upper perennial 4 = intermittent 5 = unknown perennial
L = Lacustrine	Includes wetlands and deepwater habitats with all of the following characteristics: (1) situated in a topographic depression or a dammed river channel; (2) lacking trees, shrubs, persistent emergents, mosses, or lichens with greater than 30% areal coverage; and (3) total area exceeds 8 hectares (20 acres).	Include lacustrine habitats on the wetland map.	1 = limnetic 2 = littoral
P = Palustrine	Includes all nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all such wetlands that occur in tidal areas where salinity due to ocean-derived salts is below 0.5 parts per thousand.	The majority of wetlands in a watershed will usually fall into this category.	EM = Emergent: Dominated by rooted herbaceous plants, such as cattails and grass. FO = Forested: Dominated by trees taller than 20 feet. OW = Open Water: No vegetation evident at the water surface. SS = Scrub-shrub: Dominated by shrubs and saplings less than 20 feet tall. UB = Unconsolidated Bottom: Mud or exposed soils.

Source: Cowardin, L.M., V. Carter, F.C. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States. US Fish and Wildlife Service, FWS/OBS-79-31, Washington DC.

- Position in Watershed: Using the USGS topographic maps, divide the watershed into thirds, and determine where the wetland falls: highest, middle, or lowest third. To divide the watershed into thirds, locate the highest and lowest elevations in the watershed and subtract the lowest from the highest. Divide the result by three. The resulting number represents the change in elevation that will occur within each third of the watershed. Add this number to the lowest elevation. Any wetlands that fall between the lowest elevation and the number you derived are in the lowest third of the watershed. Continue calculating in the same way to determine the middle and highest thirds. It is not uncommon for the lowest third of the watershed to contain a disproportionate amount of land area. In other words, this process divides the watershed into thirds topographically, but will probably not result in equal areas of land in each third.

- Field Visit. In this column, indicate whether a field visit would be especially helpful to clarify conditions at the wetland.

- Restoration/Enhancement Potential. Identify obvious recent impacts, such as clearing, grading, or filling, in or near the wetland. In addition, add any areas to the table that are not currently wetland, but you suspect were wetland in the recent past. For these areas, enter "Possible Former Wetland" in the wetland identifier column (instead of a number), and fill in as much of the attribute information as possible. In these instances, add the Township, Section, and Range to the comments column so that you can readily locate the area.

- Source. Identify the source of the information so that you can readily go back to the original data if needed.

- Comments. You may wish to add comments to indicate other information that you have learned about the wetland, or questions you would like to answer during field work.

Step 6. Conduct Field Visits

Field visits can greatly enhance the understanding of the watershed. However, it is understood that all watershed councils may not have the time or resources available to do this. It is possible to generate a basic wetland map without field visits, but the accuracy of the information will greatly improve with field verification. If you will not be doing any field work, go to Step 8 and continue from that point forward. If you will be visiting the wetlands, you may choose to also conduct a limited functional assessment. Read Step 6 Option A before you make this decision.

Visit a sampling of wetlands to evaluate conditions in the field. To guide your field sample selection, consider visiting those wetlands for which one of the following situations is true:

WHY DETERMINE WATER SOURCE FOR A WETLAND?

Determining the source of water for a particular wetland can be helpful in determining the role of the wetland in the watershed as well as its sensitivity to disturbance. In addition, this information will be useful if wetlands will later be classified per the hydrogeomorphic approach

[For more information, see page 26, Hydrogeomorphic (HGM) Approach for Oregon]

- You were unable to determine information required to complete the Table of Wetland Attributes from the maps and photos.

- The information on the map does not match your recollection of the area.

- The information on different maps or photos conflict with each other.

In addition, sample a range of wetland classes types (from the Cowardin codes, such as palustrine forested, palustrine emergent, and palustrine scrub-shrub), wetland sizes, and wetlands scattered throughout the watershed.

Based on the time available, determine a goal for the number of wetlands you will be able to visit. Make a list of wetlands to be visited using the guidelines above, and refine it to meet your goal. It is difficult to give useful estimates for the time a field visit will take, but be aware that in many watersheds, the travel time to a wetland will often be the most time-consuming step of the field work. Once you are at the site, a small or medium-sized wetland (less than 5 acres) can usually be evaluated in less than 1 hour, sometimes substantially less time.

Plan your field day and assemble your materials before visiting the field. The following steps will assist you in this process.

1. Plan an efficient route, and try to determine the most likely spots from which to access or at least view the wetland. If necessary, contact the property owner and request permission to visit the wetland. If you do not contact landowners ahead of time, you may wish to carry a letter of explanation to give to landowners. If gaining access to an area is a problem, either because of landowner opposition or remote location, it may be necessary to assess the wetland from public roadways with binoculars, or to eliminate those wetlands from the sample and replace them with other accessible sites.

2. Generate a field form by either printing the spreadsheet or photocopying Form W-1, and using the two columns labeled “Water Source” and “Outlet.”

3. For each wetland to be visited, assemble a packet that includes a photocopy of the relevant portion of the wetland map, newly generated field form, and aerial photograph.

Once in the field, evaluate the accuracy of each item in the Table of Wetland Attributes, and the size and location of the wetland shown on your map. If possible, determine the water sources (groundwater, sheetflow, channel, overbank flooding, precipitation), and the presence and condition of the outlet (none, culvert, channel). See Table 6 for more information on how to determine water source. Many wetlands may have more than one water source; indicate all that apply.

Table 6. Guidance on determining water source.

Water Source	Indicators
Channel	Wetland will have well-defined inlet and outlet. Water flows through the wetland.
Overbank flooding	Wetland is within the 100-year floodplain of a river or stream.
Precipitation	All wetlands will have this as one of the water sources, but in some unique situations, it will be the only source. These wetlands will be on topographic high points, and are likely to support bog communities.
Sheetflow	These wetlands receive water from the surrounding lands. Water does not enter the wetland through a defined channel, but flows downhill from surrounding lands across a broad area. These wetlands are lower than the surrounding landscape and have no defined inlet.
Groundwater	This is often very difficult to determine from field assessment. Two obvious situations in which groundwater plays a key role are springs or hillside seeps, where water is actually observed emerging from the ground. Other situations may require more detailed studies to determine whether groundwater is a major water source. If you are uncertain, indicate this on the field form.
Tidal flow	These wetlands can be either freshwater or saltwater, but are subject to tidal flows. Estuarine wetlands are included in this category.

Option A. Conduct Limited OFWAM Evaluation of Wetlands

The Oregon Freshwater Assessment Methodology (OFWAM; Roth et al. 1996) was developed specifically for use in Oregon. It is intended to be used by planners and others who are not wetland specialists for general planning and educational uses. The benefits of this approach are that it is rapid, usable by nontechnical individuals, and is locally relevant. One of the primary drawbacks to OFWAM is that it does not provide resolution between wetlands that provide a certain function. For example, the method may lead to a conclusion that eight wetlands in the watershed have intact water quality functions, but it will not help to assess whether any of these are more important than others at improving water quality. Conducting an OFWAM assessment will assist in developing a general overview of the wetlands and their functions in the watershed, but it will not rank or prioritize them.

OFWAM assesses six wetland functions:

1. Wildlife habitat
2. Fish habitat
3. Water quality
4. Hydrologic control
5. Education
6. Recreation

and assesses three wetland conditions:

1. Sensitivity to impacts
2. Enhancement potential
3. Aesthetics.

Each watershed council should make the decision as to whether information gained by an OFWAM evaluation is useful. If you will already be visiting a wetland, this step would take approximately 30 additional minutes per wetland. This time estimate will vary considerably with the expertise of the observer, familiarity with the method, and complexity and size of the wetland. It is expected that the first few wetlands will take considerably longer to assess than subsequent wetlands, as you become more familiar with the questions. Additional time will be required to organize the data and assemble a summary table.

To complete this step, obtain the OFWAM manual from: Wetlands Program, Oregon Division of State Lands, 775 Summer Street NE, Salem OR 97310; (503) 378-3805. Follow the instructions provided in the manual.

The final step in completing a limited OFWAM Evaluation is to assemble and finalize all data sheets prepared during the field assessment. Prepare a summary table per the example below.

Example of Function Summary Table

WL ID	Wildlife Habitat	Fish Habitat	Water Quality	Hydro-logic Control	Sensitivity to Impact	Enhance-ment Potential	Educa-tion	Recrea-tion	Aesthetic Quality
13-4w-7e	Intact	Intact	Impacted or degraded	Not present	Potentially sensitive	Moderate	Not assessed	Not assessed	Not assessed

Step 7. Refine Table of Wetland Attributes and Wetland Map

After the field work is complete, it will likely be necessary to correct the map and Table of Wetland Attributes. Enter any changes into the spreadsheet or, if you are not using a spreadsheet, update the form. Redraw the size, shape, and location of wetlands on the base map if necessary.

Step 8. Determine if Wetlands Play a Key Role in Watershed Issues and Problems

Wetlands can play a significant role in the watershed issues identified during the other assessment components. Determining the role and function of wetlands can be very complex and related to a variety of factors in the watershed. During the Watershed Condition Evaluation step, all participants in the watershed assessment should be present, and will provide information regarding their findings. Usually, a few key issues will surface as problems affecting the health of the watershed. Table 7 is provided as a general guide to some of the more common wetland-related issues this can be used to help identify if wetlands may play a key role in specific watershed functions.

Step 9. Determine if Additional Data Collection is Appropriate

The confidence in the data depends on a number of factors, including the analyst's skill and knowledge of the watershed, the tools (such as photos, maps, etc.) available, expertise of the analyst, and the degree of field verification of the data. Form W-2 provides a general guide to help evaluate confidence. This form will also assist in identifying ways in which to improve confidence in the data and to identify where additional data may be the most useful.

Table 7. Relationship between watershed issues and wetlands.

Watershed Issue	Relationship to Wetlands	Indicators that Wetland May Perform Function	Possible Additional Data Needs
Insufficient winter salmonid rearing habitat	Wetlands adjacent and connected to the channel can provide this.	Wetland must have direct, passable connection to a stream with anadromous fish.	Assess wetlands in key locations (connected or likely connected to channel) for opportunities and constraints.
Frequent flooding	Wetlands can help to reduce flooding by temporarily retaining water upslope.	Positioned in the middle of the watershed; topographic depression; outlet constrained.	Identify whether important wetlands have been filled or drained. Evaluate possibilities for restoration.
Insufficient flows for fish during dry months	Wetlands can be sites of groundwater discharge.	Groundwater seeps that flow year round; wetlands that store surface water year round.	Locate and protect wetlands that may provide this function.
Sedimentation in streams	Wetlands can filter sediments from surface-water runoff.	Wetland receives degraded runoff that ultimately enters the channel; wetland densely vegetated.	Identify degraded (e.g., cleared, graded, ditched/ drained) wetlands in key locations that could be replanted to restore water quality functions.

If confidence in the assessment is low, you may want to take steps to improve the confidence. This will be especially important if a watershed issue that has a direct link to wetlands (see Table 7) is identified. To improve confidence, it may be desirable to conduct a functional assessment of wetlands. Functional assessment is also recommended if wetland restoration has been identified as a goal by the watershed council. Understanding what functions are being performed, and to what degree, will help prioritize restoration goals.

Option B: Wetland Functional Assessment

The wetland functional assessment step should be undertaken when issues identified during Step 9 have a strong link to wetlands. However, the functional assessment is beyond the capabilities of most watershed councils; therefore, this manual provides only general information about wetland functional assessment, but detailed step-by-step instructions are not offered here. Final products will vary based on the approach selected and the goals of the watershed council.

Besides the OFWAM, which is discussed above (Option A. Conduct Limited OFWAM Evaluation of Wetlands), a number of different functional assessment methods currently exist, and others are under development. Brief descriptions of a few of the available tools are provided below, and Table 8 summarizes information about where the different functional assessment tools may be used. It is recommended that technical expertise be employed to conduct this step, and that the expert assist in determining an appropriate method.

Table 8. Summary of Wetland Functional Assessment Methods by Habitat Types.

Method	Use for Palustrine Wetlands?	Use for Estuaries?
Process for Assessing Proper Functioning Condition for Lentic Riparian/Wetland Areas	Yes	No
Hydrogeomorphic Approach for Oregon (HGM)	Yes	Yes
Indicator Value Approach (IVA)	Yes	Yes
Wetland Evaluation Technique (WET)	Yes	Yes
Oregon Freshwater Assessment Methodology	Yes	No

Note: This table does not include marine, lacustrine, or riverine habitats, because these are not likely to be assessed as wetlands during this process.

Process for Assessing Proper Functioning Condition for Lentic Riparian/Wetland Areas

This method (from US Department of the Interior Bureau of Land Management 1994) provides a process for assessing proper functioning condition for **lentic riparian/wetland areas**. Lentic riparian areas have standing water, such as lakes, ponds, seeps, bogs, and meadows. This approach requires a multidisciplinary team that would include vegetation, soil, hydrology, fish, and wildlife specialists. After an area is assessed, a summary determination is made that includes a functional rating (proper functioning condition, functional–at risk, nonfunctional, or unknown) and a trend for functional–at risk rating of upward, downward, or not apparent. One of the drawbacks of this method is that many of the terms used in the assessment are subjective, and therefore, this method may produce variable results. For example, the method asks the user to determine whether "favorable microsite condition is maintained by adjacent site characteristics," or "fluctuation of water is not excessive," but the document provides little guidance on how to interpret these terms. This method does not address biological requirements. In other words, a wetland can be determined to be in proper functioning condition, but may not support a species of interest.

Hydrogeomorphic (HGM) Approach for Oregon

The hydrogeomorphic approach (Adamus in progress) classifies wetlands based on three characteristics: geomorphic setting, water source and transport vector, and hydrodynamics. The method relies on using a set of reference wetlands in each wetland class to establish "attainable functions" for each region. The selected sample of wetlands in the watershed is then compared to the reference set. This method is currently under development for Oregon, and is not available for use or review; therefore, benefits and drawbacks are not addressed here. However, as it becomes available, it is expected to be an excellent tool to meet the needs of a watershed-scale functional assessment. Development of this tool was recommended in a document that provides strategies for wetland restoration in Oregon (Good and Sawyer 1997). That report also recommends the use of HGM by watershed councils.

Indicator Value Approach (IVA)

The IVA method (Hruby et al. 1995) assigns a numeric score to wetland function based on indicators of performance. The method is based on the assumption that wetlands having specific environmental indicators perform a wetland function better than those that do not have those indicators. The approach is to identify specific indicators of each function and assign additive, multiplicative, and fractional scores to each indicator. The benefits of IVA are that it provides a high degree of resolution between wetlands, can address unique watershed issues and concerns (because the set of questions are developed specifically for each watershed), and leads to numeric scores, which can be valuable if a goal is to prioritize wetlands for a specific purpose. The primary drawback to the method is that it requires specific development of the models for each function for each project, which increases the start-up time, and requires a time commitment of technical experts to assist in development of the model.

Wetland Evaluation Technique (WET)

WET (Adamus et al. 1991) is a method that evaluates 11 functions and assigns high, moderate, or low probabilities that a given function is performed. The benefits of this approach are that it is fairly rapid to use. The drawbacks are that it does not distinguish the level of performance of a function between wetlands which perform that particular function. It would probably not meet the needs of a watershed council if the goal is to prioritize wetlands for protection or restoration.

Conclusion

Selection of a method for a wetland functional assessment will be key in determining whether the data gathered is useful to address data gaps or meet other goals of a watershed council. Be sure that you understand the implications and limitations of the method that is selected for functional assessment. Also be sure that the experts assisting the watershed council with this step understand your goals for using the data. This will ensure that a technically sound and useful product is generated.

REFERENCES

Adamus, P.R., L.T. Stockwell, E.J. Clairain Jr., M.E. Morrow, L.T. Rozas, and R.D. Smith. 1991. Wetland Evaluation Technique (WET). Wetlands Research Program Technical Report WRP-DE-2. US Army Corps of Engineers, Waterways Experiment Station, Vicksburg, Mississippi.

Avery, T.E., and G.L. Berlin. 1985. Fundamentals of Remote Sensing and Photo Interpretation. Fifth edition. MacMillan Publishing Co., New York.

Castelle, A., A.W. Johnson, and C. Conolly. 1994. Wetland and Stream Buffers Size Requirements: A review. Journal of Environmental Quality 23:878-882.

Cowardin, L.M., V. Carter, F. Golet, and E.T. LaRoe. 1979. Classification of Wetlands and Deepwater Habitats of the United States, US Fish and Wildlife Service, FWS/OBS-79/31, Washington, DC.

Dunne, T., and L.B. Leopold, 1978. Water in Environmental Planning. W.H. Freeman and Co., San Francisco, California.

Good, J., and C. Sawyer. 1997. Recommendations for a Nonregulatory Wetland Restoration Program for Oregon: Final Report. Prepared for Oregon Division of State Lands and the US Environmental Protection Agency.

Gregory, S.V., and P.A. Bisson. 1997. Degradation and Loss of Anadromous Salmonid Habitat in the Pacific Northwest. Pages 277-314 in Stouder, D.J., P.A. Bisson, and R.J. Naiman, eds. Pacific Salmon and Their Ecosystems: Status and Future Options. Chapman and Hall, New York.

Hruby, T., W.E. Cesanek, and K.E. Miller. 1995. Estimating Relative Wetland Values for Regional Planning Purposes. Wetlands Vol. 15, No. 4.

Li, J.V., and S.V. Gregory. 1995. Effects of forest practices on aquatic biota. In Beschta, R.L., J.R. Boyle, C.C. Chambers, W.P Gibson, S.V. Gregory, J. Grizzel, J.C. Hagar, J.L. Li, W.C. McComb, T.W. Parzybok, M.L. Reiter, G.H. Taylor, and J.E. Warila. Cumulative Effects of Forest Practices in Oregon: Literature and Synthesis. Prepared for Oregon Department of Forestry, Salem.

May, C.W., R.R. Horner, J.R. Karr, B.W. Mar and E.B. Welch. 1997 (draft). The Cumulative Effects of Urbanization on Small Streams in the Puget Sound Lowland Ecoregion. University of Washington, Seattle.

McDade, M.H., F.J. Swanson, W.A. McKee, J.F. Franklin, and J. Van Sickle. 1990. Source Distances for Coarse Woody Debris Entering Small Streams in Western Oregon and Washington. Canadian Journal of Forestry Research 20:326-330.

Meehan, W.H., ed. 1991. Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. American Fisheries Society Special Publication 19, Bethesda, Maryland.

Mitsch, W.J., and J.G. Gosselink. 1986. Wetlands. Van Nostrand Reinhold, New York.

Moore, K.M.S., and K.K. Jones. 1997 (in prep.). Analysis and Application of Stream Survey Data for Restoration Planning and Quantification of Change at the Watershed Scale. ODFW Research Section, Corvallis.

Oregon Department of Environmental Quality. 1995. Temperature: 1992-1994 Water Quality Standards Review, Final Issue Paper. Portland.

Roth, E., R. Olsen, P. Snow, and R. Sumner. 1996. Oregon Freshwater Assessment Methodology. Second edition. Oregon Division of State Lands, Salem.

Schuett-Hames, D., A. Pleus, L. Bullchild, and S. Hall. 1994. Ambient Monitoring Program Manual. Washington State Department of Natural Ressources, TFW-AM9-94-001, Olympia.

WFPB (Washington Forest Practices Board). 1997. Standard Methodology for Conducting Watershed Analysis, Version 4.0: Riparian Function Module. Washington State Department of Natural Resources, Forest Practices Division, Olympia.

GLOSSARY

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, **channel pattern**, and **confinement**. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

conifer: Cone-bearing tree, generally evergreen (although certain exceptions occur; for example larch is a deciduous conifer), having needle-like leaves. Examples include pines, Douglas fir, cedar, and hemlock.

connectivity: The physical connection between tributaries and the river, between surface water and groundwater, and between wetlands and these water sources.

ecoregion: Land areas with fairly similar geology, flora and fauna, and landscape characteristics that reflect a certain ecosystem type.

Geographic Information System (GIS): A computer system designed for storage, manipulation, and presentation of geographical information such as topography, elevation, geology etc.

hydric soil: A soil that is saturated, flooded, or ponded long enough during the growing season to develop anaerobic conditions in the upper part.

hydrology: The science of the behavior of water from the atmosphere into the soil.

large woody debris (LWD): Generally defined as pieces of wood (either tree trunks, stumps, or large branches) greater than 6 feet long and greater than 4 inches in diameter. LWD is important in the formation of channel shape, and consequently, in creating and enhancing fish habitat. Sometimes referred to as coarse woody debris.

lentic riparian/wetland area: Lentic riparian areas have standing water, such as lakes, ponds, seeps, bogs, and meadows.

perennial surface water: Surface water that persists all year.

recruitment: In the context of riparian function, recruitment refers to adding new LWD pieces to a stream channel. It is the physical movement of LWD into the stream channel.

riparian area: The area adjacent to the stream channel that interacts and is dependent on the stream for biologic integrity.

Riparian Condition Unit (RCU): A portion of the riparian area for which riparian vegetation type, size, and density remain approximately the same.

Riparian Recruitment Situation: Groups of RCUs that have similar characteristics and that may be treated similarly for the purposes of restoration and/or enhancement.

seasonal surface water: Surface water that is normally only present during a portion of the year.

stereo aerial photo: Pairs of photos taken from the air that can be viewed through a stereoscope to reveal three-dimensional features of the landscape.

stereoscope: An instrument used to observe stereo aerial photographs in three dimensions.

wetland vegetation: Plants that are adapted to living in saturated or inundated conditions for at least part of the growing season.

Appendix V-A
Blank Forms

Form R-1: Riparian Condition Units

Name of Watershed:___________________________________Name of Analyst:_______________Date:________Page______ of ______

RCU #	Bank	Length (ft)	Stream/ Lake	Sub-water-shed	Eco-region	CHT	Stream Size	RA1 Width (ft)	RA1 Code	RA2 Code	Perm discon due to:	Shade (%)	Riparian recruitment situation	Notes

TERMS

RA1 Riparian Area 1

RA2 Riparian Area 2

Form R-2: Riparian Recruitment Situation Description

Analyst:____________________________________ **Date:**____________ **Page** _____**of** _____

Watershed:____

Riparian Recruitment Situation Name:____

Description:

Form R-3: Riparian Conditions Confidence Evaluation

Watershed:____

Analyst's Name:___________________________ **Date**________ **Page** _____ **of** ___

Resources used:

- ☐ ODF base maps
- ☐ Topographic maps
- ☐ CHT maps
- ☐ Land use maps
- ☐ Ecoregion map
- ☐ Ecoregion descriptions
- ☐ Aerial photographs
  - ☐ Black & white
  - ☐ Color
  - ☐ Color infrared

  Scale: 1:_________

  Source:__________________________
- ☐ Description of riparian vegetation and/or shade from stream surveys

  Source:__________________________

  RCU #s:____
- ☐ Field verification of riparian vegetation

  RCU #s:____
- ☐ Field verification of stream shading

  RCU #s:____________________________________

Confidence in riparian condition assessment:

☐ **Low:** Unskilled/unsure of procedure, didn't consult expert, no field-verification, no survey information used, potential for conditions to have changed since aerial photos taken

☐ **Moderate:** Some confidence in assessment procedure and personal skills, access to expert for help and/or review, some areas field-verified and/or covered by existing surveys, low potential for conditions to have changed since aerial photos taken

☐ **High:** Confident in using assessment procedure and/or personal skills, access to expert for help and/or review, extensive field-verification

Recommendation for additional field assessment; unanswered questions (if any) and why (complete on back of form):

Form W-1: Table of Wetland Attributes

Name of Analyst:____ **Watershed:**____

Date:____**Page** ______ **of**_____

Wetland ID	Sub-basin	Size (ac.)	Connected	Cowardin Code	Cowardin Code	Cowardin Code	Buffer	Watershed Position	Restoration Potential	Field?	Source	Comments

Form W-2: Wetland Confidence Evaluation

Watershed:____

Analyst's Name:___________________________ **Date**________ **Page** _____ **of** ___

Analyst's wetland experience:

☐ **Low:** No prior experience

☐ **Moderate:** Some experience

☐ **High:** Extensive experience.

Analyst's overall familiarity with watershed during different seasons:

☐ **Low:** Unfamiliar

☐ **Moderate:** Somewhat familiar

☐ **High:** Very familiar (live and/or work in the watershed)

Origin of wetland base map:

☐ **Low:** NWI map based on photos 1980 or earlier

☐ **Moderate:** NWI map based on photos 1981 or later

☐ **High:** Other recent wetland inventory information available

Aerial photo interpretation:

☐ **Low:** No aerial photos used

☐ **Moderate:** Photos greater than 5 years old were used

☐ **High:** Recent (within 5 years) photos were used.

Seasonality of photos:

☐ **Low:** Photos taken during July, August, or September

☐ **Moderate:** Photos taken October through February

☐ **High:** Photos taken March through June

Level of field verification:

☐ **Low:** None

☐ **Moderate:** Some field verification (50% or fewer of wetlands visited)

☐ **High:** Extensive (Greater than 50% of wetlands verified)

Conditions in watershed:

☐ **Low:** Greater than 50% of watershed forested

☐ **High:** Less than 50% of watershed forested

Recommendations for additional field assessment; unanswered questions (if any) and why (complete on back of form):

Appendix V-B
Field Measurement of Stream Shading

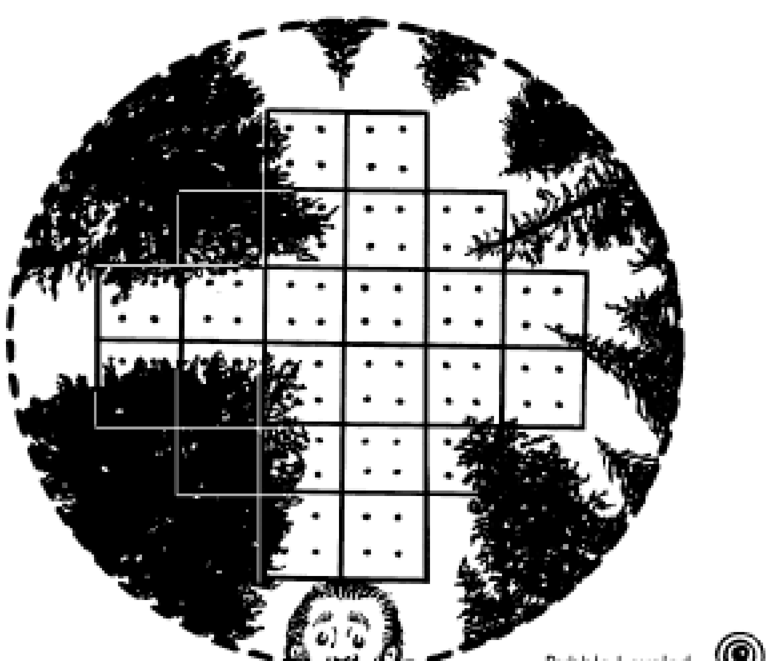
FIELD MEASUREMENT OF STREAM SHADING

(Note: The following description is modified from Schuett-Hames et al. 1994).

Shade measurements should be taken approximately every 50 to 100 feet along the channel. Shade should be measured at a minimum of 5 points for each RCU. The measurement at each point is an average of four systematic canopy closure readings taken in the middle of the channel.

Use a spherical densiometer to estimate shade to the stream channel at each point. To take a densiometer reading, hold the densiometer 12 to 18 inches in front of you at elbow height. Use the circular bubble-level to ensure that it is level. Look down on the surface of the densiometer, which has 24 squares etched into its reflective face. The reflection of the top of your head should just touch the outside of the grid (see figure below). Imagine that each square is subdivided into four additional squares, so that there are 96 smaller quarter-squares. Envision a dot in the center of each quarter-square. Count the total number of quarter-square dots covered by the reflection of vegetation (see figure below).

Four readings are made at each point. Begin with a reading facing directly upstream (Up); then turn clockwise 90 degrees and take a reading facing the left bank (LB); then turn another 90 degrees clockwise and take a reading facing downstream (Dn); and finally turn clockwise another 90 degrees and take a reading facing the right bank (RB). To determine shade, sum the number of quarter-square dots obscured with vegetation for all four readings, multiply the result by 1.04 (correction factor), and divide this result by 4. The result is the average percent shade at that point. Average the percent shade at all points to get the average percent shade for the RCU. View into a convex spherical densiometer showing placement of head reflection and bubble-level. Visualize four spaced dots in each square and count the number covered by vegetation.



Component VI
Sediment Sources Assessment

Table of Contents

Table of Contents (continued)

Component VI
Sediment Sources Assessment

INTRODUCTION

Erosion that occurs near streams and on surrounding slopes is a natural part of any watershed. Fish and other aquatic organisms in a region are adapted to deal with a range of sediment amounts that enter streams. The amount of erosion in a watershed and the sediment load in the streams vary considerably during the year, with most sediment moving during the few days that have the highest flows. The most significant land-forming events may occur during precipitation or snowmelt events that happen only once every decade or more.

In addition to natural levels of erosion, human-induced erosion can occur. Separating human-induced erosion from natural erosion can be difficult because of the highly variable nature of natural erosion patterns. Furthermore, human-caused erosion may also be highly variable in timing and spatial pattern. While it is nearly impossible to specify when a human-induced change in sediment is too much for a local population of fish and other aquatic organisms to handle, in general, the greater a stream deviates from its natural sediment levels the greater the chance that the fish and other aquatic organisms are going to be affected. Sediment in streams can have a human dimension, too. High sediment levels can increase the cost of treating drinking water, can be aesthetically displeasing, and can decrease fish angling success.

A watershed assessment of erosion and sediment within a watershed requires three steps. First, an inventory of visible signs of erosion is needed . This exercise may include locating and mapping landslide scars, road washouts, or areas with extensive gullying. The second step is to identify and map areas or situations for which erosion and movement of sediment into streams is **likely** to occur in the near future. This exercise may include such tasks as locating and mapping high-risk sections of road, undersized but still-intact culverts at stream crossings, or areas where inappropriate cropping techniques occur on highly erodible soil. The third step is to summarize information in a way that allows identification of human-caused erosion problems for which there is a high priority for developing remedies.

One thing to keep in mind is that both the intensity and density of an erosion process needs to be considered for the sediment assessment to be useful. For example, grossly undersized road culverts that have a high potential of causing road washouts during floods may be a minor sediment problem if only a limited number exist in a watershed, but a major concern if many of these culverts exist.

Methods for assessing erosion and sediment in streams vary with the nature of the human activity and the landscape. Therefore, this sediment assessment is broken into eight modules, each of which addresses the following critical questions.

Critical Questions

1. What are important current sediment sources in the watershed?

   - To determine this, use information on current slope and rural road instability; urban and rural road runoff; surface erosion from crop lands, range lands, and burned lands; and other discrete sources.

2. What are important future sources of sediment in the watershed?

   - Using field observations and road inventory data, compile information on combinations of site factors that have a high probability of becoming important sediment sources.

3. Where erosion problems are most severe and qualify as high priority for remedying conditions in the watershed?

   - Restoration opportunities are identified in the summary tables, which indicate locations where human-caused sediment increases are most severe.

Assumptions

- Sediment is a normal and critical component of stream habitat for fish and other aquatic organisms. The more that sediment levels deviate (either up or down) from the natural pattern in a watershed, the more likely that aquatic habitat conditions will be altered.

- Human-caused increases in sediment commonly occur at a limited number of locations within the watershed and can be identified using a combination of site characteristics and land use practices.

- Sediment movement is often episodic, with most erosion and downstream soil movement occurring during infrequent and intense runoff events.

Materials Needed

The first step in the assessment will be to identify potential sediment sources in the watershed that are high priority for further investigation. A number of existing resources may be available to assist in this preliminary identification and are identified in the Materials Needed to Start Sediment Sources Assessment, below. After you have identified which sediment sources will be evaluated (and thus, which of the eight modules you will follow), refer to Table 1. This table lists which materials are needed to complete each sediment source module.

Materials Needed to Start Sediment Source Assessment

- Watershed Base Map (from Start-Up and Identification of Watershed Issues component)

- Aerial photos (from Start-Up and Identification of Watershed Issues component)

- Refined Land Use Map (from Start-Up and Identification of Watershed Issues component)

Table 1. Materials needed for specific sediment source assessment modules.

Materials	Source 1: Road Instability	Source 2: Slope Instability	Source 3: Rural Road Runoff	Source 4: Urban Area Runoff	Source 5: Crop Land	Source 6: Range Land	Source 7: Burned Areas	Source 8: Other
Watershed Base Map	√	√	√	√	√	√	√	√
Updated road maps	√		√	√				
Aerial photos	√	√	√		√	√	√	√
Peak-flow map	√							
Debris-flow-potential map		√						
Landslide inventories	√	√						
Forest road hazard inventories	√							
City stormwater maps				√				
County soil surveys					√	√		
USFS soil inventories						√		
Recent burn locations							√	

- Stereoscope for 3-D viewing of aerial photographs. Although a mirrored stereoscope (with magnification) is preferable, a simple lens stereoscope is adequate.

- Updated road maps. Request 1:24,000-scale maps. If unavailable, enlarge or reduce whatever map you obtain to a 1:24000 scale (1 inch = 2,000 feet). Likely sources of updated road maps include:

  - US Forest Service (USFS)
  - US Bureau of Land Management (BLM)
  - Department of Forestry, State Lands
  - County
  - Private forest landowners

- Other supplies:

    - Transparency overlays
    - Thin permanent markers (six or more colors)
    - Engineer's ruler (English units, not metric) or map wheel for measuring lengths
    - Calculator
    - Dot grid templates (provided with this manual) or map wheel for measuring area
    - Computer spreadsheet software
    - Worksheet diskette with spreadsheets

Materials Needed for Specific Sediment Source Modules

The materials listed in Table 1 are described in the following list:

- Peak-flow map (50-year **recurrence interval** [1] for peak flows in forest streams). The map can be downloaded from the Oregon Department of Forestry (ODF) Web site at http://www.odf.state.or.us/FP/DEFAULT.HTM. It is also available in hard copy by calling the ODF hydrologist at (503) 378-3589.

- Debris-flow-potential maps. ODF is in the process of mapping debris flow potential for many parts of western Oregon. These maps are scheduled to be available June 1999 from the ODF landslide specialist at (541) 945-7481.

- Landslide inventories. These can be obtained from the same sources as updated road maps (see previous section).

- Forest road hazard inventories. Many forest landowners have recently completed inventories of their road systems using a standard protocol that is also used on state forest lands by the ODF. These inventories include information about recent landslides near roads, road surface condition, and stream crossings. The USFS and BLM may also have road inventory information, but it will not be the same format.

- City stormwater maps. Request these maps from city public works departments. These maps should show roads, streams, lakes, and the stormwater network (pipes, detention facilities, and any processing plants). Make several large-format copies and laminate them for work maps.

- County soil survey books (from Riparian/Wetlands Assessment component)

- USFS soil resources inventories. Obtain these inventories from your local USFS district office if range land managed by the USFS is to be assessed.

- Locations of recent burns

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

Area calculations can be done using **Geographic Information System** (GIS) software instead of the dot grids or map wheel if available. In addition, GIS support allows for better-quality final maps and provides more options for summarizing results.

Necessary Skills

The minimum skills necessary to conduct this assessment include the ability to read topographic maps and basic experience in operating a computer spreadsheet program. Electronic spreadsheets versions of all forms have been created; in many cases the data analysis will be much easier if the sediment source information is directly entered into a spreadsheet (referred to as worksheets throughout this document). Sediment source identification relies on aerial photo interpretation, so experience reading aerial photos will help complete the assessment. At a minimum you should have someone experienced with aerial photo interpretation help you get started to “train” your eye on how to read photo features.

Final Products of the Sediment Sources Component

Final products include maps showing points, road segments, or areas of low to high sediment risk for up to eight of the potential sediment sources. In addition, you will end up with spreadsheet databases of erosional features or areas of erosional risk. From these databases, you will be able to construct summary tables indicating relative sediment-severity ratings for subwatersheds within the watershed. Specific final products will be discussed within each of the eight modules.

METHODS

In this assessment you will be able to evaluate potential contributions of sediment from the following eight sources, with a module devoted to each source: (1) road instability, (2) slope instability, (3) rural road runoff, (4) urban area runoff, (5) sediment from crop land, (6) sediment from range or pasture lands, (7) sediment from burned areas, and (8) sediment from other identified sources. The assessment is conducted using aerial photographs, topographical maps, database inventories, and field verification as time and interest permits. It produces a database and maps that identify sediment sources. Use of a computer spreadsheet will help you complete these summaries and groupings. Each module may be completed by different users with experience or information on that specific source.

Step 1: Update Roads on Watershed Base Map

Before accurate information can be gathered about road-related sediment sources, the Watershed Base Map should be updated to include all roads. The 7.5-minute topographic maps or ODF stream maps used as the Watershed Base Map will probably display only two-thirds of the roads. Roads constructed since the map was made (or updated) will be missing. If you have obtained 1:24,000-scale maps from other sources that show the missing roads, transfer them onto the Watershed Base Map. If a 1:24000-scale map from other sources is unavailable, enlarge or reduce what map you have to achieve a 1:24000 scale (1 inch = 2,000 feet) and transfer roads onto the Watershed Base Map. You can transfer new roads onto the Base Map by placing the road or sub-basin map on a light table or window, overlaying the Base Map, taping both down, and transferring changes to the Base Map.

New roads can also be located on recent aerial photographs and transferred to the maps, but this is often a frustrating and time-consuming task. To do this, first enlarge or reduce color copies of the aerial photographs to match the 1:24000 scale, then follow the procedure described above for transferring roads to the Base Map. This is made more difficult by the variation of scale within each aerial photograph, both in elevation (objects on ridges look larger than objects in valleys) and in proximity to the photo edges. To minimize these problems, use a photo that puts the road in the center of the photo and adjust the position of the photograph underneath the map as needed to get the best fit with other landmarks. See the Start-Up and Identification of Watershed Issues component for more information on working with aerial photographs.

Once the new roads have been added to the Base Maps, assign sequential numbers to points where roads cross streams. These stream-crossing identification numbers will be used later for analysis of sediment sources and the passage of fish through culverts.

Next, make about a dozen, large-format copies of your map. You will want at least one copy to complete each sediment source assessment, it is often useful to have a working copy and a final copy. In addition, the Fish and Fish Habitat analyst will need a copy for the passage barrier assessment. For extra convenience, have your Base Maps laminated to allow easy changes as you mark the maps with the locations of sediment sources. All sediment source features will be labeled with a unique identifying number.

Step 2: Identify Potential Sediment Sources

A first step in evaluating sediment sources in your watershed is to determine which sediment topics are important to the watershed council. You could compile information on all eight of the sediment topics, but this would take quite a bit of time and you would eventually see that some sediment sources are rather insignificant in your watershed. For example, sediment topics for a watershed in the Coast Range with little urban or grazed land could probably be limited to an assessment of sediment from road runoff, road instability, and slope instability (not related to roads). For a watershed in the foothills of the Blue Mountains in eastern Oregon, a watershed council might focus its assessment on sediment from crop land, range land, and road runoff.

Your selection of priority sediment topics may depend, in part, on whether or not there is enough information about your watershed to get started on a topic. For example, if you cannot find aerial photographs for your watershed and major portions of the watershed are inaccessible to the members of the watershed council, you may not get very far addressing the topic of slope instability.

The questions listed in Form S-1, Screen for Sediment Sources in a Watershed, may be useful for helping you to determine which sediment topics should be included in the assessment. As you discuss these issues among yourselves, you can keep track of your progress by filling in Form S-1.

Many of these questions can be answered by the following method:

- Use the updated Watershed Base Map to identify areas of high rural road density.

- Use the Refined Land Use map to identify the presence of specific land uses.

- Your own experience and interviews with landowners who live in the watershed and agency staff working in the watershed.

As an example of this process, Table 2 indicates that a watershed council decided that rural road runoff and instability were the most important sediment sources to be addressed in their assessment. Urban runoff within some tributaries and slope instability (not related to roads) were of lesser importance. They chose not to expend effort on the remainder of the sediment source modules.

Table 2. Example of Form S-1: Screen for sediment sources in a watershed.

Watershed Name: The River Why	Observations	Priority
Source 1: Road instability		
Are rural roads common in watershed?	Yes	2nd
Do many road washouts occur following high rainfall?	Some	
Are many new roads or road reconstruction planned?	Yes	
Source 2: Slope instability (not related to roads)		
Are landslides common in watershed?	Yes	4th
Many high-sediment, large-scale landslides?	None	
Source 3: Rural road runoff		
Is sediment-laden runoff from rural roads and turbidity in streams common?	Yes	1st
Is there a high density of rural roads?	Yes	
Source 4: Urban runoff		
Are many portions of the watershed urbanized?	Some	3rd
Importance of these tributaries to watershed council:	High	
Source 5: Surface erosion from crop land		
Is there much crop land in watershed?	Low	Topic not high priority
Is there much evidence of sediment in streams flowing through crop land?	Little	
Source 6: Surface erosion from range land		
Is there much range land in the watershed?	Low	Topic not high priority
Is there evidence of sediment in streams flowing through range land?	Little	
Source 7: Surface erosion from burned land		
Have many burns occurred recently (last 5 years), especially hot fires?	Few	Topic not high priority
Was there much sediment created by these burns?	Low	
Source 8: Other discrete sources of sediment		Topic not high priority
List or identify any other suspected sources of sediment:	None	

Step 3: Evaluate Sediment Sources

The next step describes how to evaluate each of the eight potential sediment sources. Remember, you will probably not be doing all eight of the modules described herein; only the ones identified in the previous step as important to you.

Source 1. Road Instability

The stability of a rural road depends on how well the road was built and the inherent stability of the land it traverses. In general, roads are most stable if built along ridges, especially where slopes are not steep. Less stable locations include steep terrain at the middle of slopes and near streams. Large amounts of subsurface water cause soils to lose much of their strength, so most road failures occur during high-intensity rainstorms or snowmelt periods that produce saturated soils.

The type of road construction influences the stability of the road. Sidecast roads are constructed by digging into the hillside to form the inside of the road and using the excavated soil to build up the outside of the road (Figure 1). This works well in moderate terrain but can lead to problems on steep slopes. Excavated material used to build up the outer side of the road (the **fill slope**) on a steep slope can be unstable. This unstable wedge of soil may be transformed into a landslide sometime in the future (Figure 1). Alternatively, when **full-bench road construction** is used, soil is excavated to a stable location rather than using it as the outer edge of the road. This type of road construction is more stable but the cost is considerably higher.

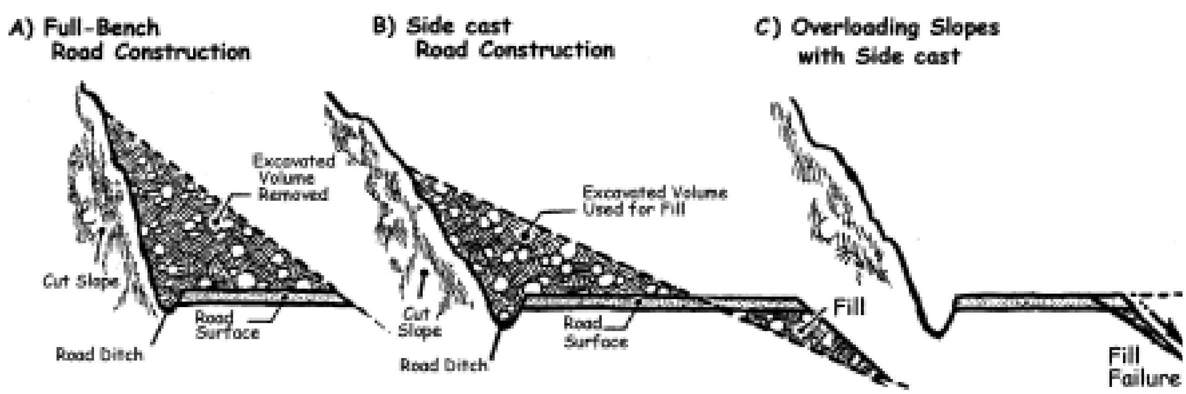


Figure 1. The type of road construction influences the stability of the road. Sidecast roads, built by digging into the hillside to form the inside of the road and using the excavated soil to build up the outside of the road, can cause failure on steep slopes. In full-bench road construction, soil is excavated to a stable location rather than using it as the outer edge of the road.

Road **cut slopes**, the inside slope of the road, may also become unstable, and sections of the cut slope can fall or creep into the road during wet weather. Small cut-slope failures can end up diverting ditch water onto the road surface or fill slope, creating gullies or triggering a landslide. An inherently unstable section of hill slope can be made even less stable when a road is excavated into the base of the unstable area.

Finally, road crossings with culverts that fail can cause large pulses of sediment to enter channels. Culverts that are inadequate to pass a flood flow or get plugged with floating wood can wash out the road or divert it down the road, thereby creating gullies.

Understanding rural road instability in a watershed involves two investigations. One involves collecting information about recent road washouts and possible factors that caused their failure, and the other involves identifying high-risk situations within the watershed that are likely to lead to road washouts in the future.

Gather Information

Road Inventory Databases

Information about road conditions and recent road-related landslides in your watershed may come from a number of sources. Forest landowners are good potential sources. Many have recently completed inventories of their road systems using a standard protocol also used on state forest lands by the ODF. These inventories include information about recent landslides near roads, road surface condition, and stream crossings. The protocol for these road inventories can be obtained from the ODF Web site at http://www.odf.state.or.us/FP/DEFAULT.HTM. Road inventory information may also be available from the USFS and BLM, but it will not be the same format. Remember, private landowners are under no obligation to share inventories. Allow extra time to obtain information from public agency databases; while they are required to provide their information upon request, they are often understaffed and may be slow to respond.

Road inventory databases have several weaknesses:

- Database features are sometimes difficult to match with a map location. Since the locations of features are usually determined in the field by measuring the distance from the last road junction, base map errors and field measurement errors may cause the landslide to be plotted in the wrong place. To confirm the accuracy of inventory site locations, use other nearby features noted in the inventory that also appear on the map. For example, if major stream crossings bracket a landslide, the distance to the landslide may be checked by comparing the noted distances with distances measured on the map.

- The database may not be up-to-date; recent road repairs may not be noted in the inventory. And, of course, road problems that developed after the inventory was completed will be missing. The database originator will know if the database is updated as road problems are fixed.

Aerial Photographs

Recent aerial photographs can be very useful for also identifying existing road-related landslides throughout the watershed. However, you will find that denser stands of trees greater than 30 years old will conceal landslides on aerial photographs.

Field surveys made by driving around the watershed are a good source of information and helpful for verifying the information compiled from other road inventories and aerial photographs. However, this activity is time-consuming, and some areas may be inaccessible due to locked gates or denial of permission to enter the area by the landowner.

Map and Compile Existing Road Instability Information

Compile information on existing road-related instability by marking landslide locations on the Base Map, and recording landslide information on Form S-2, Information on Existing Road-Related Instability. Locations are recorded where a landslide either appears in the aerial photographs, is described in a road hazard inventory, or is noted during a field visit.

Use Form S-2, or the ROADLAND Worksheet, to compile information on the subwatershed, and on the landslide type, whether or not it reached a stream, what distance it traveled, and road position. After marking the landslide on the Base Map, assign it a unique number and enter the information into the worksheet. Table 3 provides an example of information gathered on existing road-related instability.

Table 3. Example Form S-2: Information on existing road-related instability.

Number	Subwatershed	Landslide Type	Reached Stream?	Distance Traveled (ft)	Road Location
101	Deer	Debris flow	Yes	2,200	Mid-slope
102	Deer	Debris flow	No	1,000	Near ridge
103	Elk	Road prism failure	No	200	Mid-slope
104	Skunk	Culvert washout	Yes	-	Near stream

Number: Unique identification number.

Subwatershed: Subwatershed in which landslide occurs.

Landslide Type: Debris flow = initiates as shallow landslide in steep area and then flows down a channel, picking up additional soil, logs, and water. Road prism failure = downhill movement of the road cut or road fill; does not initiate a debris flow. Culvert washout = road fill partially or completely missing where the road crosses a stream.

Reached Stream?: Whether or not the landslide material ended up in the stream.

Distance traveled: The distance from initiation point to where the landslide stopped (not applicable to culvert washouts).

Road Location: General location of road: near ridge, mid-slope, near stream.

Map and Compile Potential Road Instability Information

Identifying the location of potential high-risk landslides or road washouts in the watershed allows a council to focus on preventing road instability. This information can be obtained from road inventory data and road surveys. In this portion of the assessment you will identify locations where (1) water is flowing over the road surface and fill slopes, (2) large cracks or slumps in the fill portion of the road, and/or (3) stream crossings that have undersized culverts. Culverts sizes are evaluated using a method adapted from the ODF in which you first document the current culvert capacity and then you compare this to the capacity needed.

Use Form S-3, Culvert Capacity and Risk of Large Amounts of Sediment Entering Stream, or the CULVERT Worksheet, to determine if the existing culvert is appropriately sized. First enter the subwatershed name and the unique number for each culvert (Columns 1 and 2). Identify the owner of the road in Column 3, if known. Then enter the current culvert size (from field information or road inventory data) in Column 4. Fill in current culvert capacity (Column 5) with values from Table 4. This table shows the flow capacity of both round culverts and of **pipe-arch culverts** of various standard sizes (pipe arches are wider than they are tall).

You will use the peak-flow map (50-year recurrence interval for peak flows in forest streams) from ODF to determine how large a culvert is needed for a stream crossing; enter the information in Column 6. In western Oregon and some of eastern Oregon, this map shows lines of equal value of peak flow associated with 50-year recurrence interval ranging from 50 to 600 cubic feet per second

Table 4. Capacity of culverts of various sizes.

Round Culverts		Pipe-Arch Culverts	
Diameter (inches)	Capacity (cfs)	Span x Height	Capacity (cfs)
15	3.5	22" x 13"	4.5
18	5.5	25" x 16"	7
21	8	29" x 18"	10
24	12	36" x 22"	16
27	16	43" x 27"	26
30	20	50" x 31"	37
33	26	58" x 36"	55
36	32	65" x 40"	70
42	47	72" x 44"	90
48	67	6'-1" x 4'-7"	130
54	88	7'-0" x 5'-1"	170
60	115	8'-2" x 5'-9"	240
72	180	9'-6" x 6'-5"	340
84	260	11-'5" x 7'-3"	470
96	370	12'-10" x 8'-4"	650
108	500	15'-4" x 9'-3"	930
120	670		
132	840		

(cfs) per square mile of drainage area. In much of eastern Oregon you will see areas that have a regional average value. Culverts installed on nonfederal forest roads are required to at least pass a peak flow of the magnitude shown for your location on the map. For example, if your watershed is in the central Coast Range and the 200 line runs through it, culverts need to be sized to handle at least 200 cfs of flow for each square mile of drainage area upstream of the site.

You can measure the drainage area of a site using the Base Map. Starting from the culvert site, delineate the drainage boundary by drawing a line that is always perpendicular to the elevation contours (see method for delineating watersheds in the Start-Up and Identification of Watershed Issues component). Measure the area bounded by the line using a map grid or map wheel (see method for calculating drainage area in Start-Up component) and enter the value in Column 7. Multiply the drainage area (Column 7) times the peak flow value (Column 6). For example, a site that has a design criteria of 200 cfs per square mile and a drainage area of 0.65 square miles needs a culvert that passes 131 cfs (200 x 0.65 = 131). Enter the multiplied value in Column 8.

To determine the appropriate culvert size corresponding to the design flow, refer to Table 4. Find the culvert size required to pass the calculated peak flow value (from Column 7) and enter the value in Column 9. In the above example, the minimum culvert size is a 72-inch circular culvert or a 7'-x-5'1" pipe arch. Now, look up the capacity of the current culvert in Table 4 and write it down in Column 5. If the current culvert was 48 inches in diameter, the capacity would be 67 cfs. Next, calculate a ratio (Column 10) of the 50-year flow (Column 6) divided by the current culvert's capacity (Column 5). In the example above, this ratio would be 131/67= 2.0.

The height of the fill at the stream is important information for evaluating the consequences of a road washout. If a culvert washes out, the amount of soil entering the stream can be low if the fill is small or large if the fill is high. Enter fill height (estimated at the outside edge of the road surface) in Column 11. Next, assign culverts to various risk classes (low through extreme) as shown at the bottom of Form S-3. The risk class goes in Column 12. An example of an inventory of culvert information is shown in Table 5.

Identify Road Segments at Risk

The three risk factors used to identify potential road instability are cracks and slumps in roads (cracks/slumps), water running down a road or onto an unstable fill (water/fill), and undersized culverts in high fills at stream crossings (culvert). Use information within road surveys or your own knowledge of the watershed to identify locations where cracks and slumps in roads exist. Do the same for locations where water is running down a road or onto an unstable fill. Assign each location a unique identification number and mark on the Base Map the location of each site and the identification number.

Combine information about all three risk factors into Form S-4, High-Risk Road Segments for Existing Roads, or the ROADRISK Worksheet (including only culverts with a hazard rating of high, very high, or extreme). Table 6 provides an example of what information to include.

Table 5. Example Form S-3: Culvert capacity and risk of large amounts of sediment entering stream.

1 Sub-watershed	2 Num.	3 Road Owner-ship	4 Current Culvert/ Pipe-Arch Size	5 Current Culvert Capacity (cfs)	6 ODF Peak-Flow Value (cfs/mi²)	7 Drainage Area (mi²)	8 50-Year Peak Flow (Col. 6x7) (cfs)	9 Culvert/ Pipe-Arch Size Needed for 50-Year Peak Flow	10 Ratio of 50-Yr Flow to Current Capacity	11 Fill Height (ft)	12 Hazard Rating *
Deer	201	USFS	30"	20	200	0.65	131	72"	6.5	20	Extreme
Elk	202	County	30"+30"	40**	200	0.44	88	54"	2.2	18	Very high
Elk	203	Un-known	9'-6"x 6'-5"	340	200	2.73	545	12'-10"x8'-4"	1.6	3	Moderate
Skunk	204	County	60"	115	200	0.38	75	54"	0.7	35	Low
Skunk	205	State	72"	180	200	0.60	119	72"	0.7	3	Very low

* Hazard rating:

Very low — Fill height is 15 feet or less and ratio is less than 1.25.

Low — Fill height is greater than 15 feet and ratio is less than 1.25.

Moderate — Fill height is 15 feet or less and ratio is between 1.25 and 1.75.

High — Fill height is greater than 15 feet and ratio is between 1.25 and 1.75; or, fill height is 15 feet or less and ratio is between 1.76 and 3.

Very high — Fill height is greater than 15 feet and ratio is between 1.76 and 2.99; or, fill height is 15 feet or less and ratio is greater than 3.

Extreme — Fill height is greater than 15 feet and ratio is greater than 3.

** Stream crossing had two 30"-diameter culverts.

Table 6. Example Form S-4: High-risk road segments for existing roads.

Sub-Watershed	Num.	Feature Type	Hazard Rating of Culvert	Road Ownership
Deer	201	Culvert	Extreme	Forest Service
Deer	251	Water/fill	-	Forest Service
Deer	252	Water/fill	-	Private landowner
Elk	202	Culvert	Very high	County
Elk	253	Cracks/slumps	-	Private landowner
Skunk	254	Water/fill	-	Private landowner
Skunk	255	Cracks/slumps	-	Private landowner

Map 1 in Appendix VI-A provides an example of a finished map showing information compiled for both existing and potential road instability sites.

Summary: Road Instability

A final step in this process is to create summary tables (Form S-5, Summary of Information on Road Instability, or the ROADINST Worksheet) that allow subwatersheds and/or land ownership classes to be compared. Existing road instability (from Form S-2) and high-risk areas for future instability (from Form S-4) are both entered into the table but are evaluated separately. The number of sites in a subwatershed are divided by the subwatershed area and displayed on a per-unit basis. Table 7 provides an example of the summary table. An expanded version can be constructed by breaking down each subwatershed summary into road ownership classes.

This example highlights several issues that should be examined and discussed, including: a high density of landslides in the Deer and Eagle subwatersheds; a high density of high-risk culverts in the Eagle subwatershed; and a high density of road cracks, slumps, and road water in the Skunk and Bear subwatersheds. Note in what locations within these subwatersheds the landslides are occurring. Examine the Base Map to see if landslides are more common nearest streams or nearest ridge-tops. Does slope steepness explain the variation in landslide clusters? Check if landslides occur in clumps along only a few roads or are evenly spread out. Examine the map and see if landslides tend to clump according to land ownership. Such examination will help you determine landslide causes.

The example also highlights another issue: the high density of high-risk culverts in one subwatershed. Refer to the Base Map to determine why. Does the road mostly follow streams, thereby requiring many stream crossings? Do a high percentage of these high-risk culverts occur on a certain land ownership? Do the high-risk culverts occur mainly within one size class of stream? Answers to these questions may require the help of a road engineer to help unravel the spatial variability of high-risk culverts and suggest remedies.

Table 7. Example Form S-5: Summary of information on road instability.

Subwater-shed	Area (mi²)	Road Failures that Reached Streams		Sites with High-Risk Culverts		Sites with Cracks and Slumps		Sites with Water Flowing Over Fills	
		#	Density (#/mi².)	#	Density (#/mi².)	#	Density (#/mi².)	#	Density (#/mi².)
Deer	4.6	13	2.8	3	0.7	0	0.0	0	0.0
Elk	6.5	2	0.3	4	0.6	2	0.3	5	0.8
Skunk	8.3	15	1.8	10	1.2	18	2.2	20	2.4
Bear	2.1	3	1.4	2	1.0	4	1.9	4	1.9
Eagle	10.1	21	2.1	15	1.5	9	0.9	3	0.3
Total	31.6	54	1.7	34	1.1	33	1.0	32	1.0

Table 7 also highlights the high density of road segments with cracks, slumps, or areas where runoff water flows onto road fills in the Skunk and Bear subwatersheds. In this case, it will take additional evaluation to determine if this is related to side-slope steepness, position on the hill slope, or road-building practices and maintenance on the part of the landowner.

Other information can be brought in to help decipher road instability questions, such as geological information, road age, and rainfall patterns. A geological map of the area may provide information on general rock types; landslides can be more common at the contact zone between two rock types. The era in which the road was built may explain why some are stable and some are unstable. You may be able to assign ages to road segments by estimating the age of the oldest **harvest units** in the general area. Finally, you should consider when the last sustained and high-intensity rainfall occurred and how it might have varied across the watershed. Road instability is seldom noticeable until the road is tested by severe storms.

Source 2. Slope Instability (not related to roads)

Slopes can be unstable for reasons other than roads. Landslides can be a natural part of the landscape, especially where slopes are steep and rainfall is abundant. Landslides include both shallow slope failures that go a short distance and those that travel down a channel, gathering up soil, water, and wood and creating a debris flow (Figure 2). Landslides also include deep-seated failures that creep or ooze downhill at slow rates. A combination of the two can occur when the over-steeped face of a deep-seated landslide becomes the site of shallow slope failures.

Shallow landslides typically occur in very steep terrain. There is some evidence that removal of trees on steep slopes (greater than about 80%) makes an area vulnerable to shallow landslides and can lead to a temporary acceleration of the landslide rate. This window of vulnerability begins when many of the finer roots of the harvested trees become rotten (about 4 years) and ends once the

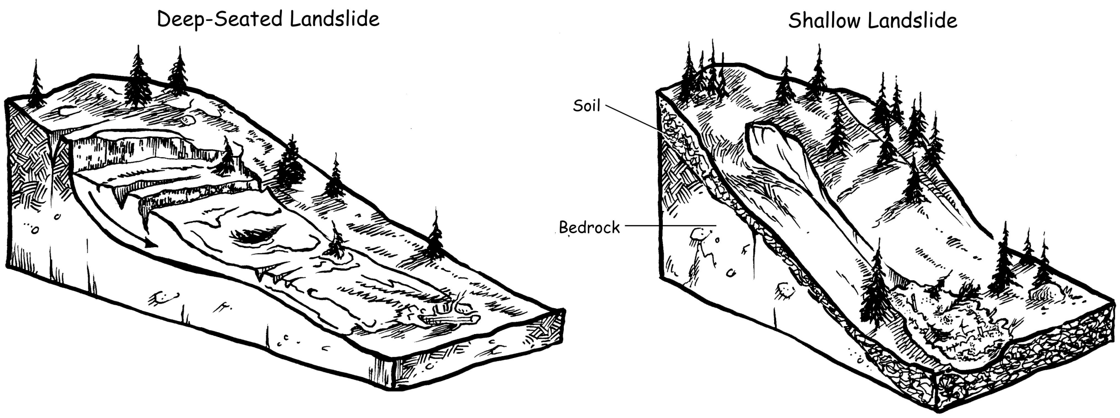


Figure 2. Some landslides travel down a channel, gathering up soil, water, and wood and creating a debris flow. Landslides also include deep-seated failures that creep or ooze downhill at slow rates.

replacement stand has developed a dense root network (about 30 years for wet portions of the state).

Most deep-seated landslides are natural. The only times when human-activities seem to influence these landslides is when a road or other feature undercuts the base of the slide or adds weight to the top of the slide. A deep-seated landslide area can also be triggered by road runoff water diverted onto an unstable slope. Deep-seated landslides are not restricted to steep slopes. Some of the most active and extensive landslides can occur on moderate slopes with weak soils. Deep-seated landslides add sediment to streams by pinching off stream channels. When a stream is constricted by an encroaching landslide, the stream carves away at the base of the landslide, causing the slope to be further destabilized.

Slope instability (unrelated to roads) is evaluated by collecting information about recent landslides and high-risk areas in the watershed that are likely to move in the future. This is done using recent aerial photographs, referring to federal or state agency aerial photograph landslide inventories of portions of the basin, and asking landowners, local fishermen, and fisheries biologists where landslides are located. Deep-seated landslides next to streams can cause chronic turbidity, but are often difficult to identify on aerial photos unless they have bare surfaces.

Finding information on existing landslides will probably be frustrating. You can use recent aerial photographs to detect some landslides but you will seldom be able to observe landslides among dense trees older than about 30 years. You might find that a federal or state agency has already done some aerial photography or ground-based landslide inventories of portions of the basin, but they may not be recent surveys. In many cases, it will probably be better to conduct your own inventory from recent photos so that you can cover the entire watershed, have a current inventory, and be able to gather other information that is useful in this assessment.

Recent Landslides

Begin the mapping of existing landslides by locating landslides seen in the aerial photographs, skipping those that initiate at roads. At first glance, some features may appear similar to a landslide. **Skid trails**, **cable yarding scars**, **landings**, **borrow pits**, and **rock pits** can leave patches of bare soil that appear similar to the scar left by a landslide. You can usually resolve these uncertainties by examining the aerial photographs using a **stereoscope**. A stereoscope will allow you to see the feature in three dimensions. If necessary, take the photos to the field and verify what you see on the ground and what you see in the photographs. Assign a unique number to each landslide located on the aerial photographs and mark the location on the Base Map. Use roads, timber harvest boundaries, and streams for orientation. Observing the landslide in stereo will show its location with respect to nearby ridges and **draws**, which show up on the Base Map. Enter the subwatershed name, unique number, and type of landslide on Form S-6, Current Landslides Not Related to Roads, or the LANDCUR Worksheet. Table 8 provides an example of this.

From the aerial photograph, estimate the age of the vegetation at the landslide's initiation point (see the Start-up Component for guidance on how to read aerial photos). Also determine the distance the landslide traveled from the initiation point and whether or not it reached a stream. Enter this information in the appropriate columns on Form S-6. From the Base Map, determine slope steepness at the initiation point by measuring the distance between 5 contour intervals using the 20-scale of an engineer's scale. Multiply the vertical distance represented by a single contour (usually 40 feet) by 5, divide by the distance between 5 contour intervals, and then multiply by 100, as shown below:

Slope (%) = 5 x 40 feet / distance x 100

If the contour interval of the Base Map happens to be 20 feet, then substitute 20 for 40 in the above equation. Figure 3 provides an example of a landslide in an aerial photo and the measured site characteristics. Map 2 in Appendix VI-A provides an example of a finished map showing information compiled on slope instability not related to roads.

Table 8. Example Form S-6: Current landslides not related to roads.

Sub-watershed	Num.	Type of Landslide	Age of Vegetation (years)	Landslide Reached Stream?	Distance Landslide Traveled (feet)	Slope Steepness at Initiation Point (%)
Deer	301	Shallow	10	Yes	1,700	110
Deer	3702	Deep-seated	20	Yes	200	50
Elk	303	Shallow	5	Yes	1,600	100
Elk	304	Shallow	10	No	900	75
Skunk	305	Unknown	30	No	300	80
Skunk	306	Shallow	5	Yes	800	95
Skunk	307	Deep-seated	10	No	100	45

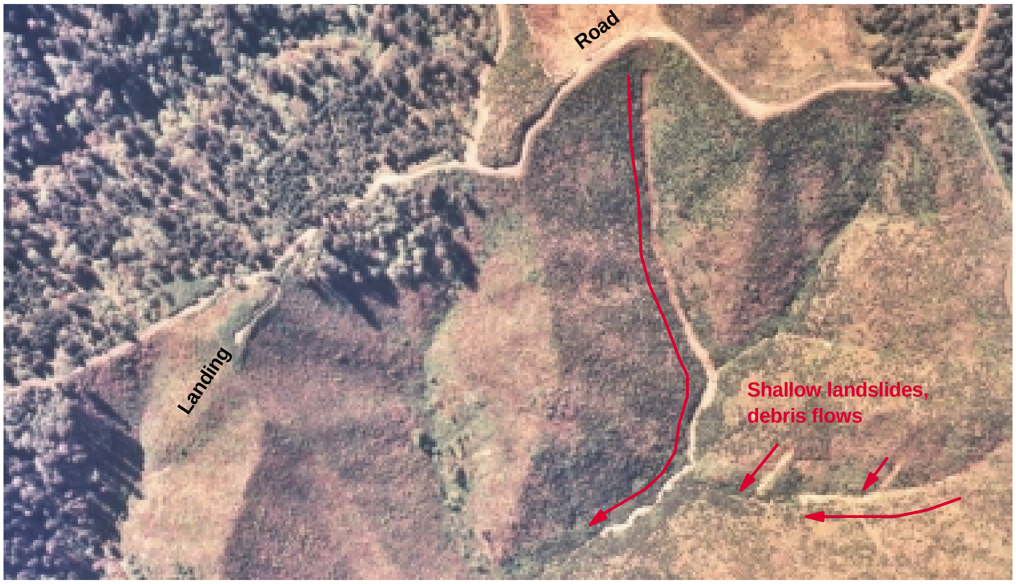


Figure 3. From the aerial photograph, you can estimate the age of the vegetation at a landslide's initiation point, and determine the distance the landslide traveled.

High-Risk Areas for Debris Flows

The ODF is in the process of finishing debris-flow-hazard maps for forested regions of Oregon. These maps will indicate areas prone to landslides and will provide a rating of the degree of landslide hazard. Since the maps are not yet available it is not possible to predict how the final maps will indicate the landslide hazard or **hazard delineations**. The maps will probably consist of polygons of high- and extreme-hazard delineations. The remainder of the area in the watershed will not be marked. To include this information on your Base Map, transfer the outlines of the high- and extreme-hazard polygons using a light table or window. Determine the area of these polygons using a grid or map wheel and compile the information, as demonstrated in Form S-7, Potential for Debris Flows, or the LANDPOT Worksheet. Table 9 provides an example of a completed Form S-7.

Table 9. Example Form S-7: Potential for debris flows.

Subwatershed	Areas Predicted to be High Risk for Debris Flows (mi^2)		
	High Hazard	Extreme Hazard	Combined
Deer	0.5	0.2	0.7
Elk	1.1	0.4	1.5
Skunk	0.4	0.1	0.5
Bear	0.2	0	0.2
Eagle	1.2	0.5	1.7
Total	3.4	1.2	4.6

Summary: Slope Instability

Combine information on recent shallow and deep-seated landslides and the potential for future debris into a single summary using Form S-8, Summary of Information on Slope Instability (not related to roads), or the LANDSUM Worksheet. The picture this form presents will be incomplete, because most of the existing landslides hidden by trees will have not been detected. In addition, the landslide potential rating addresses only debris flows and not deep-seated landslides. Nevertheless, the information can help you understand the relative abundance of landslides throughout the watershed. (See Table 10 for an example of a completed Form S-8.)

Information like that displayed in Table 10 can help you understand landslide patterns in the watershed and possible reasons for these patterns. For example, the Elk subwatershed has a low density of current shallow landslides (0.5/square mile) but a high percentage of the land has a high potential for debris flows (23%). In this case, it would be good to check the aerial photographs and work map to first see if there was an undercount of current shallow landslides in the Elk subwatershed simply because most of the land was covered by older trees that obscure existing landslides. Elsewhere, you can note that there is a higher-than-average density of current shallow landslides in the Eagle subwatershed (1.7), which is in agreement with the higher-than-average percentage of land that is classified as high risk for debris flows (17%).

Other information may help you understand patterns in landslide abundance. A change in geology may cause clusters of landslides to occur. Use a geologic map of basic rock types to see if high landslide density coincides with changes in geology, especially near streams. Also check to see whether or not current shallow landslide density coincides with the extremely steep slopes in the watershed. Finally, consider when the last sustained and high-intensity rainfall occurred and how it might have varied across the watershed. Like road instability, landslide activity unrelated to roads may be common only after a severe storm has hit the area.

Table 10. Example Form S-8: Summary of information on slope instability (not related to roads).

Sub-Watershed	Area (mi^2)	Current Landslides				Debris-Flow High-Risk Areas (combined high and extreme)	
		Shallow Landslides		Deep-Seated Landslides			
		Number (#)	Density (#/mi^2.)	Number (#)	Density (#/mi^2.)	Area (mi^2.)	Percent
Deer	4.6	10	2.2	2	0.4	0.7	15
Elk	6.5	3	0.5	0	0.0	1.5	23
Skunk	8.3	11	1.3	4	0.5	0.5	6
Bear	2.1	3	1.4	0	0.0	0.2	10
Eagle	10.1	17	1.7	6	0.6	1.7	17
Total	31.6	44	1.4	12	0.4	4.6	15

Source 3. Rural Road Runoff

The water draining from roads can move considerable amounts of sediment from the inside drainage ditch and unpaved road surfaces. The road ditch is filled in with sediment from **ravel**, sliding, and erosion of the road cut slope. Usually, roads are designed so water flowing through the ditch picks up this sediment as it flows into streams or small draws. However, some land managers have now adopted a technique whereby roads are designed to divert ditch water onto a stable slope using a **cross-drain culvert** at a site adjacent to but before the stream enters the stream. When the sediment-laden water is diverted onto stable and well-drained slopes, the sediment is filtered out as the ditch water goes subsurface.

The condition and amount of sediment coming from the surface of an unpaved road depends on the quality of the surface rock, road maintenance, weather conditions, and the weight and frequency of traffic. The break-up of the road surface is most rapid during wet weather and when heavy truck traffic is frequent. Poor-quality surface rock quickly breaks down into fine material and develops potholes. If the road is not maintained, ruts then begin to develop.

The amount of sediment potentially contained in runoff from any single road is difficult to estimate because road conditions can change so rapidly. A road surfaced with high-quality rock can be quickly reduced to a quagmire if water is allowed to pool during wet weather and there is heavy truck traffic. Conversely, a road with a poor-quality surface may not degrade much at all if it is used mainly during dry weather.

In this section, you will compile information about road segments in the watershed and assign an overall hazard rating that indicates the **general** propensity of that road segment to deliver sediment to streams. Two different assessments are described. The first, a basic assessment, simply identifies site conditions that are conducive for high amounts of sediment in road runoff to enter streams. The second assessment is detailed, and requires much more time but yields more useful information about the road systems in your watershed.

This section covers road runoff from rural roads. Rural roads are all roads except those that are within cities and towns and are hooked up to a stormwater drainage system.

Basic Rural Road Runoff Assessment

Some basic information about roads and the likelihood of sediment delivery to streams can be obtained by reviewing base maps and aerial photographs. From the maps, you can identify sections of road that are within 200 feet of a stream, either laterally or longitudinally (see Figure 4). Throughout the watershed, these are the road segments more likely to have ditches that flow directly into the stream and are the most difficult to keep sediment-laden runoff water from entering streams. You can also identify on the topographic maps where these road segments close to the streams also have steep slopes (greater than 50%) uphill of the road. Roads with steep side slopes usually have more soil accumulating in the road ditches than roads with less steep side slopes. Plugged road ditches are common cause of road surfaces breaking down. Also, you can gather some road information from the aerial photographs. Use the color of the road to determine whether the surface is paved, rock, or dirt. Finally, local experience by landowners and land managers can provide information on whether or not a road is a high-use road. By combining all these sources of information you can identify where in the watershed higher-risk situations exist for road runoff.

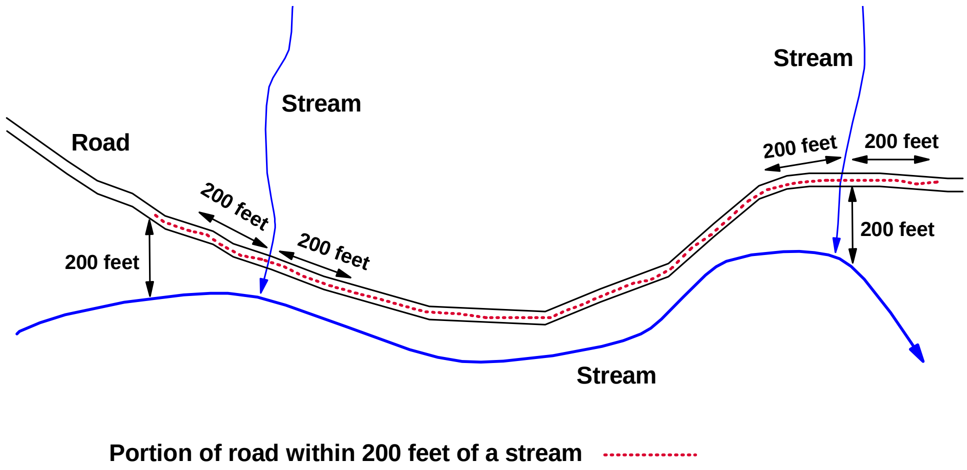


Figure 4. From maps, you can identify sections of road that are within 200 feet of a stream, which may help you determine the likelihood of sediment delivery to streams.

On the Base Map, identify and highlight road segments (400 feet or longer) within 200 feet of a stream, either laterally or longitudinally (see Figure 4). Assign the road segment a unique number and measure its length. Record this information on Form S-9, Basic Information on Road Segments Close to Streams with Steep Slopes, or the RUNOFF Worksheet. For each of the road segments, also determine which segments have a side slope greater than 50%.

You can identify 50% slopes by examining the spacing between contour lines. The contour lines on a topographic map (1:24000) with a contour interval of 40 feet are spaced slightly closer than the smallest units on the 20-scale of an engineer's scale where the slope is 50%. Measure the length of those portions of the road segment that have slopes greater than 50%. Finally, use the color of the road on aerial photographs to determine whether the surface is paved, rock, or dirt. By combining this information, higher-risk situations for road runoff can be identified. Table 11 provides an example of a completed Form S-9, and Map 3 in Appendix VI-A provides an example of a finished map showing basic information compiled on rural road runoff.

Table 11. Example Form S-9: Basic information on road segments close to streams with steep slopes.

Subwatershed	Num.	Distance <200' from Stream (feet)	Distance <200' from Stream and Slope >50% (feet)	Road Surface	Road Use
Deer	401	1,800	600	Paved	High use
Deer	402	2,200	0	Rock	Low use
Deer	403	1,200	400	Rock	Low use
Deer	404	900	800	Dirt	High use
Elk	405	1,400	300	Rock	High use
Elk	406	3,100	1,700	Rock	Low use
Elk	407	600	0	Rock	Low use
Elk	408	1,500	300	Rock	Low use

Detailed Rural Road Runoff Assessment

The mileage of road within in a watershed is usually too great for a watershed council to gather detailed information on each road section; however, in some areas of the watershed this information may have already been gathered by private forest landowners and state forest land managers. Most of these inventories use a standard protocol so information can be shared and combined. This information may be added to your assessment if you are willing to deal with difficulties matching database records to Base Map locations; be prepared for the process to take a long time.

Table 12 provides an example of information collected on road runoff that is included in a typical road inventory database. You will be taking information from tables such as these and summarizing them for inclusion in a summary table. You will also be adding the location of each road to the Base Map. The variables are listed below the table. Descriptions for ditch condition, cut-slope condition, surface condition, surface material, and road use are the average conditions for the road section beginning at the previous feature noted and extending to the current feature. See the ODF Forest Road Hazard Inventory Protocol (available from the hydrologist at the ODF, 503-378-3589) for more information.

Raw inventory data may be summarized (on Form S-10, Summarized Runoff-Related Information for a Single Road, or the SEDROADS Worksheet; see Table 13 for an example) for a single road by adding up road lengths or occurrences for each classification that a variable takes. Features for all roads within a subwatershed can then be summed as illustrated later in this section.

Summary: Basic Assessment

Summarize information on road segments near streams by subwatershed using Form S-11, Summary of Information on Road Runoff—Basic Assessment, or the RUNOFF Worksheet. Table 14 provides an example of a completed form. For each of the various categories (Roads <200' from a Stream; also with Steep Slopes, also with High Use, and also with Low Use), the lengths of road are summed and a density value calculated by dividing road length by subwatershed area. A variation could be constructed by including information about the road surface in the summary, yielding 26 rather than 10 columns and making it a more detailed table.

Summary information like this can help you identify areas where high-risk roads are common. For example, both the Skunk and Eagle subwatersheds have an unusually high density of roads within 200 feet of a stream. The situation in Skunk is likely to be of more concern because it also has the highest density of these segments that have steep slopes uphill of the road. Furthermore, the Skunk subwatershed has the greatest density of high-use roads.

Patterns like these should lead you to examine the base maps again and note where in the Skunk subwatershed these conditions are most prevalent. The Skunk subwatershed would be a high priority for a site visit (pick a very rainy day when the road is being used) to see whether or not these indicators of high sediment in runoff water coincide with actual conditions.

A variation of Table F14 could be constructed by including information about the road surface in the summary. As you can imagine, the introduction of the variable, Road Use, with its three categories (paved, rock, dirt) makes for a messier table. With the addition of Road Use you will end up with 26 columns rather than the 10 shown in Table F14.

Table 12. Example of runoff-related information in a road inventory database.

Eagle Creek Road									
Stationing (feet)	**Feature**	**% Grade (+/-)**	**Ditch Condtn.**	**Cut-Slope Condtn.**	**Surface Condtn.**	**Surface Material**	**Culvert Condtn.**	**Filtering Opportun.**	**Road Use**
0	Start rd.	0							
231	Grade Break	5	Good	Good	Good	Rock			Active
641	X drain culvert	3	Good	Good	Good	Rock	Good		Active
1191	Grade Break	7	Good	Ravel	Good	Rock			Active
1708	X drain culvert	-7	Good	Good	Good	Rock	Good		Active
2263	Road junction	-9	Good	Good	Good	Rock			Active
2619	X drain culvert	16	Good	Ravel	Good	Rock	Good		Active
3004	Stream crossing	10	Good	Ravel	Good	Rock	Good	No	Active
3520	X drain culvert	11	Good	Good	Good	Rock	Damaged		Active
3667	X drain culvert	9	Good	Ravel	Good	Rock	Good		Active
4093	X drain culvert	11	Good	Ravel	Good	Rock	Good		Active
4570	X drain culvert	11	Good	Ravel	Good	Rock	Good		Active
4870	Stream crossing	7	Good	Ravel	Good	Rock	Good	No	Active
5623	Stream crossing	7	Good	Good	Good	Rock	Good	No	Active
5778	Stream crossing	12	Good	Good	Good	Rock	Good	No	Active
6129	X drain culvert	9	Full	Good	Rutted	Dirt	Plugged		Inactive

Stationing (feet): Distance from the starting point of the survey to the beginning of the road segment.
Feature: Grade breaks; cross-drain culverts; stream crossings; road junctions.
% Grade: The gradient of the road in percent.
Ditch Condition: Good; downcutting, diverted onto road; full of sediment.
Cut-Slope Condition: Good; ravel problems; sloughed into road.
Surface Condition: Good; rutted; bermed; eroded.
Surface Material: Rock; dirt; pavement.
Culvert Condition: Good; damaged; plugged by sediment.
Filter Opportunity: Yes; no; possibly (whether or not site conditions would allow diversion of ditch water onto a stable slope before it enters a stream).
Road Use: Active; inactive.

Table 13. Example Form S-10: Summarized runoff-related information for a single road.

Road Name	Variable	Classification	Length (feet)	Occurrences (#)
Eagle Creek Road	Overall road length	-	7,742	-
Eagle Creek Road	Ditch condition	Good	5,778	-
Eagle Creek Road	Ditch condition	Full	1,964	-
Eagle Creek Road	Cut-slope condition	Good	5,101	-
Eagle Creek Road	Cut-slope condition	Ravel	2,641	-
Eagle Creek Road	Surface condition	Good	5,778	-
Eagle Creek Road	Surface condition	Rutted	1,964	-
Eagle Creek Road	Surface material	Rock	5,778	-
Eagle Creek Road	Surface material	Dirt	1,964	-
Eagle Creek Road	# Culverts	-	-	15
Eagle Creek Road	Culvert condition	Good	-	12
Eagle Creek Road	Culvert condition	Plugged / Damaged	-	3
Eagle Creek Road	# Stream crossings	-	-	6
Eagle Creek Road	# Stream crossings	Ditch water can be filtered	-	0
Eagle Creek Road	Road use	Active	5,778	-
Eagle Creek Road	Road use	Inactive	1,964	-

Table 14. Example Form S-11: Summary of information on road runoff—basic assessment.

Sub-watershed	Area (mi^2)	Roads < 200' from Stream		Roads < 200' from Stream and Slope > 50%		Roads < 200' from Stream and High Use		Roads < 200' from Stream and Low Use	
		Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)
Deer	4.6	2.5	0.5	1.5	0.3	0.5	0.1	2.0	0.4
Elk	6.5	3.3	0.5	0.6	0.1	2.0	0.3	1.3	0.2
Skunk	8.3	9.6	1.2	8.0	1.0	7.5	0.9	2.1	0.3
Bear	2.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Eagle	10.1	14.5	1.4	5.5	0.5	1.5	0.2	13.0	1.3
Total	31.6	29.9	0.9	15.6	0.5	11.5	0.4	18.4	0.6

Summary: Detailed Assessment

The detailed information from the road inventories that was compiled for each subwatershed (Table 13) offers many options for summarizing the data. There are too many variables for you to construct a single table. Instead, combine several variables in a way that allows you to look at one aspect of road runoff. Table 15 provides an example of how the condition of road ditches and of culverts could be combined to examine road maintenance issues.

Table 15. Example summary of some of a road-runoff detailed assessment.

Subwatershed	Area (mi^2)	Roads with Ditches in Good Condition		Roads with Ditches Filled with Sediment		Culverts in Good Condition		Culverts Plugged	
		Length (mi.)	Density (mi./mi^2)	Length (mi.)	Density (mi./mi^2)	Length (mi.)	Density (mi./mi^2)	Length (mi.)	Density (mi./mi^2)
Deer	4.6	21.0	4.6	5.2	1.1	65	14.1	26	5.7
Elk	6.5	12.0	1.9	1.0	0.2	112	17.2	21	3.2
Skunk	8.3	9.5	1.1	6.0	0.7	71	8.6	39	4.7
Bear*	-	-	-	-	-	-	-	-	-
Eagle	10.1	35.5	3.5	2.0	0.2	154	15.3	24	2.4
Total	29.5	78.0	2.6	14.2	2.2	402	13.6	110	3.7

* No road inventories were completed for this subwatershed.

In this example, the Deer subwatershed has the highest density of sediment-filled ditches that no longer convey water on the inside of the road. In addition, this subwatershed has the highest density of plugged culverts. This suggests that roads are not being maintained as well as roads elsewhere in the watershed. Refer to the Base Map and, after sketching in land ownership on the map, check to see if the problems are confined to one or more groups of land managers. You might also check the geology and Base Maps to see if there is anything different about the terrain in that area. The depth of your investigation into road surface runoff may be limited only by the time you have to work the numbers.

Source 4. Runoff From Urban Areas

Sediment in urban areas enters streams differently than elsewhere in the watershed. In cities and towns, most sediment is delivered to streams via the stormwater system. The stormwater system is the maze of underground pipes and ditches that convey runoff from streets, other paved areas, and roofs to a nearby stream, river, or lake. The sediment within stormwater can come from a number of sources, including wind-deposited soil, degrading pavement, sand applied to roads during icy conditions, and erosion from yards and from construction sites. The sediment within stormwater also includes a large component of organic matter.

Different types of land within an urban setting produce different amounts of sediment. Residential neighborhoods produce the least amount of sediment per square mile. Commercial areas produce moderate loads of sediment, and heavy industrial areas produce even higher amounts. The highest amounts occur in areas that are actively being developed. Earth disturbances and bared surfaces usually makes sediment production the highest within a town, albeit the sediment production usually decreases once the construction is complete.

A particular problem with sediment from urban areas is that pollutants are often attached to the sediment particles. Many heavy metals, toxic compounds, nutrients, and bacteria readily attach to sediment particles derived from urban sources. Of major concern are zinc, copper, oil and grease, yard pesticides, and phosphorus. These compounds are known to be harmful to fish and other aquatic life at high concentrations. A number of innovative ways have been developed to remove urban sediments and their attached pollutants before they reach streams or lakes. One simple method for removing sediment is to simply allow much of the sediment to settle in a **detention pond** or underground basin before bypassing the water to a stream or lake. Well-designed detention ponds can remove about one-half of the sediment in stormwater. A more expensive but very effective solution is to temporarily store the stormwater, and then process it at the sewage treatment plant during nonpeak periods.

Regular street cleaning can make quite a difference in how much sediment ends up in stormwater. Normal mechanical sweeping does a moderately good job of reducing sediment in curbs and parking lots. Vacuum-assisted cleaning following mechanical sweeping removes an even larger portion of the surface sediments, especially those sediments that are small and do not readily settle out in detention ponds. Table 16 provides a summary of the factors that influence stormwater sediment loads within urban areas.

Work Maps

Use work maps acquired from the public works department to evaluate sediment from a city in your watershed. The maps should show roads, streams, lakes, and the stormwater network (pipes, detention facilities, and any processing plants). Take the map to a photocopy shop and make several large-format copies. Delineate the stormwater watershed boundary or boundaries on the maps. These boundaries may not be the same as the natural drainage boundaries, because stormwater pipes may shuttle water from one sub-basin to another. Create separate stormwater subwatersheds if one set of pipes drain to one stream and another set to another stream. Using the streets on the map and aerial photographs as a guide, along with your knowledge of the city, further classify the stormwater watersheds into urban area types (residential, commercial, heavy industrial, and developing urban). Mark these boundaries on the map.

Next, meet with the person at the public works department most familiar with the stormwater system, and ask about city street-cleaning practices for various portions of the city. Add boundaries to your map that show where the street-cleaning activities indicated in Table 16 are performed. Ask about sediment removal efforts such as detention ponds or basins that were constructed to settle out some of the sediment load and highlight these features on the map. Ask how effective the detention facilities have been for trapping sediment. Also, ask if any of the stormwater is being conveyed to the sewer treatment plant for processing. Add boundaries to the map showing these sediment removal zones (Table 16). Finally, ask about any areas within the urban growth boundary that will be developed within the next 5 years. Highlight these areas on the map and label them “developing urban.”

Table 16. Factors that influence sediment loads within urban stormwater.

	Classification	Rating	Code
1. Urban area type: Relative sediment production per unit area of land	Residential	Low	L1
	Commercial	Moderate	M1
	Heavy industrial	High	H1
	Developing urban	Very high	VH1
2. Street cleaning: Amount of curbside and parking-lot sediment eliminated	None or infrequent	Small	S2
	Frequent mechanical	Moderate	M2
	Vacuum-assisted	Large	L2
3. Sediment removal: Amount of sediment removed from stormwater	None	None	N3
	Detention ponds/basins	Moderate	M3
	Treatment plant processing	High	H3

Summary: Urban Runoff

Transfer information from the work map to a final map. Using various colors and styles, redraw the boundaries for the information you collected. Assign a unique number to each polygon on the map. Next, assign a code for each polygon on the map that represents the combination of conditions for that polygon (Table 16). The code will have three parts. The first part indicates the urban area type, the second indicates street-cleaning methods, and the third indicates any processes for removing sediment from the stormwater before it enters the stream.

An example of a code for a polygon would be L1/M2/N3. This code would indicate:

- L1- Area has a relatively low amount of sediment production (residential housing).
- M2 - Sediment removal from streets and parking lots is moderate (regularly cleaned with mechanical sweeping).
- N3- Sediment removal from stormwater does not occur.

Use a grid or map wheel to determine the area of each of the polygons within each stormwater watershed, and calculate the percentage of total area that falls within each polygon. Enter this information on Form S-12, Information on Urban Runoff Polygons, or in the URBAN Worksheet. Table 17 provides an example of polygon attributes and their area. Map 4 in Appendix VI-A provides an example of a finished map showing basic information compiled on urban runoff.

Table 17. Example Form S-12: Information on urban runoff polygons.

Stormwater Subwatershed	Polygon #	Polygon Area (acres)	Area as a Percentage of Total	1. Sediment Production	2. Street Cleaning	3. Sediment Removal
Oak Creek	501	2,555	79	L1	M2	N3
Oak Creek	502	250	8	VH1	M2	N3
Oak Creek	503	360	11	M1	M2	M3
Oak Creek	504	50	2	H1	M2	M3
Total		3,215	100			
Johnson Creek	506	1,550	69	L1	M2	M3
Johnson Creek	507	120	5	VH1	M2	M3
Johnson Creek	508	420	19	M1	M2	M3
Johnson Creek	509	160	7	H1	M2	M3
Total		2,250	100			

This analysis can help identify opportunities for minimizing the sediment that enters urban streams and lakes. For example, 87% of the Oak Creek subwatershed has no sediment removal infrastructure (N3). Oak Creek is mostly residential (L1), with some developing areas (VH1); in Johnson Creek, detention basins (M3) service all of the residential and developing areas (69% of total). One could then assume that, all else being equal, Oak Creek suffers from a much higher load of urban sediment than does Johnson Creek. If the construction of detention basins is not an option, an alternative worth considering is the use of better street cleaning (L2) in those areas without detention basins (M3).

A detailed engineering study would be required to assign actual sediment amounts to each of the relative ratings shown in Table 16. If such a study is completed, you would be able calculate estimated sediments loads (tons of sediment per acre per year) for each polygon.

Source 5 Sediment from Crop Land

Evaluating soil erosion for crop land is complicated, since erosion from crop land is related to many factors, such as the types of crops planted, soil type, farming practices, steepness of the land, and the timing of erosion-causing events. Most erosion and sediment movement occurs during unusual events such as summer thunderstorms, quick snowmelt, or high-intensity rainfall. For much soil movement to occur, these unusual events must coincide with the crop land being vulnerable to erosion. When a field is covered by vegetation with thick roots, a high-intensity rainfall will not create much erosion. Yet, when that same field is freshly plowed, a high-intensity rainfall may cause extensive erosion.

Erosion on crop land is often difficult to spot. **Rills** that form during a runoff event may disappear once a field is tilled or the crop begins to grow and cover the soil, or soil eroded from the top of a slope may simply be deposited at the bottom of the slope in an even layer. The best place to look for signs of excessive erosion is along draws and streams, especially if the land is relatively flat next to the channel. Here, you would expect to find thick mounds of newly deposited soil near the banks following a severe runoff event that caused much erosion.

An approach used in this manual for evaluating the potential for soil erosion makes use of information about the susceptibility of the soil to erosion, the slope of the land, the type of crop planted, and general farming practices. You will classify areas according to these factors and use your own experience and observations by others to determine which combinations of these factors have low, medium, or high soil erosion potential in your watershed. The decision process is set up as follows:

> **If:** erodibility class of the soil is W, **and** slope steepness class is X, **and**
>
> crop type is Y, **and** the farming practice is Z,
>
> **Then:** soil erosion rating is V.

You will map information about soil erodibility class, slope steepness class, crop type, and farming practice on a site-specific basis and then use site observations of actual erosion to assign a relative erosion rating (low, moderate, high). You will track combinations of site characteristics that lead to high erosion rates, and apply this information across the watershed.

Task 1

Use county soil survey books to determine the soil erodibility class. All of the county soil surveys, except some that have not been updated since 1970, will have a table about the physical and chemical properties of soils. The table includes a column called "Erosion Factors." Here, you will find that each soil type has been assigned a value for K. The erosion factor K indicates the susceptibility of a soil to **sheet erosion** and rill erosion by water. The higher the value, the more susceptible the soil is to erosion. Some soil surveys provide a K value for various soil depths; use the K value associated with about the top 12 inches of soil. Many soil types have roughly the same K values. To simplify this assessment, aggregate the soils into three K value classes: low (<.20), moderate (.20 to .40) and high (>.40), and compile information in a three-column table. An example of this is shown for a set of soils in Umatilla County in Table 18.

Task 2

Transfer K classes to the topographic base maps. Make photocopies of the soil maps (those in the watershed with crop lands, and those with range lands if they also will be assessed) in the soil survey book. Reduce the soil maps by 20% (or 80% of the original size) when photocopied to achieve 1:24000 scale (the soil map scale is 1:20000). Although more expensive, you can make color copies in order to retain the aerial photograph backdrop in the soils maps. This is helpful when transferring the field boundaries to the Base Map.

Use a colored marker to highlight the boundaries of the three K classes on the soils maps. Keep your table of soil types and K classes (like Table 18) handy to determine where the boundaries should go, and label the K-value zones as Low, Medium, or High. Transfer these boundaries and labels to the Base Map using a light table or window, adjusting the soil map as needed to ensure alignment.

Table 18. Example of soil types segregated by K values.

Soil Types		
Low K* < .20	Moderate K .20 - .40	High K > .40
2D	6E	1C
3D	7F	1D
4C	8F	1E
5C	9F	12B
10E	24	13B
17	25E	14B
43F	26	16D
51D	27	17B
56B	28	18D
	32	20B
		22B

* K = Susceptibility of the soil to water erosion.

Task 3

Delineate zones of common steepness on the Base Map. The slope steepness classes used in this module are <10%, 10 to 20%, 20 to 40%, and >40%. Use the 20-scale on an engineer's ruler to measure the contour line. Refer to Table 19 to determine the distance between contour lines for each steepness zone. This distance varies depending on the map contour interval . Check the map legend for the contour interval (either 40 feet, 20 feet, or 10 feet). When drawing in the boundaries of the slope steepness classes, ignore very small islands of one class that fall within another class.

Task 4

Transfer field boundaries to the Base Maps. Reduced color copies of the soils maps provide the best information on field boundaries. Use recent aerial photographs to determine general crop types and to add or revise any fields not on the soils maps. Use a light table or window to transfer field boundaries onto the Base Map, labeling each field or groups of fields with codes indicating the same crop type (Table 20).

This results in a Base Map with polygons representing various combinations of soil erosion susceptibility, slope steepness, and crop type. Map 5 in Appendix VI-A provides an example of a finished map showing information compiled on surface erosion from crop land.

Table 19. Distance between contour lines for each slope steepness class.

Map Contour Interval	Slope Steepness Class	Distance Between Contour Lines (feet)
40 feet	<10%	>400
	10 to 20%	200 to 400
	20 to 40%	100 to 200
	>40%	<100
20 feet	<10%	>200
	10 to 20%	100 to 200
	20 to 40%	50 to 100
	>40%	<50
10 feet	<10%	>100
	10 to 20%	50 to 100
	20 to 40%	25 to 50
	>40%	<25

Table 20. General crop types.

Crop Type	Label
Wheat	W
Other grain	G
Grass seed	GS
Hay	H
Corn	C
Other row crops	R
Berries	B
Orchards	O
Vineyards	V
Christmas trees	CT
Nursery operations	N
Poplar plantations	P
Other	Oth

Task 5

Next, create a database of observations on how combinations of site factors and farming practices influence erosion in your watershed. This is the most difficult but perhaps the most informative task. Observations are best made immediately after a high-runoff period and during the time when fields are most vulnerable to erosion. For wheat, this may be when the field is fallow. Christmas tree farms may be most vulnerable the first winter after the site has been prepared for a new planting. For a grass field, this may be during the fall rains immediately after a new planting.

Site observations are meant to be a collaborative process that includes not only the analysts but also farmers and others with knowledge of farming practices in the watershed. During a site observation you will be noting several items. First, examine the area for signs of moderate or high erosion. Erosion severity classes for crop land are defined as follows:

- High: Deep rills or gullies. Extensive deposits of sediment on flatter areas near or in streams and draws. Deep sediment deposits at culvert inlets or at the uphill sides of elevated roads.

- Moderate: Shallow but numerous rills. Shallow deposits of sediment on flatter areas near streams and draws. Shallow sediment deposits at culvert inlets or at the uphill of elevated roads.

- Low: Otherwise.

You will also want to note the condition of the field previous to recent runoff events (e.g., freshly plowed, fallow, early stage of crop growth, crop removed, crop occupies site), as well as the crop planted or to be planted. Next, look for evidence of soil conservation measures used by the farmer, or better yet, contact the farmer and ask about any soil conservation measures used on that field. Mark the location where the field was observed and assign it a unique number. Soil conservation measures for crop land include:

- Crop rotation: Cover crops are planted for the winter in order to prevent erosion and runoff when winter rains or spring snowmelt arrives.

- Contour cultivation: On gently sloping land, fields are tilled on the contour rather than up and down the slopes in order to retard the velocity of overland flow of water. Not effective on steep slopes.

- Strip cropping: A cropping technique in which alternate strips of different crops are planted in the same field, usually on the contour.

- Conservation tillage: Any tillage system that reduces tillage and leaves at least 30% of the field surface covered with crop residue after planting is completed.

- Riparian strips: Establishment of buffers or grass, shrubbery, and trees along channels to slow runoff and prevent scouring of the channel banks and bottom.

Enter the information from the Base Map with that obtained from field observations in Form S-13, Database for Tracking Field Observation and Mapped Information on Crop Land and Range Land, or the CROP Worksheet. Table 21 provides an example of a completed Form S-13 for crop land.

Summary: Crop Land

After a number of observations have been included in the database, you may start to see patterns developing. For example, combinations of the soil K factor, slope steepness, and field conditions may result in moderate erosion when normal wheat-farming practices are used but low when certain conservation practices are used. Enter summary information in Form S-14, Summary of Crop Land and/or Range Land, Grazing Erosion Observations, or in the CROPSUM Worksheet. Table 22 provides an example of a completed Form S-14. The various combinations of site and farming practices are listed and the number of observations with low, medium, or high erosion are summarized.

The information gained from a data set like the one shown in Table 22 provides insight into combinations of site factors where an improved farming practice would yield the greatest reduction in incidences of moderate to high soil erosion. One of the main benefits of this approach is that the information is tailored to your watershed. From observations made by the watershed council and farmers, you can begin to develop rules-of-thumb that apply to the watershed.

Source 6. Sediment from Range Land and Pasture

Soil erosion on range land and pasture (referred to as range land in the remainder of this section) is usually more subtle than on cropped areas. Like crop land, sediment movement from range land occurs during infrequent and unusual runoff events, such as summer thunderstorms, quick snowmelt, or high-intensity rainfall. However, the grass itself is a significant barrier to soil movement. Dense grass and the associated root mass present reduces soil movement when unusual runoff events occur. Large-scale gullying and rilling usually occur only on the most heavily overgrazed lands. Few people witness these periods of soil movement, and in steeper terrain, there may be no clear evidence that soil erosion has occurred.

Grazing often occurs on steeper slopes where natural sediment movement is relatively high, which makes it difficult to separate natural erosion from grazing-caused erosion. In addition, areas near streams are often most vulnerable to erosion. These areas are usually green into late summer and fall. Animals are attracted to the green vegetation. When intense grazing occurs in the late summer and fall, these streamside areas are left with sparse foliage and root mass during potential high-flow periods in winter and spring.

Table 21. Example Form S-13: Database for tracking field observation and mapped information on crop land.

Sub-Watershed	Observation	K Class	Slope Steepness Class	Crop	Farming Practices	Field Condition	Actual Erosion	Runoff Event
Deer	601	Medium	10 to 20	Wheat	Normal	Fallow	Moderate	Observed after a late-summer thunderstorm
Deer	602	Medium	10 to 20	Wheat	Normal	Stubble	Low	Observed after a late-summer thunderstorm
Bear	603	Low	<10	Wheat	Normal	Fallow	Low	Observed after a late-summer thunderstorm
Elk	604	Low	10 to 20	Wheat	Riparian strips / conservation tillage	Stubble	Low	Observed after a late-summer thunderstorm
Skunk	605	High	10 to 20	Wheat	Normal	Stubble	High	Observed after a late-March snowmelt
Skunk	606	High	10 to 20	Wheat	Conservation tillage	Fallow	Moderate	Observed after a late-March snowmelt
Skunk	607	High	20 to 40	Wheat	Conservation tillage	Fallow	High	Observed after a late-March snowmelt

Table 22. Example Form S-14: Summary of crop-land erosion observations for wheat.

Crop: wheat

K Class	Slope Class	Farming Practice	Field Condition	Number of Observations by Erosion Class			
				Low	Mod-erate	High	Total
Low	<10	Normal	Fallow	4	2	0	6
Low	<10	Normal	Stubble	8	0	0	8
Low	<10	Conserv. tillage	Fallow	9	0	0	9
Low	<10	Conserv. tillage	Stubble	7	0	0	7
Low	10 to 20	Normal	Fallow	3	3	0	6
Low	10 to 20	Normal	Stubble	4	3	0	7
Low	10 to 20	Conserv. tillage	Fallow	5	2	0	7
Low	10 to 20	Conserv. tillage	Stubble	6	2	0	8
Moderate	<10	Normal	Fallow	4	5	0	9
Moderate	<10	Normal	Stubble	4	2	0	6
Moderate	<10	Conserv. tillage	Fallow	5	4	1	10
Moderate	<10	Conserv. tillage	Stubble	6	2	0	8
Moderate	10 to 20	Normal	Fallow	1	2	3	6
Moderate	10 to 20	Normal	Stubble	1	3	1	5
Moderate	10 to 20	Conserv. tillage	Fallow	1	4	3	8
Moderate	10 to 20	Conserv. tillage	Stubble	3	6	0	9

Some of the best places to detect sediment movement on range land is along draws and streams. Here, the runoff water slows down and deposits some of its load of sediment. Another place to look for signs of high sediment movement is at culvert inlets and the uphill side of elevated roads.

Potential soil erosion from range land is evaluated much like crop-land potential erosion. Grazing areas are first subdivided by slope class and the erodibility class of the soil (K). Then you make observations of soil erosion following high-runoff events during the time of year that the soil is most vulnerable to movement. Areas are classified according to site factors and observed soil erosion, and ultimately, rules-of-thumb will be developed that apply to your watershed. The decision process is set up as follows:

If: erodibility class of the soil is X, **and** slope steepness class is Y, **and** grazing practice is Z,

Then: soil erosion potential is W.

You will map soil erodibility class and slope steepness class ahead of time. Information about grazing practices and soil erosion is gathered during site observations. The erodibility class of soils

(K) you will use for range land is the same that was developed for crop land. Use county soil surveys and the techniques described in the crop-land section (Task 5) to determine the erodibility class of soils. County soil surveys do not include soil typing on USFS land, so if USFS lands are to be assessed, use the soil resources inventory for the local district office. USFS soil inventories are not the same as county soil surveys and seldom contain the K values for each soil type, but most will at least have a low, moderate, and high erodibility rating for each soil. Assume that the USFS low rating corresponds with soils for which K is <.20, moderate corresponds with soils for which K is between .20 and .40, and high corresponds with soils for which K is >.40.

The soil steepness classes do not have to be as detailed for range land as for crop land, so soil steepness is compressed into two classes; 40% or less, or >40%. Use the same procedures described in Tasks 1 through 4 to record K class and slope steepness information on the Base Map, or simply display range-land information on the crop-land map. Map 6 in Appendix VI-A provides an example of a finished map showing information compiled on surface erosion potential for range land.

After mapping range-land information, create a database of observations on how combinations of site factors and grazing practices influence erosion patterns. Factors to note include erosion severity, plant condition, and soil conservation measures employed (methods described in the next few paragraphs). Observations are meant to be a collaborative process that includes not only your observations but ranchers and others with knowledge of grazing practices in the watershed. Assign a unique number to each field observation and mark and label the location on the map. Then, enter the information on Form S-13, Database for Tracking Field Observation and Mapped Information on Crop Land and Range Land, or the RANGE Worksheet. Table 23 provides an example of how site information and erosion observations are compiled for range land. Site observations are best conducted immediately after a high-runoff period and during the time of year when the land is more vulnerable to erosion. In regions that experience thunderstorms and rapid snowmelt, this time is from summer to spring; however, in some areas this window of vulnerability is probably during the winter. During a site observation, assign the area an erosion severity class, and record areas with moderate or high erosion severity as defined in the crop-land section.

Also note plant conditions and soil conservation measures used. Record the foliage and root mass condition of the plants as dense, moderate, or sparse. Examine evidence of soil conservation measures used by the rancher, and contact the rancher to determine these measures. Some soil conservation measures used for range land include:

- Rest rotation: The land is periodically not grazed during the growing season so plants have a chance to replace reserves.

- Controlled stocking: The number of animals is controlled so that forage is at least 4 to 6 inches after grazing and more than 50% of current growth is left intact.

- Distribution control: Animals are moved or excluded by fences so that certain areas do not become degraded (especially streamside areas).

- Plant improvement: The health of browsed plants is enhanced using combinations of fire, seeding, **scarification**, or fertilization.

Table 23. Example Form S-13: Database for tracking field observations and mapped information on crop land and range land.

Sub-Watershed	Observation	K Class	Slope Steepness Class	Plant Cover Condition	Grazing Practices	Actual Erosion	Runoff Event
Deer	701	Medium	<40	Dense	Normal	low	Observed after a late-summer thunderstorm
Deer	702	Medium	>40	Dense	Normal	moderate	Observed after a late-summer thunderstorm
Bear	703	Low	<40	Moderate	Rest rotation	low	Observed after a late-summer thunderstorm
Elk	704	Low	<40	Sparse	Controlled stocking	moderate	Observed after a late-summer thunderstorm
Skunk	705	High	<40	Sparse	Normal	moderate	Observed after a late-March snowmelt
Skunk	706	High	>40	Moderate	Plant improvement (2 years ago)	moderate	Observed after a late-March snowmelt
Skunk	707	High	<40	Sparse	Plant improvement (3 years ago)	low	Observed after a late-March snowmelt

Summary: Range Land

After a number of observations have been included in the database, patterns may develop. For example, combinations of the soil K factor, slope steepness, and plant condition may result in moderate erosion when normal grazing practices are used, but low erosion when certain soil conservation measures are added. Compile site observations on Form S-14, Summary of Crop Land and/or Range Land, Grazing Erosion Observations. Table 24 provides an example showing a comparison of soil erosion under normal grazing practices to soil erosion under controlled stocking. You may wish to construct other tables focusing on other combinations of grazing practices and site conditions. Each table will include various combinations of site conditions and grazing practices, and the number of sites with low, medium, or high erosion. The number of sites can also be expressed as a percentage of the row total to provide a clearer picture of how combinations compare. These tables may be used to target combinations of site factors that indicate sites where improved grazing practices would yield the greatest reduction in moderate to high soil erosion. This approach tailors the information to your watershed; from your own observations, you can begin to develop rules-of-thumb that work for your watershed.

Source 7. Surface Erosion from Burned Areas

Recently burned areas can have a high potential for erosion within the first year or two following the fire. The removal of surface organic matter by fire can release soil that has collected uphill of the

Table 24. Example Form S-14: Summary of range-land erosion observations.

K Class	Slope Class	Grazing Practice	Plant Condition	Number of Observations by Erosion Class			
				Low	Mod-erate	High	Total
Moderate	<40	Normal	sparse	4	2	0	6
Moderate	<40	Normal	mod./dense	8	0	0	8
Moderate	<40	Controlled stocking	sparse	8	1	0	9
Moderate	<40	Controlled stocking	mod./dense	7	0	0	7
Moderate	>40	Normal	sparse	3	4	0	7
Moderate	>40	Normal	mod./dense	4	2	0	6
Moderate	>40	Controlled stocking	sparse	4	3	0	7
Moderate	>40	Controlled stocking	mod./dense	5	2	0	7
High	<40	Normal	sparse	2	5	2	9
High	<40	Normal	mod./dense	3	4	0	6
High	<40	Controlled stocking	sparse	2	7	1	10
High	<40	Controlled stocking	mod./dense	3	6	0	9
High	>40	Normal	sparse	0	6	2	8
High	>40	Normal	mod./dense	0	6	0	6
High	>40	Controlled stocking	sparse	2	6	0	8
High	>40	Controlled stocking	mod./dense	3	2	0	5

organic matter. It also leaves the surface vulnerable to **rain-splash erosion**. Under some conditions, the burned soil surface will actually temporarily repel water. This leads to more of the runoff occurring along the soil surface, thereby causing surface soil movement. Water-repelling soil conditions usually disappear after a few runoff events in Oregon. Fires can also bare the banks of draws and streams. Soil raveling from those bared and steep slopes immediately adjacent to the channel can cause them to partially fill with loose sediment. These sediments are then vulnerable to downstream movement during runoff events.

Fire containment activities such as the construction of temporary access roads and fire lines can sometimes lead to significant inputs of sediment into streams. Access road and fire lines are often built in a hurry and sometimes without much consideration to where excavated soil is placed. Unless these temporary roads and fire lines are carefully obliterated or rehabilitated after the fire, they can also become sources of sediment. Erosion is usually caused by water running down the surfaces of the roads or trails, and is made worse if the fire area later attracts motorcyclists, all-terrain-vehicles, or 4-wheel-drive operators.

Not all fires cause significant increases in stream sediment. Cool fires that consume only part of the surface organic matter may not be a source of accelerated erosion. Fires that skip over stream channels also may have little effect on soil erosion.

In some areas, the forests are now intentionally burned at a frequent interval in order to decrease the likelihood of a catastrophic wildfire that would kill large trees or harm the soil. For many decades, intentional burns have also been used to remove **slash** and brush following the harvest of timber, to treat fields in anticipation of the next crop, or to manage range-land plant health and composition. Nevertheless, recent air quality control measures are making it hard for landowners to find windows of opportunity to burn. The main goal of these air quality control measures is to keep smoke out of populated areas. The incidence of intentional burns has decreased substantially in some parts of the state as a result of the air quality control measures.

Evaluation of surface erosion from burned areas in the watershed will be limited to identifying the presence of recent burns, if any. Your assessment will result in mapping of recently burned areas and combining of various site factors with observations on obvious evidence of erosion.

Task 1

The first step for compiling information on recently burned areas is to determine the boundaries of the fire and transfer them to a topographic base map. You may be able to do this simply by driving through the burned area and noting the relationship of the fire boundary to roads, streams, and ridges. You may also want to use aerial photographs for large burned areas and especially areas that did not burn uniformly. The ODF, USFS, or BLM will sometimes have aerial photographs flown immediately after large-scale fires, so check with them first.

Task 2

Segregate the burn area into two slope steepness classes (40% or less, >40%) and two K factor classes (.40 or less, >.40), as described in the sections on surface erosion from crop land and range land. Add information about fire intensity to the map. This is best done using a combination of site observations and aerial photographs, although you may be able to complete this without aerial photographs if there is good road access into the burn area. Focus mostly on how the fire burned when it encountered streams and draws. Classify according to the three burn intensity classes described below.

- Cool: Original surface organic material is mostly intact. Finer organic material may have been consumed. A majority of shrubs and trees near streams and draws are alive.
- Moderate: Most of the finer original organic material is consumed. About one-half of coarser material still intact. About one-half of shrubs and trees near streams are alive.
- Hot: Nearly all original organic material is consumed. Bare soil dominates. Only larger logs remain on surface. Nearly all shrubs and trees near streams killed by fire.

Each map polygon will have an associated K class, slope steepness class, and burn intensity. For each of the polygons within the fire area, make field observations on the condition of the access roads and fire lines. Note any activity that has led to degradation of access roads and fire lines, whether they are gullied, and whether they have been **waterbarred** and the condition of waterbars. Make field observations of the erosion class of the polygon as indicated by rilling, sediment deposits along or within channels, or sediment pooling at the upstream end of culverts. Classify erosion as follows:

- High: Numerous rills. Extensive deposits of sediment on flatter areas near or in streams and draws. Deep sediment deposits at culvert inlets or at the uphill sides of elevated roads.
- Moderate: Some rills. Shallow deposits of sediment on flatter areas near streams and draws. Shallow sediment deposits at culvert inlets or at the uphill of elevated roads.
- Low: Otherwise.

Map 7 in Appendix VI-A provides an example of a finished map showing information compiled on erosion potential for burned land.

Record information on Form S-15, Database for Tracking Field Observations and Mapped Information on Burned Areas, or the BURN Worksheet. Determine the area of each polygon using a grid or map wheel and add the area to your table. Table 25 provides an example of compiled information.

Summary: Burned Lands

The evaluation of burned areas within the watershed does not lend itself to a summary that can begin to link burn conditions and site conditions to erosion potential. It is mostly limited to a summary of primary information about a single to a few burns. You will complete Form S-16, Summary of Areal Extent of Erosion Classes Within Burns, or the SEDBURN1 Worksheet. Table 26 provides an example of Form S-16, illustrating a format for comparing acreage by erosion class for two fires.

Table 25. Example Form S-15: Database tracking field observations and mapped information on burned areas.

Burn name: Sow Creek fire

Date area burned: 8/98

Date evaluated: 6/99 and 7/99

Years between evaluation and fire: 1.2

Type of fire: Wildfire

Land cover prior to fire: Forested with some meadows on south slopes

Observation	K Class	Slope Steepness Class	Burn Intensity	Condition of Access Roads and Fire Lines	Erosion Class	Area (acres)
801	<.40	<40	Low	Good condition; all waterbarred	low	1,250
802	<.40	>40	Moderate	Good condition; all waterbarred	moderate	510
803	<.40	<40	Low	Good condition; all waterbarred	moderate	450
804	<.40	<40	Moderate	Deeply rutted; 4WD activity	moderate	1,100
805	>.40	<40	Moderate	Deeply rutted; 4WD activity	high	970
806	>.40	>40	Hot	Deeply rutted; 4WD activity	high	410
807	>.40	<40	Hot	Good condition; all waterbarred	moderate	960

Table 26. Example Form S-16: Summary of areal extent of erosion classes within burns.

Burn Name	Area and % of Total Area by Erosion Class							
	Low Erosion		Moderate Erosion		High Erosion		Total	
	Acres	%	Acres	%	Acres	%	Acres	%
Sow Creek fire	1,250	22	3,020	53	1,380	25	5,650	100
Little Pig Creek fire	420	17	1,120	44	980	39	2,520	100

Source 8. Other Discrete Sources

Other discrete sources of accelerated soil erosion and stream sedimentation may be present in your watershed. This manual does not include procedures for evaluating these sources, but they should be documented during this assessment process. Your documentation should include not only those sources that currently are a source of sediment, but also those that have strong potential to become a source in the future. A partial listing of other discrete sediment sources and their potential influence on streams follows:

- In-channel gold mining: Periods of chronic turbidity; deposition of fine sediments.
- Mining spoil piles: **Calving-off** of piles or surface erosion into nearby streams; turbidity and deposition of fine sediments.
- Gravel pit drainage: Chronic turbidity.
- Winter animal holding areas near streams: Trampling of banks—surface runoff over compacted soils; chronic turbidity; deposition of fine sediments.
- Road sanding: Chronic turbidity; deposition of fine sediments.
- Wind erosion: Chronic turbidity; deposition of fine sediments.

Step 4: Evaluate Confidence in Assessment

Rate your confidence in the quality and completeness of information you compiled for your watershed assessment of sediment sources (Form S-17, Confidence Evaluation). For each source, rate the **quality** of information (where it existed for the watershed) as Good, Fair, or Poor; rate the completeness of the information (Not Missing, Partially Missing, Mostly Missing). Explain the factors that prevented you from compiling good information for the entire watershed. Skip sources that you did not include in your assessment.

REFERENCES

Alt, D.D., and D.W. Hyndman. 1996. Roadside Geology of Oregon. Mountain Press Publishing Co. Missoula, Montana.

Anderson, H.W. 1954. Suspended Sediment Discharge as Related to Streamflow, Topography, Soil, and Land Use. Transactions of the American Geophysical Union 35(2):268-281.

Benda, L., and T. Dunne. 1987. Sediment Routing by Debris Flow. Pages 213-224 in: Erosion and Sedimentation in the Pacific Rim. IAHS Publication No. 165.

Bilby, R.E. 1985. Contributions of Road Surface Sediment to a Western Washington Stream. Forest Science 31(4):827-838.

Bilby, R.E., K. Sullivan, and S.H. Duncan. 1989. The Generation and Fate of Road-Surface Sediment in Forested Watersheds in Southwestern Washington. Forest Science 35(2):453-468.

Bisson, P.A., and R.E. Bilby. 1982. Avoidance of Suspended Sediment by Juvenile Coho Salmon. North American Journal of Fisheries Management 2:371-374.

Booth, D. 1991. Urbanization and the Natural Drainage System—Impacts, Solutions, and Prognosis. Northwest Environmental Journal 7(1):93-118.

Duncan, S.H., R.E. Bilby, J.W. Ward, and J.T. Heffner. 1987. Transport of Road-Surface Sediment Through Ephemeral Stream Channels. Water Resources Bulletin 23(1):113-119.

Lisle, T.E. 1987. Channel Morphology and Sediment Transport in Steepland Streams. Pages 287-298 in: Erosion and Sedimentation in the Pacific Rim. IAHS Publication No. 165.

Megahan, W. F. 1987. Increased Sedimentation Following Helicopter Logging and Prescribed Burning on Granitic Soil. Pages 259-260 in: Erosion and Sedimentation in the Pacific Rim. IAHS Publication No. 165.

Newcombe, C.P., and D.D. MacDonald. 1991. Effects of Suspended Sediments on Aquatic Systems. North American Journal of Fisheries Management 11:72-82.

Sessions, J., J.C. Balcom, and K. Boston. 1987. Road Location and Construction Practices: Effects on Landslide Frequency and Size in the Oregon Coast Range. Western Journal of Applied Forestry 2(4):119-124.

Tasker, G.D., and N.E. Driver. 1988. Nationwide Regression Models for Predicting Urban Runoff Water Quality at Unmonitored Sites. Water Resources Bulletin 24(5):1091-1101.

GLOSSARY

borrow pit: An area where rock or soil is excavated from the hillside.

cable yarding scar: An area within a timber harvest unit that is bare due to logs dragging on the ground as they are being moved by cables to the road.

calving-off: The rapid movement of soil from the steep leading edge of a large landslide.

cross-drain culvert: A culvert that drains water which collects within the inside ditch of a road to the outside slope of the road.

cut slope: The sloping excavated surface on the inside of a road.

detention pond: A pond constructed to temporarily store water, thereby allowing sediment to settle out of the water.

draw: A very small stream that may have flowing water only during the wet season.

fill slope: The outer edge of a road that extends downhill of the road surface.

full-bench construction: A practice of constructing a road on steeper slopes whereby excess excavated soil or rock is hauled away in trucks to a stable storage area rather than disposed of by pushing it downhill of the road.

Geographic Information System (GIS): A computer system designed for storage, manipulation, and presentation of geographical information such as topography, elevation, geology etc.

harvest unit: An area from which trees have been harvested.

hazard delineation: Mapping the boundaries of areas with inherently unstable slopes.

landing: An area adjacent to a road where logs accumulate and are loaded onto trucks during timber harvesting.

pipe-arch culvert: A corrugated pipe that is wider than it is tall.

ravel: Erosion caused by gravity, especially during rain, frost, and drying periods. Often seen on steep slopes immediately uphill of roads.

recurrence interval(s) (return interval): Determined from historical records. The average length of time between two events (rain, flooding) of the same size or larger. Recurrence intervals are associated with a probability. (For example, a 25-year flood would have a 4% probability of happening in any given year.)

rills: Very shallow gullies that can develop on a hillslope that is eroding.

rock pit: An area where rock is excavated from a hillside and is usually processed as road-surfacing material.

scarification: The mechanical loosening of compacted soil usually using subsoilers attached to a crawler tractor.

sheet erosion: Soil erosion caused by surface water that occurs somewhat uniformly across a slope.

skid trail: Trail that develops when logs are hauled by ground-based machinery to a landing.

slash: Detached tree limbs, branches, and other woody material that is left on the ground after a timber harvest is completed.

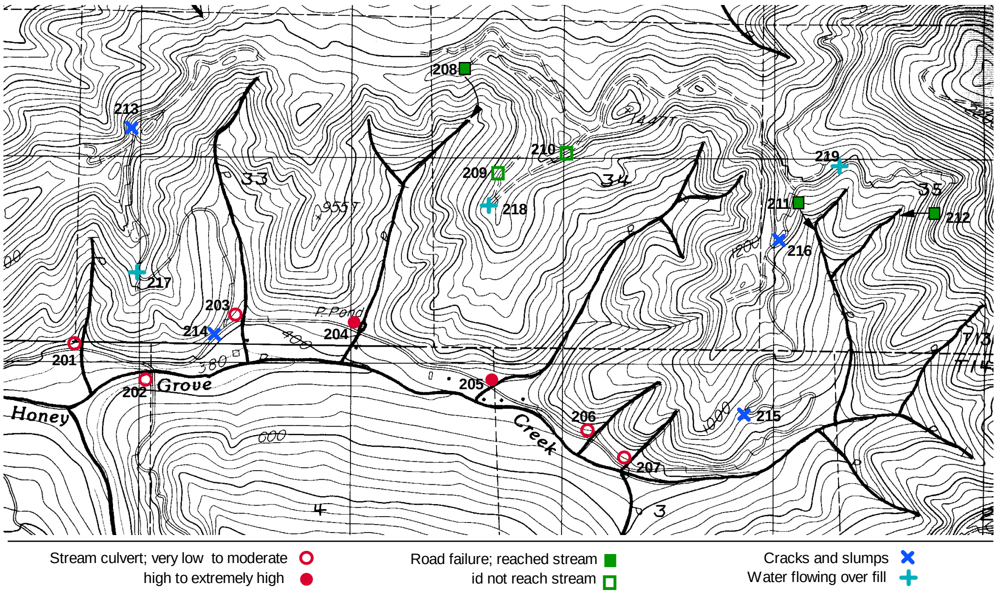
stereoscope: An instrument used to observe stereo aerial photographs in three dimensions.

waterbar: A deep trough in a skid trail or road that is excavated at an angle to drain surface water from the skid trail or road to an adjacent area that is not compacted.

Appendix VI-A
Examples of Finished Sediment-Source Maps

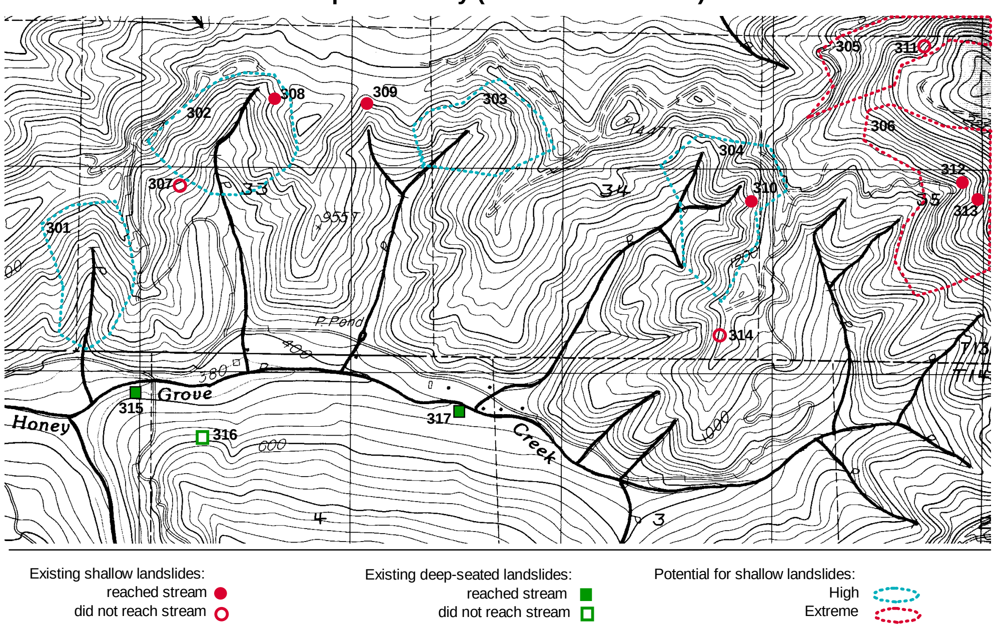
APPENDIX VI-A: EXAMPLES OF FINISHED SEDIMENT - SOURCE MAPS

Road Instability



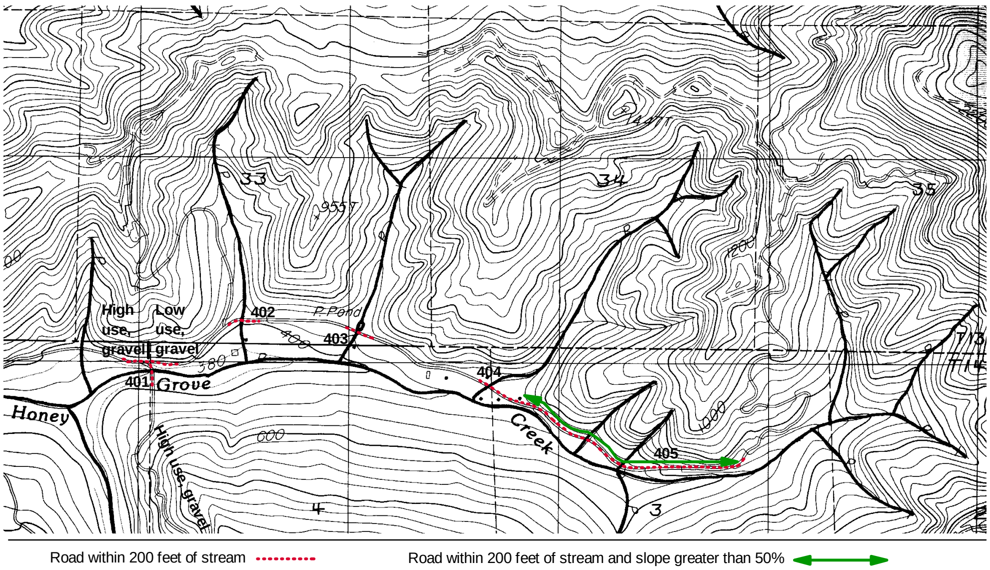
Map 1. Example of a finished map showing information compiled for both existing and potential road instability sites.

Slope Instability (not related to roads)

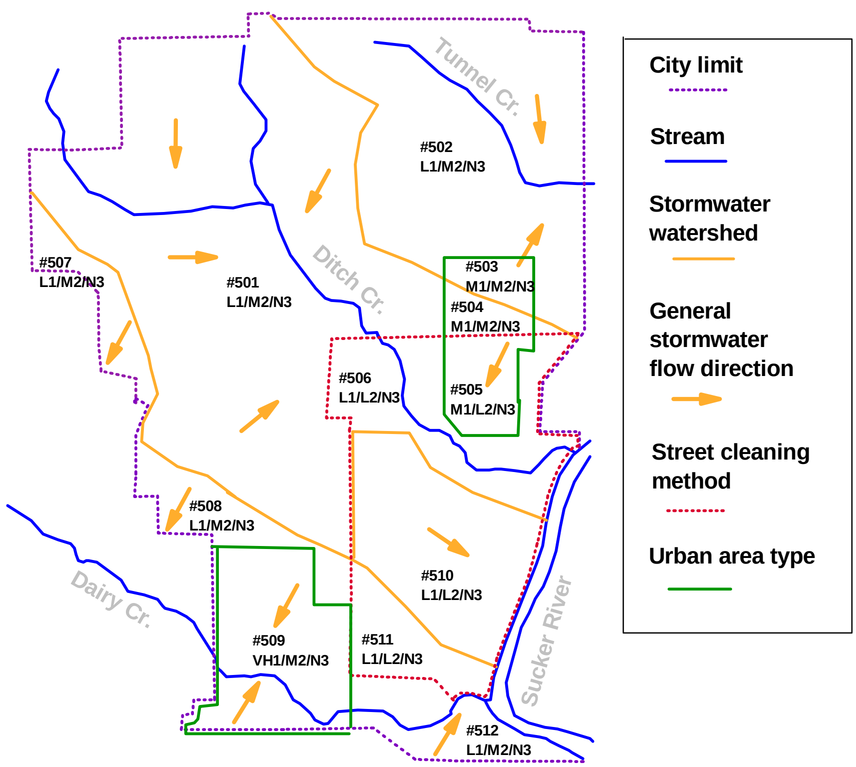


Map 2. Example of a finished map showing information compiled on slope instability not related to roads.

Rural Road Runoff

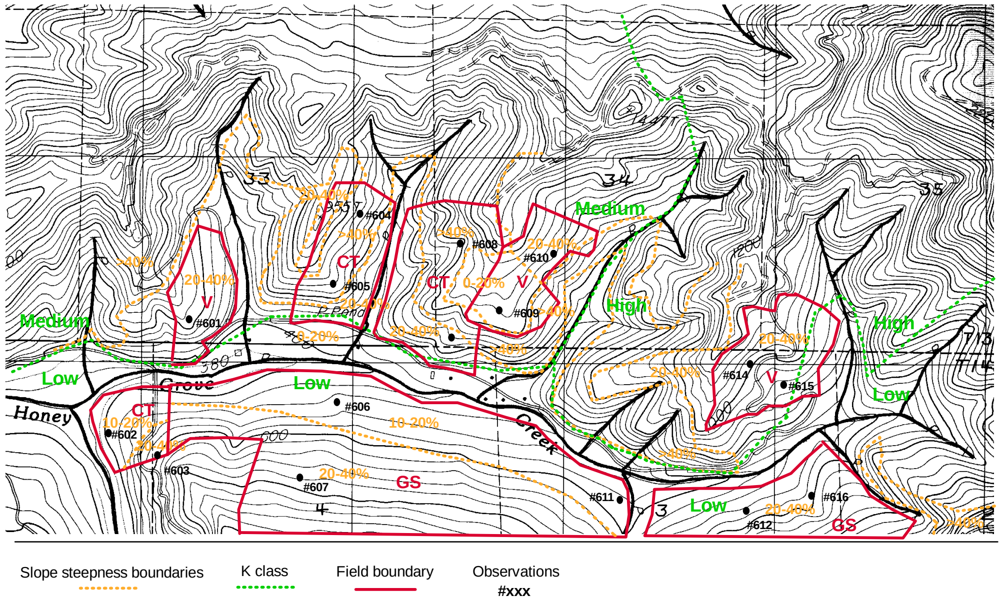


Map 3. Example of a finished map showing information compiled on rural road runoff.



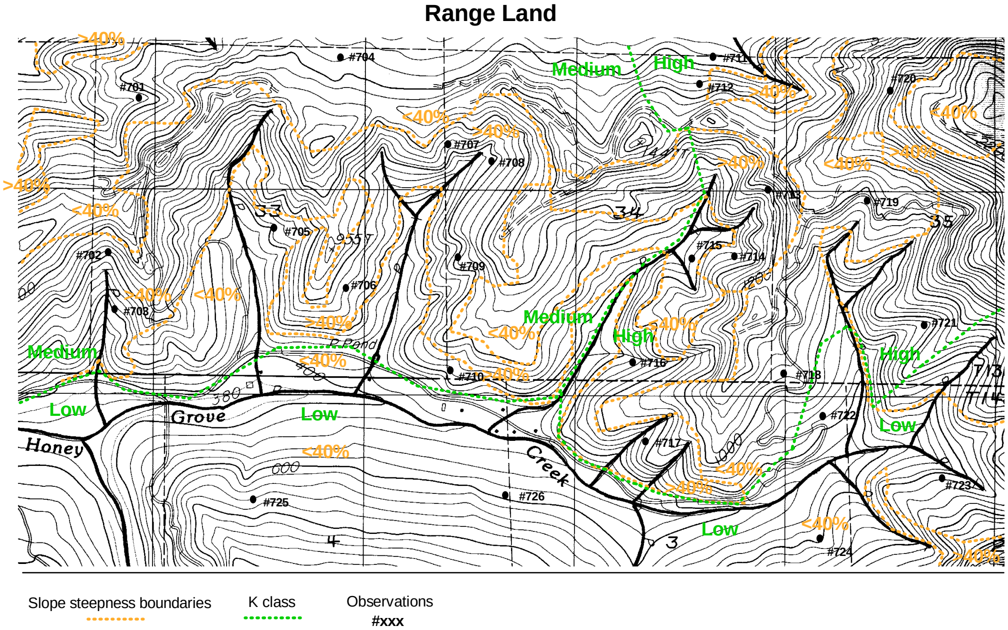
Map 4. Example of a finished map showing basic information compiled on urban runoff.

Crop Land



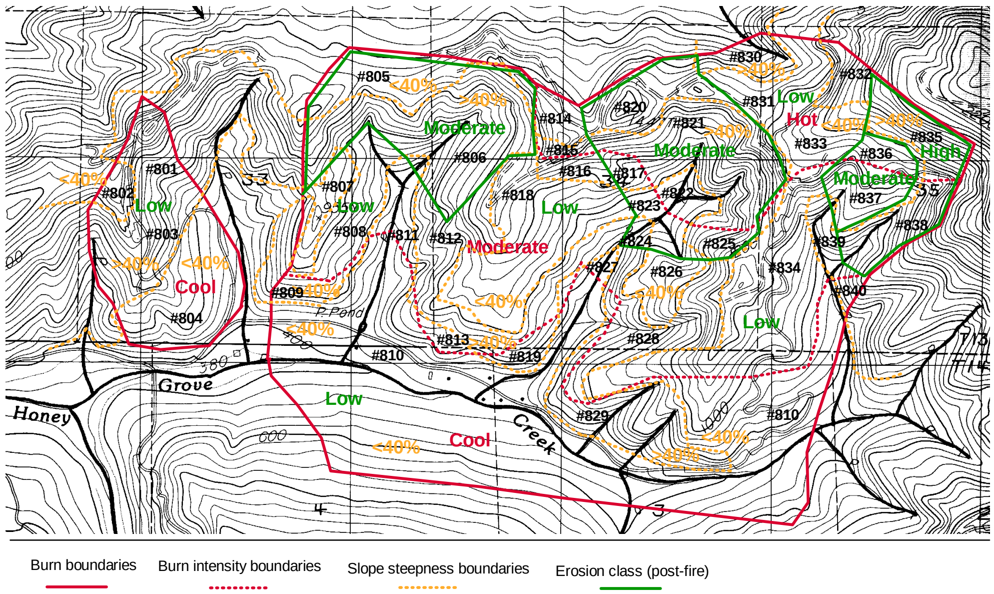
Map 5. Example of a finished map showing information compiled on surface erosion from crop land.

Range Land



Map 6. Example of a finished map showing information compiled on surface erosion potential for range land.

Burned Areas



Map 7. Example of a finished map showing information compiled on erosion potential for burned land.

Appendix VI-B
Blank Forms

Form S-1: Screen for Sediment Sources in a Watershed

Watershed:

Analyst's Name:

Watershed Name: The River Why	Observations	Priority
Source 1: Road instability Are rural roads common in watershed? Do many road washouts occur following high rainfall? Are many new roads or road reconstruction planned?		
Source 2: Slope instability (not related to roads) Are landslides common in watershed? Many high-sediment, large-scale landslides?		
Source 3: Rural road runoff Are sediment-laden runoff from rural roads and turbidity in streams common? Is there a high density of rural roads?		
Source 4: Urban runoff Are many portions of the watershed urbanized? Importance of these tributaries to watershed council:		
Source 5: Surface erosion from crop land Is there much crop land in the watershed? Is there much evidence of sediment in streams flowing through crop land?		
Source 6: Surface erosion from range land Is there much range land in watershed? Is there evidence of sediment in streams flowing through range land?		
Source 7: Surface erosion from burned land Have many burns occurred recently (last 5 years), especially hot fires? Was there much sediment created by these burns?		
Source 8: Other discrete sources of sediment List or identify any other suspected sources of sediment:		

Form S-2: Information on Existing Road-Related Instability

Watershed:

Analyst's Name:

Num.	Subwatershed	Landslide Type	Reached Stream?	Distance Traveled (ft)	Road Location

Number: Unique identification number.

Subwatershed: Subwatershed in which landslide occurs.

Landslide Type: Debris flow = initiates as shallow landslide in steep area and then flows down a channel, picking up additional soil, logs, and water. Road prism failure = downhill movement of the road cut or road fill; does not initiate a debris flow. Culvert washout = road fill partially or completely missing where the road crosses a stream.

Reached Stream?: Whether or not the landslide material ended up in the stream.

Distance traveled: The distance from initiation point to where the landslide stopped (not applicable to culvert washouts).

Road Location: General location of road: near ridge, mid-slope, near stream.

Form S-3: Culvert Capacity and Risk of Large Amounts of Sediment Entering Stream

Watershed:

Analyst's Name:

1 Sub-watershed	2 Num.	3 Road Owner-ship	4 Current Culvert/ Pipe-Arch Size	5 Current Culvert Capacity (cfs)	6 ODF Peak-Flow Value (cfs/mi²)	7 Drainage Area (mi²)	8 50-Year Peak Flow (Col. 6x7) (cfs)	9 Culvert/ Pipe-Arch Size Needed for 50-Year Peak Flow	10 Ratio of 50-Yr Flow to Current Capacity	11 Fill Height (ft)	12 Hazard Rating *

* Hazard rating:

Very low	Fill height is 15 feet or less and ratio is less than 1.25.
Low	Fill height is greater than 15 feet and ratio is less than 1.25.
Moderate	Fill height is 15 feet or less and ratio is between 1.25 and 1.75.
High	Fill height is greater than 15 feet and ratio is between 1.25 and 1.75; or, fill height is 15 feet or less and ratio is between 1.76 and 3.
Very high	Fill height is greater than 15 feet and ratio is between 1.76 and 2.99; or, fill height is 15 feet or less and ratio is greater than 3.
Extreme	Fill height is greater than 15 feet and ratio is greater than 3.

Form S-4: High-Risk Road Segments for Existing Roads

Watershed:

Analyst's Name:

Sub-Watershed	Num.	Feature Type	Hazard Rating of Culvert	Road Ownership

Form S-5: Summary of Information on Road Instability

Watershed:

Analyst's Name:

Subwater-shed	Area (mi^2)	Road Failures that Reached Streams		Sites with High-Risk Culverts		Sites with Cracks and Slumps		Sites with Water Flowing Over Fills	
		#	Density (#/mi^2.)	#	Density (#/mi^2.)	#	Density (#/mi^2.)	#	Density (#/mi^2.)
Total									

Form S-6: Current Landslides not Related to Roads

Watershed:

Analyst's Name:

Sub-watershed	Num.	Type of Landslide	Age of Vegetation (years)	Landslide Reached Stream?	Distance Landslide Traveled (feet)	Slope Steepness at Initiation Point (%)

Form S-7: Potential for Debris Flows

Watershed:

Analyst's Name:

Subwatershed	Areas Predicted to be High Risk for Debris Flows (mi²)		
	High Hazard	Extreme Hazard	Combined

Form S-8: Summary of Information on Slope Instability (not related to roads)

Watershed:

Analyst's Name:

Sub-Watershed	Area (mi^2)	Current Landslides				Debris-Flow High-Risk Areas (combined high and extreme)	
		Shallow Landslides		Deep-Seated Landslides			
		Number (#)	Density (#/mi^2.)	Number (#)	Density (#/mi^2.)	Area (mi^2.)	Percent
Total							

Form S-9: Basic Information on Road Segments Close to Streams with Steep Slopes

Watershed:

Analyst's Name:

Subwatershed	Num.	Distance <200' from Stream (feet)	Distance <200' from Stream and Slope >50% (feet)	Road Surface	Road Use

Form S-10: Summarized Runoff-Related Information for a Single Road

Watershed:

Analyst's Name:

Road Name	Variable	Classification	Length (feet)	Occurrences (#)

Form S-11: Summary of Information on Road Runoff—Basic Assessment

Watershed:

Analyst's Name:

Sub-watershed	Area (mi^2)	Roads < 200' from Stream		Roads < 200' from Stream and Slope > 50%		Roads < 200' from Stream and High Use		Roads < 200' from Stream and Low Use	
		Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)	Length (mi.)	Density (mi./mi².)

Form S-12: Information on Urban Runoff Polygons

Watershed:

Analyst's Name:

Stormwater Subwatershed	Polygon #	Polygon Area (acres)	Area as a Percentage of Total	1. Sediment Production	2. Street Cleaning	3. Sediment Removal
Total						

Form S-13: Database for Tracking Field Observation and Mapped Information on Crop Land and Range Land

Watershed:

Analyst's Name:

Sub-Watershed	Observation	K Class	Slope Steepness Class	Crop/ Plant Cover Cond-ition	Farming/Grazing Practices	Field Condition	Actual Erosion	Runoff Event

Form S-14: Summary of Crop Land and/or Range Land, Grazing Erosion Observations

Watershed:

Analyst's Name:

K Class	Slope Class	Farming/Grazing Practice	Field Condition/Plant Condition	Number of Observations by Erosion Class			
				Low	Mod-erate	High	Total

Form S-15: Database Tracking Field Observations and Mapped Information on Burned Areas

Watershed:

Analyst's Name:

Burn name:
Date area burned:
Date evaluated:
Years between evaluation and fire:
Type of fire:
Land cover prior to fire:

Observation	K Class	Slope Steepness Class	Burn Intensity	Condition of Access Roads and Fire Lines	Erosion Class	Area (acres)

Form S-16: Summary of Areal Extent of Erosion Classes Within Burns

Watershed:

Analyst's Name:

Burn Name	Area and % of Total Area by Erosion Class							
	Low Erosion		Moderate Erosion		High Erosion		Total	
	Acres	%	Acres	%	Acres	%	Acres	%

Form S-17: Confidence Evaluation

Rate your confidence in the quality and completeness of information you compiled for your watershed assessment of sediment sources. For each source, rate the **quality** of information (where it existed for the watershed) as Good, Fair, or Poor; rate the completeness of the information (Not Missing, Partially Missing, Mostly Missing). Explain the factors that prevented you from compiling good information for the entire watershed. Skip sources that you did not include in your assessment.

1. Rural road instability

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing ______

Factors that prevented compilation of good information for the entire watershed:

____

____

____

____

____

2. Rural road runoff

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing ______

Factors that prevented compilation of good information for the entire watershed:

____

____

____

____

____

3. Slope instability (not related to roads)

Quality: Good _____ Fair _____ Poor _____

Completeness: Not Missing _____ Partially Missing _____ Mostly Missing ______

Factors that prevented compilation of good information for the entire watershed:

____

____

____

____

____

Form S-17: page 2.

4. Urban runoff

Quality: Good _ _ _ _ _ Fair _ _ _ _ _ Poor _ _ _ _ _

Completeness: Not Missing _ _ _ _ _ Partially Missing _ _ _ _ _ Mostly Missing _ _ _ _ _ _

Factors that prevented compilation of good information for the entire watershed:

_ _
_ _
_ _
_ _
_ _

5. Surface runoff from crop land

Quality: Good _ _ _ _ _ Fair _ _ _ _ _ Poor _ _ _ _ _

Completeness: Not Missing _ _ _ _ _ Partially Missing _ _ _ _ _ Mostly Missing _ _ _ _ _ _

Factors that prevented compilation of good information for the entire watershed:

_ _
_ _
_ _
_ _
_ _

6. Surface runoff from range land

Quality: Good _ _ _ _ _ Fair _ _ _ _ _ Poor _ _ _ _ _

Completeness: Not Missing _ _ _ _ _ Partially Missing _ _ _ _ _ Mostly Missing _ _ _ _ _ _

Factors that prevented compilation of good information for the entire watershed:

_ _
_ _
_ _
_ _
_ _

Form S-17: page 3.

7. Surface runoff from burned areas

Quality: Good _ _ _ _ _ Fair _ _ _ _ _ Poor _ _ _ _ _

Completeness: Not Missing _ _ _ _ _ Partially Missing _ _ _ _ _ Mostly Missing _ _ _ _ _ _

Factors that prevented compilation of good information for the entire watershed:
_ _
_ _
_ _
_ _
_ _

8. Other discrete sources of sediment

Quality: Good _ _ _ _ _ Fair _ _ _ _ _ Poor _ _ _ _ _

Completeness: Not Missing _ _ _ _ _ Partially Missing _ _ _ _ _ Mostly Missing _ _ _ _ _ _

Factors that prevented compilation of good information for the entire watershed:
_ _
_ _
_ _
_ _
_ _

Component VII
Channel Modification Assessment

Table of Contents

Component VII
Channel Modification Assessment

INTRODUCTION

In-channel structures and activities such as damming and dredging or filling hinder fish migration, alter the physical character of streams, and change the composition of stream **biota**.[1] The degree of impact to habitat will depend on the type of channel and the type and magnitude of channel modification. Channels are dynamic systems that modify themselves in response to changes in physical watershed features regardless of human involvement. This section identifies how human activities have directly changed channel **morphology** and aquatic habitat. This information is then synthesized with information from the other components to assess overall watershed health and function.

In this portion of the watershed assessment, you will map and categorize current channel modifications and incorporate historic channel modification information from the Historic Conditions Assessment component. During the final part of this assessment, you will overlay the channel modification map with the **Channel Habitat Type** (CHT) Map (from the Channel Habitat Type Classification component) to identify which CHTs have been directly impacted by these activities.

Critical Questions

1. Where are channel modifications located?

2. Where are historic channel disturbances, such as dam failures, **splash damming**, hydraulic mining, and **stream cleaning**, located?

3. What CHTs have been impacted by channel modification?

4. What are the types and relative magnitude of past and current channel modifications?

Assumptions

- Channel modifications and historic land use and in-channel activities may have altered the quality and/or quantity of aquatic resources in the basin.

- In the absence of documentation on pre-European settlement conditions, the impact to aquatic resources from the channel modification can be inferred from the type of modification or historic disturbance **and** the CHT affected.

- Channel disturbances, such as channel widening, extensive bank erosion, or large gravel deposits, with no apparent adjacent cause, are response indicators of changes in upstream channel input factors that may or may not be related to human activities; channels do modify their form through natural disturbance events. Conversely, channel **gradient** can be used to

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

predict zones of potential channel impacts due to declining transport ability and sediment deposition.

Materials Needed

- 7.5-minute US Geological Survey (USGS) topographic maps of the watershed (from the Start-Up and Identification of Watershed Issues component)
- Project base map (from the Start-Up and Identification of Watershed Issues component)
- Sharp pencil, colored pencils, thin permanent markers (optional: colored adhesive dots)
- USGS topographic map symbol legend
- Data and information on channel modification (see Step 1 below for list of potential sources)
- Federal Emergency Management Agency (FEMA) floodplain maps (if available)
- National Wetland Inventory (NWI) maps
- A map wheel (or an engineer's ruler with inches marked in 10ths so you can easily enter measurements into a calculator will work if you measure carefully)
- Aerial photos of the basin (from the Start-Up and Identification of Watershed Issues component)

Necessary Skills

The minimum skills necessary to produce the Channel Modification Map include (1) the ability to read and use topographic maps, (2) the ability to accurately transfer information between maps of different scales, and (3) an ability to search for and compile information from many sources. The ability to use aerial photographs will aid this task, but is not required.

Final Products of the Channel Modification Assessment

1. Channel Modification Map (CM-1)
2. Channel Modification Inventory (Form CM-1) corresponding to numbered sites on the map
3. Channel Modification Summary (Form CM-2), a summary by subwatershed of the amount of channel modified by each activity
4. Confidence Evaluation (Form CM-3) assessing your confidence in the accuracy and comprehensiveness of the overall mapping

CHANNEL MODIFICATION MAPPING PROCEDURES

Step 1: Gather Available Information

Ideally, you would obtain the Historical Channel Modifications Map (from the Historical Conditions Assessment component) showing locations where historic activities affect stream channels shown. It is likely, however, that this map will be in preparation and not available at the onset of this task. If this is the case, you will prepare a map of current channel modifications and combine that map with the historic impacts map at a later date. To begin mapping, obtain a copy of the project base map. It is also possible to do the initial mapping on topographic maps, or on a Mylar overlay of the base map or topographic maps.

A number of sources are available to gather information concerning current channel modifications, such as the following.

Topographic Maps

Many channel modifications are shown on topographic maps. Most notably are **impoundments**, dikes, roads along streams, and channel straightening. Structures in or immediately adjacent to the channel may also be apparent. Note the date of the map and the presence of updated features, usually shown in a violet color.

Aerial Photographs

Depending on the quality of the photos and the skill of the reviewer, aerials can be one of the most useful tools in evaluating channel modifications and their potential impacts to the channel and aquatic habitat. Many modifications are quite obvious on photos, and are readily identified by people with limited photo interpretation experience. Again, noting the date and scale of the photos will aid in assessing the condition of the channel and the modification. Because time will be limited, start by reviewing the photos of the largest channels in the watershed. Modifications to smaller channels may not be visible on the photos.

Agency Records and Personnel

While not all of the agencies listed in Table 1 will have information concerning channel modifications, contact any agency that has jurisdiction over waterways and **riparian areas** in your watershed. It is prudent to make inquiries as early as possible, because information may take some time to reach you.

As a start, two agencies, the US Army Corps of Engineers (Corps) and the Oregon Department of State Lands (DSL), have jurisdiction over activities in "**Waters of the State**," including wetlands. The Portland office of the Corps (503-808-5150) can be contacted concerning the federal Clean Water Act Section 404 permits dealing with fills and in-stream structures. Contact the Salem office of DSL (503-378-3805) concerning Fill and Removal permits in the watershed.

Other agencies such as the Oregon Department of Fish and Wildlife (ODFW), County Public Works, Oregon Department of Transportation (road maintenance issues), diking districts, the US Bureau of Land Management (BLM), or local port authorities may also have useful information.

In addition, NWI maps display some channel modifications. Consult with the Riparian/Wetland Assessment component analyst concerning the date and accuracy of the maps.

Floodplain Mapping

There are two purposes in identifying the location of the **100-year floodplain** within the watershed. The first is to identify areas where channel diking and levees have disconnected the river from its floodplain. The second is to provide information for the decision process regarding flood protection versus restoration potential that will follow the completion of the Watershed Condition Evaluation component. Recognize that determining the 100-year floodplain for many streams may be unnecessary (confined channels in narrow valleys). Field verification and assistance from professionals may be needed if extensive floodplains and/or flooding issues are important in the basin.

FEMA floodplain maps are available for most large rivers as a requirement for qualification of federal flood insurance. They can be ordered directly from FEMA or are available for copying at most county planning or public works departments. Some counties and cities may have funded additional river or stream studies. Check with your local county or city planners to find out what floodplain mapping they use to best reflect potential flooding conditions. It is important to note that many floodplain maps are outdated or contain erroneous information. Verify to the extent possible the accuracy of the mapping with knowledgeable personnel. If floodplains are extensive, it may be worthwhile to transfer the location of the floodplain to the Channel Modification Map.

Land Owners/Field Work

Land owners may be a valuable source for information concerning activities in or near the channel. Inventories of activities may be available in basins with large industrial land owners such as timber companies. Local residents may also be able to provide information. Obviously, the more time the analyst can spend in the field mapping and assessing the magnitude of any modifications, the higher the quality of the final products.

Step 2: Map Channel Modifications

The following steps apply to mapping all types of channel modifications.

1. Investigate all probable and likely sources of information on channel modification activities within your watershed.

2. Draw each modification site onto the Channel Modification Map using the appropriate number to tie to Form CM-1 containing information about the activity. Where more than one modification activity overlaps, draw both mapping symbols. Where you are unsure of the exact beginning or end of a feature, put a question mark at the beginning and/or end of the map symbol.

3. Mark small features with an X or brightly colored dot.

4. Label each channel modification/disturbance site with a number. Fill out the first three columns on the Channel Modification Inventory (Form CM-1) for each site.

5. Create a map legend. If appropriate, include the 100-year floodplain and all numbers/symbols used to depict the various channel modifications or disturbance sites. Sign and date the map.

Step 2a: Map Current Modifications

Table 1 lists potential channel modification activities that may be present in your watershed and likely sources of information. The list of potential channel modification activities is not inclusive. When inquiring about the presence of projects or past activities, be sure to ask about any other activities that may have taken place.

Table 1. Potential channel modifications.

Channel Modification Activity	**Sources of Information**
Hydroelectric and irrigation dams	Topo maps, Corps, Bureau of Reclamation
Reservoirs and artificial impoundments	Same as above, NWI maps
Small agricultural impoundments, cattle ponds, fire ponds	Topo maps, irrigation districts, local farmers and ranchers, forestry landowners, fire-protection district maps, NWI maps
Dikes, levees (usually for flood control)	County engineering or public works department, Corps, local diking districts, NWI maps
Channelization (channel straightening, hardening, or relocation)	County/city planning or public works departments, local conservation districts, comparisons with historic maps
Dredged channels	Port authorities, Corps, county engineering department
Stream-bank protection (***riprap***, pilings, bulkheads)	Local and state hydraulic permit officials, county engineering or public works departments, Corps, DSL permits
Built-up areas in floodplains, in/near estuaries, wetlands, and channels	USGS topo maps, comparisons with maps or photos predating the fill (assessor's photos), engineering reports on fill materials, project environmental impact statements
Roads next to streams	County road maps; ODFW, US Forest Service (USFS), BLM and other forestry road maps; fire-protection district maps
Extensive fill associated with road crossings (~250+ feet)	County road maps; ODFW, USFS, BLM and other forestry road maps; fire-protection district maps
Tide gates	Local officials, residents, diking and water control districts
Water withdrawals	State Water Resource Department, State Department of Environmental Quality 303(d) (1)-listed streams, local officials
Push-up dams	State Water Resource Department, local officials
Sand and gravel mining in/near channels, ***tailing***s deposits	DOGAMI (Department of Geology and Mineral Industries), county land use/zoning, DSL permits

Be aware that interpretation of some channel modifications will be a judgment call. For example, roads are frequently located in the flat-lying valleys and encroach into the floodplains of channels. To protect the road from inundation and erosion, roadbeds are elevated and the banks of streams often armored. Such roads will effectively act as dikes or levees, preventing the stream from meandering and eliminating refuge sites for fish during flood flows. You will need to exercise some judgment concerning whether the road does potentially infringe into the channel or floodplain. If the road falls within the FEMA floodplain or the floodplain clearly stops artificially at the base of the road grade, then the road should be mapped.

Step 2b: Incorporate Historic Conditions Information

The final products for the Channel Modification Assessment component will meld the information from the Historical Conditions component regarding channel modifications with identified current modifications. As such, it is important that there be a high degree of coordination between the people performing these two assessments. While it is important that the final products display both sets of information, the precise timing regarding merging of information is not critical.

It may be difficult to categorize some activities as either historic or current. For example, old dike systems that are sporadically maintained or expanded could be considered either a historic or current modification. Another example may be a 100-year-old road that affects channel migration patterns. In general, consider historic those activities that are not ongoing or maintained. Often, these activities will have ceased over 30 years ago.

It is not critical whether a specific modification be deemed historic or current; only that the activity be documented and some assessment be made as to the type and magnitude of channel impact resulting from the activity.

The product of this portion of the assessment will be a map displaying channel modifications (Map CM-1), and Form CM 1 with sites cross-referenced to the map.

Step 3: Evaluate Impact of Modifications

Once the location and type of channel modifications (both historic and current) have been inventoried, you can make an assessment of their impact on channel conditions. The goal is to identify the type of impact and assign a relative degree of impact. This task may involve some judgment calls, but your focus is to identify those modifications that have the greatest impact on channel characteristics and aquatic habitat. Table 2 lists channel modifications and their probable impact. The presented information is meant as a guide, and not all possible impacts can be identified and listed. You are encouraged to query knowledgeable fish biologists as to possible impact type and degree.

In order to identify a general degree or magnitude of impact, you need to assign each identified channel modification activity a rating of low, moderate, or high. Although subjective, this rating identifies those activities most likely to affect channel characteristics and aquatic habitat. Obviously, field verification of modifications greatly increases the accuracy of the impact assessment. The following guidelines will help you for assign ratings. Consider the type of impact, the geographic extent, age, and longevity of the modification when assigning a degree. Enter the type and degree of impact data for each channel modification on Form CM-1.

- **Low**
  - Channel impacts are not readily apparent.
  - Impacts likely affect only a small (~<1% of channel or wetland) area.
  - Channel characteristics such as pattern, width, substrate type, bank erosion, pool features, and large wood distribution are largely unchanged.
- **Moderate**
  - Impacts are localized but apparent.
  - Changes to channel characteristics such as pattern, width, substrate type, bank erosion, pool features, and large wood distribution are detectable but not obvious.
- **High**
  - Impacts are obvious: gross changes in channel characteristics such as pattern, width, substrate, and bank erosion.
  - A significant length of the channel is affected.
  - A significant portion of a wetland is affected (drained, filled).

Step 4: Identify Affected CHTs

Overlay the Channel Modification Map on the Channel Habitat Type Map to determine which habitat types have been most affected. Enter this information in Form CM-1. Summarize the length of channel affected within each sub-basin and enter this information into Form CM-2.

Step 5: Evaluate Confidence in the Assessment

You can evaluate the strength of your channel modification assessment by considering the resources used, whether information was field-verified, and so on. Form CM-3 provides criteria for the evaluation. If the type or quality of information used to map the watershed differs significantly from area to area, fill out a form that evaluates each general area.

Table 2. Probable impacts from channel modifications.

Channel Modification Activity	Probable Impact
Hydroelectric and irrigation dams	Migration barrier, loss of spawning and rearing habitat, non-native fish introduction
Reservoirs and artificial impoundments	Flow alteration, loss of spawning gravels
Small agricultural impoundments, cattle ponds, fire ponds	Migration barrier, loss of spawning and rearing habitat, non-native fish introduction, water quality impacts
Dikes, levees (usually for flood control)	Loss of side-channels and floodplain function, decrease in channel length, and reduction of habitat complexity
Channelization (channel straightening, hardening, or relocation)	Reduction in key habitat features such as pools and sorted gravel
Dredged channels	Decrease of habitat complexity
Stream-bank protection (riprap, pilings, bulkheads)	Decrease in lateral scour pools; likely to incite bank erosion downstream
Built-up areas in floodplains, in/near estuaries, wetlands, and channels	Loss of side-channels, flood attenuation, and food-chain support
Tide gates	Loss of off-channel rearing areas and food-chain support
Roads next to streams	Loss of side-channels, lateral pools, and riparian function
Extensive fill associated with road crossings (~250+ feet)	Loss of habitat complexity, downstream erosion
Push-up dams	Migration barrier, habitat loss, flow alteration
Sand and gravel mining in/near channels, tailings deposits	Pool filling, decreased habitat complexity

GLOSSARY

100-year floodplain: That area adjacent to the channel which has a 1 in 100 chance of being flooded in any given year.

biota: Living matter.

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, **channel pattern**, and **confinement**. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

gradient: Channel gradient is the slope of the channel bed along a line connecting the deepest points (thalweg) of the channel.

impoundment: A structure meant to dam or hold back water.

morphology: A branch of science dealing with the structure and form of objects. Geomorphology as applied to stream channels refers to the nature of landforms and topographic features.

riparian area: The area adjacent to the stream channel that interacts and is dependent on the stream for biologic integrity.

riprap: Material (usually boulders) placed along a stream bank to prevent erosion of the bank.

splash damming: Historical practice where a small dam was built across a stream to impound water and logs. The dam was then removed (usually with explosives) to release the impounded logs and water, causing scour downstream.

stream cleaning: The removal of large wood or fine organic matter (i.e., branches, twigs, leaves, etc.) from stream channels. Historically, this practice was used to remove debris jams that were thought to block fish passage, or to remove fine organic matter that was thought to cause water quality problems such as reducing aquatic oxygen levels. Because stream cleaning was found to damage fish habitat, it is currently not a common practice.

tailings: Washed or milled rock that has been processed for ore removal.

Waters of the State: Those water bodies over which the State of Oregon has regulatory authority.

Appendix VII-A
Blank Forms

Form CM-1: Channel Modification Inventory

Watershed: **Page_____of_____**

Name: **Date:**

Site No.	Channel Modification Activity Description	Data/Information Source	Channel Habitat Type	Channel Length (mi)	Degree of Impact	Type of Impact

Form CM-2: Channel Modification Summary

Watershed: **Page_____of_____**

Name: **Date:**

Sub-basin	Miles of Channel Modified					Total Miles
	Dredging	Diking	Road Along Stream	Riprap	Etc.	
Total Miles						

Form CM-3: Confidence Evaluation in Channel Modification Assessment

Watershed:

Name of Mapper(s):

Technical expertise or relevant experience:

Resources used:

- ☐ Topographic maps
- ☐ ODFW
- ☐ FEMA flood maps/county maps
- ☐ Local irrigation/diking district
- ☐ Historical records
- ☐ Local officials/records
- ☐ Road maps: county/ODF/USFS/BLM/forestry landowners/fire-protection district
- ☐ DOGMI mining records
- ☐ Local knowledge/personal knowledge
- ☐ Others (list)
- ☐ Field verification
- ☐ Newspaper archives
- ☐ Army Corp. Engineers personnel/documents
- ☐ Forestry landowners (all / some)
- ☐ Long-time residents, old-timers
- ☐ Bureau of Rec. personnel/documents
- ☐ County/city zoning maps
- ☐ Port authorities

Confidence in channel modification mapping:

- ☐ **Low to moderate:** Unsure of procedures and/or used minimal resources; no field verification.
- ☐ **Moderate:** Understood and followed procedures; used at least one resource for all categories mapped; no field verification; suspect some modification activities not known.
- ☐ **Moderate to high:** Understood and followed procedures; used many resources for mapping; some field verification; suspect some modification activities not known.
- ☐ **High:** Used many resources; historical activities in area well-documented; field-verified all questionable locations; suspect few modification activities not known.
- ☐ **If none of the above** categories fits, describe your own confidence level and rationale:

Component VIII
Water Quality Assessment

Table of Contents

Component VIII
Water Quality Assessment

INTRODUCTION

The term "water quality" includes the water column and the physical channel required to sustain aquatic life. The goal of the federal Clean Water Act, "*to protect and maintain the chemical, physical, and biological integrity of the nation's waters,*" establishes the importance of assessing both water quality and the habitat required for maintaining fish and other aquatic organisms. Although water quality potentially encompasses a wide range of topics, it is necessary in a watershed assessment to focus on critical issues and partition the evaluation into components.

The purpose of the Oregon watershed assessment manual is to complete a **screening-level** [1] assessment The screening level is used to flag obvious areas of water quality **impairment** in the watershed. This is accomplished by comparing selected measurements of water quality to evaluation **criteria**. A more rigorous approach would use detailed statistical assessments to evaluate seasonal fluctuations, to evaluate trends over time, or to evaluate the specific sources of pollution by using an upstream/downstream set of stations. Watershed councils will need to conduct detailed water quality studies to fill data gaps or investigate the sources of pollutants: see Appendix VIII-A and the Watershed Condition Evaluation and Monitoring components of this manual for examples and further discussion. The council should obtain the services of a water quality specialist for these kinds of projects. The Additional Resources section at the end of this component provides more resource information on finding help to conduct a water quality analysis.

Water quality is evaluated by comparing key indicators against evaluation criteria. Indicators are selected water quality measures that are representative of a pollution category. For example, total phosphorus is used as the single indicator for the effect of phosphorus as a plant nutrient in water. In a more detailed analysis, as may be required for a **Total Maximum Daily Load (TMDL) plan**, an analyst would evaluate the biological availability of the phosphorus by examining dissolved and other forms of phosphorus. The decision to pursue more detailed analysis will depend on the importance of the issue in the watershed and the potential costs of pollutant load reduction versus resource benefits.

Because water quality is such a broad topic, some aspects of water quality are addressed in other components. Fine sediments are evaluated in the Fish and Fish Habitat Assessment component; the source of sediment is addressed in the Sediment Sources component; the processes that affect temperature are addressed in the Riparian/Wetlands Assessment component (riparian continuity and shade), and in the Hydrology (low flows) and Water Use component. The Water Quality Assessment component addresses water quality issues that are not evaluated elsewhere in the manual: temperature, **dissolved oxygen**, **pH**, nutrients, bacteria, chemical contaminants, and **turbidity**.

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

Critical Questions

1. What are the designated **beneficial uses** of water for the **stream segment**?

   The beneficial uses of water, identified in the Oregon Water Quality Standards, provide the basis for selecting criteria used to assess water quality.

2. What are the water quality criteria that apply to the **stream reaches**?

   Water quality rules contain both narrative and numeric standards. Values for narrative standards may be based on local conditions and are derived from the literature. This assessment suggests default values for the narrative standards. These two sources of criteria are combined and used as "evaluation criteria" for the purposes of this assessment.

3. Are the stream reaches identified as water quality limited segments on the 303(d) list by the state?

   Stream reaches that are on the 303(d) list have already been targeted for development of **nonpoint source** management plans or TMDL plans by the state. The TMDL process has identified water quality issues that should be addressed in the assessment.

4. Are any stream reaches identified as high-quality waters or Outstanding Resource Waters?

   Designation as Outstanding Resource Water indicates a stream of high quality or important ecological value. These stream segments have already been identified as a high priority for protection.

5. Do water quality studies or evaluations indicate that water quality has been degraded or is limiting the beneficial uses?

   The water quality analysis will evaluate existing data for temperature, dissolved oxygen, pH, nutrients, bacteria, chemical contaminants, and turbidity.

Assumptions

- The assessment will focus on water quality parameters encountered most frequently as an issue in Oregon watersheds. These issues include temperature, dissolved oxygen, pH, nutrients, bacteria, turbidity, organic contaminants, and metal contaminants.

- Evaluation criteria are derived from the Oregon Water Quality Standards. Evaluation criteria are based on an interpretation of narrative and numeric standards in the Oregon Water Quality Standards. Where numerical criteria are not provided in the state standards, we have indicated **evaluation indicators** that are based on the literature. These evaluation criteria could be modified to fit watershed conditions based on local technical knowledge with concurrence from the Oregon Department of Environmental Quality (ODEQ).

- Sensitive beneficial uses such as **salmonid** fish serve as **surrogate measures** for other beneficial uses of water in characterization and assessment of water quality.

- The scope of parameters is limited to evaluation indicators or criteria that are representative of the type of pollution. For example, although there are many forms of phosphorus that can be measured, we use total phosphorus as the indicator for phosphorus enrichment.

- Organic contaminants are screened by tallying the number of “detections” above minimum detection levels. This does not constitute an evaluation of harm to beneficial uses; it simply serves as a screening tool. A more detailed evaluation of effects is required where organic contaminants are an issue or the number of detections indicate potential risk to beneficial uses.

- The limited list of metal contaminants (six) is based on their occurrence in Oregon as reported in the ODEQ Statewide Water Quality Status Reports.

- At decision points where one interprets water quality data, a conservative approach is taken. The screening-level assessment is designed to detect patterns of impairment. When combined with information from other components of the watershed assessment manual, these patterns help identify potential problem areas spatially within the watershed. More detailed evaluation may be needed before any restoration actions are undertaken.

Materials Needed

- Refined Land Use Map (from the Start-Up and Identification of Watershed Issues component)

- Watershed Base Map (from the Start-Up and Identification of Watershed Issues component)

- ODEQ Water Quality Standards for the basin

- ODEQ 303(d) list and decision matrix

- State reports on water quality (from ODEQ and Oregon Department of Fish and Wildlife [ODFW

- Land management reports (from US Forest Service [USFS], US Bureau of Land Management [BLM], and corporate landowners)

- Calculator

- Spreadsheet program (recommended) (e.g., Excel, Lotus, Quattro Pro)

Necessary Skills

Performing this assessment involves dealing with numeric data and averages. The analyst should be willing to perform basic math functions.

Final Products of the Water Quality Assessment

- Beneficial Uses and Water Quality Issues form (Form WQ-1) (Step 1 result)

- Summary of Percent **Exceedance** Criteria (Form WQ-2) (Step 4 result)
- Summary of Water Quality Impairment (Form WQ-3) (Step 5 result)
- Confidence Evaluation (Form WQ-4)

ASSESSMENT OVERVIEW

The water quality assessment is based on a process which identifies the beneficial uses that occur within the watershed, identifies the evaluation criteria which apply to these uses, and evaluates water quality conditions by comparison of existing data with these criteria. This conceptual framework is consistent with the guidelines established by the US Environmental Protection Agency (EPA) under authority of the federal Clean Water Act and the water quality programs of the ODEQ.

The assessment is completed in a step-wise procedure illustrated in Figure 1. The first three steps address the following questions: (1) What are the beneficial uses of concern? (2) What criteria apply? (3) What do we know about water quality conditions? In Steps 4 through 6, we compare current conditions to the evaluation criteria and determine if there is a water quality problem. Determining the potential cause of water quality decline is completed during the Watershed Condition Evaluation component when information from the other components are combined and synthesized.

Step 1: Identify Sensitive Beneficial Uses in the Watershed

The requirements for in-stream water quality are based on protection of recognized uses of water. The term "beneficial uses" is legally defined in the Oregon Water Quality Standards and refers to uses such as drinking water, aquatic life, swimming, and boating. In practice, the sensitive beneficial uses drive the evaluation of water quality and are the basis for establishing best management practices (Table 1).

The list of beneficial uses are found in the Oregon Water Quality Standards for the 19 hydrologic basins in Oregon. The official list of beneficial uses for a waterbody are determined by consulting the basin-specific list. In most waterbodies the sensitive beneficial uses shown in Table 1 apply, and these are the uses that should be carefully evaluated. Exceptions to these general assumptions can be identified by examining the basin tables in the Oregon Water Quality Rules (Oregon Administrative Rules 340.41). See the Water Quality Information Resources sidebar to find out how to identify beneficial uses in your watershed.

Table 1. Sensitive beneficial uses of water applicable to this assessment

Beneficial Uses
Aesthetic quality
Fishing
Domestic water supply
Resident fish and aquatic life
Salmonid fish rearing
Salmonid fish spawning
Water contact recreation

Aquatic species, particularly salmonid fish, are often considered the most sensitive beneficial uses in a watershed. Salmonid species—the pacific salmon, char, and whitefish—are adapted to cold-water, high-gradient habitats where temperatures are cool and dissolved oxygen is high. Salmonids have highly variable life histories (see Watershed Fundamentals component of this manual for a description of salmonid life histories), but display similarity in laying eggs in gravels and have **fry** and **juveniles** that rear close to where they hatch from the egg. These early life stages are particularly sensitive to changes in water quality.

At this step, also determine if the stream is on the 303(d) list and, if so, identify for which parameters the stream segment is listed. See the Water Quality Information Resources sidebar (next page) to find out where to get information on the 303(d) list. Also, the assessment team may already have obtained this information in the Start-Up and Identification of Watershed Issues component. If so, transfer the information to the Beneficial Uses and Water Quality Issues form (Form WQ-1), and pat yourself on the back for a job well done !

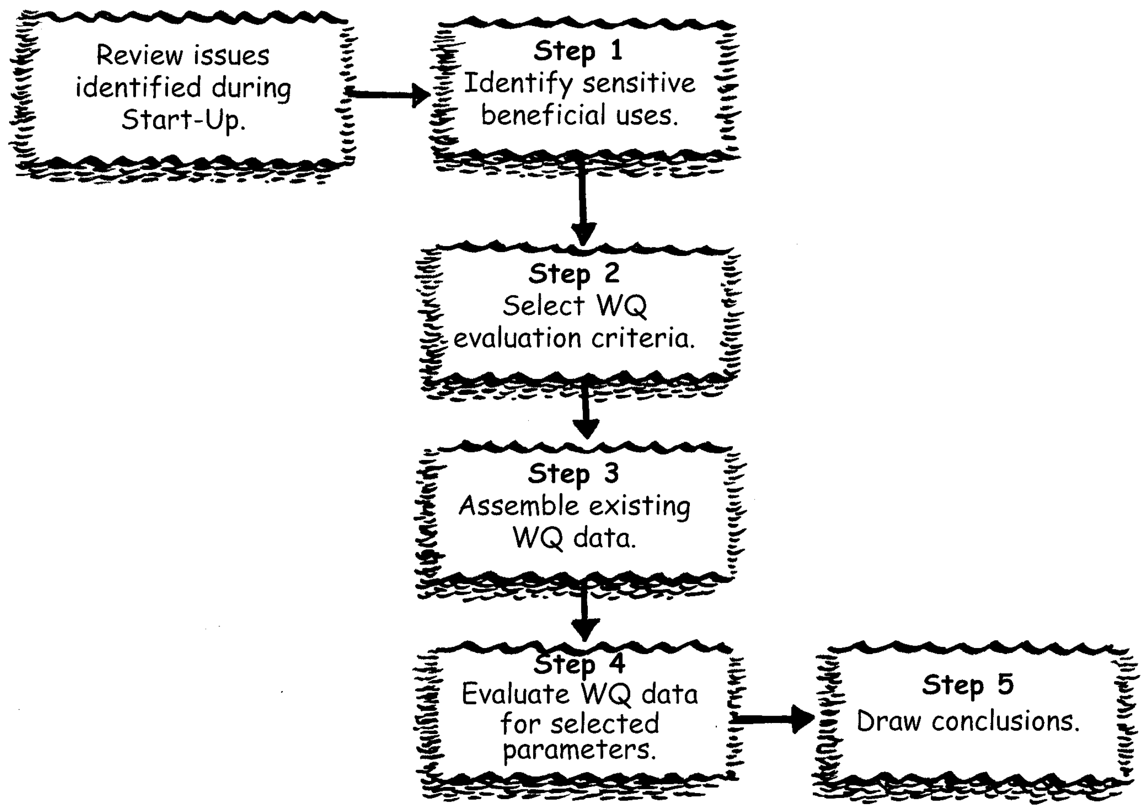


Figure 1. The water quality assessment is performed using a step-wise procedure that identifies the beneficial uses which occur within the watershed, identifies the evaluation criteria which apply to these uses, and evaluates water quality conditions by comparison of existing data with these criteria.

WATER QUALITY INFORMATION RESOURCES

Oregon Division of Environmental Quality Web Site
ODEQ home page: http://www.DEQ.state.or.us

Information on beneficial uses, water quality criteria, and 303(d) listings are available on the ODEQ Internet site. The information can be obtained by following the hypertext links starting with the ODEQ home page address listed above. Several pathways and the information found by following them are described in the following sections:

http://waterquality.deq.state.or.us/wq [Select “Water Quality Program Rules” from the menu.]

Beneficial Uses
The water quality rules are organized by river basins, which are shown in the Basin Index Map. Download the figure for the specific river basin which shows the stream segments located in the basin. Download the basin table which lists the beneficial uses in the basin.

Table 20 – Water Quality Criteria Summary
This table provides criteria for toxins such as pesticides and heavy metals. Download this table only if toxic chemicals are an issue in the basin.

Table 21 – Dissolved Oxygen Criteria
Download this table only where dissolved oxygen has been identified as a water quality issue in the basin and a more detailed analysis is required.

OAR 340 – Oregon Administrative Rules, Chapter 340
These rules provide the official list of water quality standards for the basin. This section is very lengthy and is generally not needed for the screening-level assessment. Refer to these rules only if there is question about the application of a specific water quality standard. Download a summary of the water quality criteria contained in the 303(d) list site.

http://waterquality.deq.state.or.us/wq [Select “Water Quality Limited Streams (303d)” from the menu.]

Listing Criteria for 1998 303(d) List
The listing criteria provide a summary of the Oregon Water Quality Standards. This list also provides the rationale for deciding what information is needed to place streams on the 303(d) list.

Oregon’s Water Quality Limited Waterbodies - Section 303(d) List
This list shows the parameters, basis, and supporting data for including a waterbody on the stream segment. Query the list only for the specific stream segments of interest and download this information.

More 303(d) Information
The 303(d) List site contains additional information about water quality limited streams and TMDLs. Refer to this site for information on TMDL schedules, priorities, 303(d) database, fact sheets, guidance, and examples of TMDLs.

http://www.DEQ.state.or.us/lab/lab.htm

The ODEQ laboratory home page provides information on water quality and biological monitoring. The Water Quality Index basin summary provides a summary of types of pollution and their potential severity in the basin.

Phone Numbers
(800) 452-4011 ODEQ Public Information
(503) 229-5279 Water Quality Division
(503) 229 5983 ODEQ Laboratory regional water quality monitoring coordinators

Step 2: Identify Water Quality Criteria Applicable to the Sensitive Beneficial Uses

The Oregon Water Quality Standards are several hundred pages in length, so the brief summary of water quality criteria discussed here and listed in Table 2 should be used with caution. In general, the values summarized in the table apply to the majority of stream and river systems and are sufficient for the purposes of this assessment. The official state standards for the basin should be consulted where a key issue relative to water quality is under consideration.

Evaluation criteria are based on an interpretation of narrative and numeric standards in the Oregon Water Quality Standards. Where numerical criteria are not provided in the state standards, we have indicated evaluation indicators that are based on the literature. These are useful for evaluating water quality conditions, but do not have any regulatory standing.

Step 2 result: Highlight the criteria in Table 2 that are applicable to the watershed assessment. Note any modifications based on local water chemistry.

Table 2. Water quality criteria and evaluation indicators.

Water Quality Attribute	Evaluation Criteria		
Temperature	Criteria: Daily maximum of 64°F (7-day moving average)		
Dissolved Oxygen	Criteria: 8.0 ***mg/l***		
pH	Criteria: 6.5 to 8.5 units		
Nutrients	No statewide numeric criteria. See state standards for water quality criteria established in specific basins.		
Total Phosphorus	Indicator: 0.05 mg/l		
Total Nitrate	Indicator: 0.30 mg/l		
Bacteria	Water-contact recreation (criteria) 126 *E. coli*/100 ml (30-day log mean—minimum 5 samples) 406 *E. coli*/100 ml (no single sample can exceed the criteria) Marine waters and estuarine shellfish growing area 14 fecal coliform/100 ml (median) 43 fecal coliform /100 ml (not more than 10% of samples)		
Turbidity	Indicator: 50 NTU maximum above background		
Contaminants, Organic	Indicator: Above detection limits		
Contaminants, Metal	Chronic toxicity for freshwater aquatic life:		
	Hardness	100 mg/l	25 mg/l
	Arsenic	190.0 ***µg/l***	
	Cadmium	1.1 µg/l	0.4 µg/l
	Chromium (Hex)	11.0 µg/l	
	Copper	12.0 µg/l	3.6 µg/l
	Lead	3.2 µg/l	0.5 µg/l
	Mercury	0.012 µg/l	
	Zinc	47.0 µg/l	32.7 µg/l

Step 3: Assemble Existing Water Quality Information

Now that the potential pollutants, beneficial uses, and water quality criteria have been identified, you need to search for applicable information on water quality regarding your watershed.

Water quality information may be accessed in different forms—raw data, reports, and professional judgement. These sources of information all start with some form of data—the "raw material" of an assessment. This raw material must be processed in a technically sound manner. Water quality data is turned into information by comparing data against criteria or comparing data between collection sites.

Consider beginning your search with the following data sources:

- Raw data. Data in tabular format from agency or private-company files. Data is commonly stored on spreadsheet programs, such as Quattro Pro, Excel, or Lotus. Raw data is processed using the procedure described in Appendix VIII-B.

- Reports. The most common sources of information are state and federal agencies, such as ODEQ, ODFW, USFS, BLM, and the US Geological Survey (USGS). Studies are also completed by private corporations, universities, private contractors, and municipal water providers. In urban areas, local public works agencies may have collected water quality data. Reports should summarize water quality conditions in the Conclusion section. This information may be directly transferable to the Watershed Condition Evaluation component.

- Professional judgement. Local specialists in hydrology, fisheries, water quality, and other professions that are familiar with a watershed can provide some useful insight into conditions. Although this professional expertise can provide valuable information, professional judgement is not a substitute for assessments based on data.

An inventory of available information should answer the following questions:

- Who collected the information?
- What data were collected?
- At which locations were the data collected?
- Was data analyzed?
- Was a report filed?
- Were conclusions made?

You also need to evaluate and record the applicability and reliability of available information. Criteria to consider when evaluating information includes:

1. How old is the information?

2. Have watershed conditions changed since the evaluation was completed?

3. Was the data coverage (over time and geographic extent) sufficient to assess conditions?

4. Is the information based on inventory methods (primarily observations) or on more rigorous studies (primarily measurements)?

Step 4: Evaluate Water Quality Conditions Using Available Data

This procedure is an initial data evaluation; more rigorous statistical procedures may be required to draw conclusions confidently from the data set. The analysis can be completed using a hand-held calculator; however, using spreadsheet software will help speed up data analysis and organize the information.

The same general procedure is used for each pollutant category. The procedure is illustrated in Appendix VIII-B using nutrients as an example. The purpose of the analysis is to:

1. Describe the existing condition of the stream under study.

2. Compare the existing condition to reference sites where available (upstream sites or adjacent watersheds).

3. Compare existing condition to water quality criteria.

Temperature

Cool water temperatures are a basic requirement for native salmon, trout, amphibians, and other aquatic life. Growth and reproduction are adversely affected when water temperature is outside of the range to which these organisms were adapted. There is continuous debate about the actual numerical values that should be used for setting the temperature criterion. This is because the temperature cycle varies daily and seasonally, and different life stages and species of fish exhibit different tolerances.

The following temperature criteria are established in the Oregon Water Quality Standards (OAR 340-41-[basin][2][b]) for the protection of resident fish and aquatic life, and salmonid spawning and rearing.

> Seven (7) day moving average of the daily maximum shall not exceed the following values unless specifically allowed under a Department-approved basin surface water temperature management plan:
>
> - 64°F (17.8°C);
> - 55°F (12.8°C) during times and in waters that support salmon spawning, egg incubation and fry emergence from the egg and from the gravels;
> - 50°F (10°C) in waters that support Oregon Bull Trout:
> - 68°F (20°C) in the Columbia River (mouth to river mile 309);
> - 68°F (20°C) in the Willamette River (mouth to river mile 50);

[except when air temperature during the warmest 7-day period of the year exceeds the 90th percentile of the 7-day average daily maximum air temperature calculated in a yearly series over the historical record]

Water Quality Limited Criteria: Rolling seven(7) day average of the daily maximum exceeds the appropriate standard listed above. In the cases where data was not collected in a manner to calculate the rolling seven (7) day average of the daily maximum, greater than 25 percent (and an minimum of at least two exceedances) of the samples exceed the appropriate standard based on multi-year monitoring programs that collect representative samples on separate days for the season of concern (typically summer) and time of day of concern (typically mid to late afternoon).

The screening-level assessment bypasses these complexities by using the daily maximum temperature of 64°F as the evaluation criterion. Because temperature is such an important water quality issue in Oregon, you may find it useful to complete a more exacting evaluation by calculating the 7-day moving average as described in the state standards. See Appendix VIII-A, which provides an example of a more detailed temperature analysis.

Action: For this level of assessment, tally the number of days that the maximum temperature exceeds 64°F. Follow the procedure described in Appendix VIII-B to summarize results, and record the result in the Summary of Percent Exceedance Criteria (Form WQ-2).

Dissolved Oxygen

Like temperature, high dissolved oxygen is characteristic of watersheds throughout the Pacific Northwest that support cold-water organisms such as native salmon and trout. These species are adapted to waters with high dissolved oxygen. Developing salmon and trout embryos are especially sensitive to dissolved oxygen. The Oregon Water Quality Standards, therefore, have specified higher dissolved oxygen for salmonid spawning. The standards also specify a standard for oxygen in the gravel when salmon and trout eggs are developing.

Oxygen is dissolved in running water in equilibrium with the atmosphere. The water temperature and pressure determine the percent oxygen saturation from the atmosphere. Oxygen solubility varies inversely with temperature, colder water containing a higher concentration of oxygen. Dissolved oxygen fluctuates on a daily cycle that is tied to the daily change in temperature and the photosynthesis and respiration of aquatic organisms. Dissolved oxygen generally reaches a high in the afternoon due to photosynthesis from algae, and a low at night, shortly before dawn, due to the uptake of oxygen by all the organisms in the stream, including algae.

The requirement for measuring dissolved oxygen appropriately is therefore very similar to temperature. Dissolved oxygen must be measured over a 24-hour period to be useful. Data based on single grab samples of oxygen are fairly useless in characterizing the actual oxygen levels that influence aquatic organisms. Devices for measuring dissolved oxygen over a daily cycle are more expensive and require more expertise than the simple temperature data loggers. For this reason, there are likely very few adequate existing data records for dissolved oxygen.

The Oregon Water Quality Standards contain a number of dissolved oxygen criteria. More restrictive criteria are specified for dissolved oxygen during the period that salmonid fish are spawning (11 mg/l). Also, the standards specify a dissolved oxygen concentration (8 mg/l) in the gravel used by spawning fish. Additional specific language addresses the difference between cold-water, cool-water, and warm-water fish.

For the purposes of the screening-level assessment, the evaluation criterion is set at a minimum of 8 mg/l in the water column for cold-water fish. Because the criterion is a minimum, tally the measurements found below the criterion.

Action: Use the criterion of 8 mg/l for dissolved oxygen. Follow the procedure described in Appendix VIII-B to summarize results and record the result in Form WQ-2. Where dissolved oxygen is identified as a critical issue in the watershed, consult the water quality standards for the specifics of the water quality standards.

pH

The pH is a measure of the hydrogen ion concentration of water. pH is measured in a logarithmic scale, with pH below 7 indicating acidic conditions and pH above 7 indicating alkaline conditions. pH of water is important in determining the chemical form and availability of nutrients and toxic chemicals. Measurement of pH is especially important in mining areas because there is potential for both generation of heavy metals and a decrease in pH. Metal ions shift to a more toxic form at lower pH values. The pH of waters varies naturally across Oregon due to the chemical composition of the rock type in the watershed and the amount of rainfall. Eastside basins generally will have more alkaline water than westside and coastal basins.

The Oregon Water Quality Standards specify the expected pH range for all the basins in Oregon. The pH criteria is generally 6.5 to 8.5 for westside basins, and 7.0 to 9.0 for eastside desert basins. It should be recognized that, like dissolved oxygen, pH also varies in streams naturally throughout the day due to the photosynthesis and respiration cycles of attached algae.

Action: To simplify the statewide screening-level assessment, use a pH range of 6.5 to 8.5. Follow the procedure described in Appendix VIII-B to summarize results and record the result in Form WQ-2. If the screening assessment shows values outside of this range, consult the specific basin standards.

Nutrients

Total phosphorus measures primarily phosphates in the water column and phosphorus in suspended organic material. **Total nitrate** (commonly measured as nitrite plus nitrate) provides a measure of the majority of nitrogen present in surface waters. Evaluation criteria are based on literature values that have been identified as causing excessive plant growth. Local watershed or basin-specific values should be used if they have been identified through a state-approved planning process.

Excess algae and aquatic plant growth can create a problem in slow-moving streams and rivers, and in still waters such as ponds and lakes. The excessive growth can result in low or no dissolved oxygen, can interfere with recreation, and with certain algae can produce chemicals that are toxic to livestock and wildlife. Phosphorus and nitrogen, the major growth-limiting nutrients in water, are the focus of the water quality evaluation. Although aquatic scientists measure nutrients in many forms, these are two primary chemical forms limit plant growth.

Action: Where TMDLs have not been established, use the evaluation criteria of 0.05 mg/l for total phosphorus and 0.30 mg/l for total nitrates. Follow the procedure described in Appendix VIII-B to summarize results and record the result in Form WQ-2.

Bacteria

Bacteria in the coliform group are used as indicators to test the sanitary quality of water for drinking, swimming, and shellfish culture. For the purpose of screening bacterial contamination, bacterial numbers can be compared to a single sample criterion: 406 **E. coli**/100 ml in fresh waters and 43 **fecal coliform**/100 ml in marine waters. This approach provides an appropriate red flag for bacterial contamination and maintains simplicity for the watershed assessment. Where bacterial data have been collected for a specific study (e.g., in public bathing beaches or below waste treatment facilities), the analysis and the conclusions should be available in agency reports.

Action: Follow the procedure described in Appendix VIII-B to evaluate bacterial numbers using the single sample criterion. Transfer the results to Form WQ-2.

Contaminants: Organic Compounds, Pesticides, and Metals

The term “contaminants” refers to chemicals that may cause toxicity in aquatic organisms. Organic compounds are man-made chemicals that are used for a variety of industrial purposes and as pesticides and herbicides. Because of the wide variety of organic chemicals it is not feasible to list the criterion for each chemical in a screening assessment. Establishing the “safe” level for these chemicals is the subject of continuing debate among scientists.

For organic compounds, the suggested assessment is to count the number of “detections” or “hits” in a data set that are above minimum detection levels. The detection level for these chemicals is usually reported in the parts per billion range, and the detection limit varies by compound. A high percentage of observed detections should be considered a red flag, and a more detailed evaluation of the data should be completed by a water quality specialist or toxicologist.

Criteria for metals are expressed as acute and chronic values. Chronic values are intended to protect the organism from sublethal effects such as physiological stress, growth inhibition, and decreased reproduction. Toxicity for most metals is based on the **hardness** of the receiving water, and therefore the regulatory criterion is expressed as a formula. To simplify the process, the chronic criterion for freshwater aquatic life is listed for only two hardness levels, 25 and 100 mg/l of hardness. As hardness decreases, the toxicity of the metal increases. Request assistance from the ODEQ in adapting the criteria to the local water chemistry conditions if hardness levels are outside of this range.

Action: For organic compounds, count the number of detections and express this count as a percentage of measurements taken. For metals, compare the values to the evaluation criteria in Table 2 and use the data analysis procedure described in Appendix VIII-B. Transfer the results of the assessment to Form WQ-2.

Turbidity/Suspended Sediment

Turbidity is a measure of the clarity of water. In most cases water is cloudy due to runoff of sediment, and therefore turbidity is a useful surrogate for measuring **suspended sediment**. Turbidity can also be caused by other sources of suspended material such as algae or fine materials from glaciers, so the assumed relationship to suspended sediment should be verified by checking with local experts. Suspended sediment can directly affect fish by damaging their gills and reducing the feeding ability of sight-feeding fish such as salmonids. Suspended sediment is a carrier for other pollutants (nutrients, pesticides, and bacteria) and is therefore a concern for water quality in general. In addition, suspended sediment interferes with recreational uses and the aesthetic quality of water. State tourism bureaus like to advertise the gin-clear mountain streams—those waters with low suspended sediment and turbidity.

Turbidity is measured optically by passing a light beam through a sample. With increased suspended material, less light passes through the sample and a higher turbidity value is recorded. The unit of measure, an **NTU** (nephelometric turbidity unit), is based on the original measurement device and has no direct meaning.

Turbidity varies naturally with the soil type in a landscape. The small particle sizes, silts and clays, will stay suspended for long periods and cause turbidity. Soils that break down into sand-size fractions will settle to the bottom and result in comparatively low turbidity values. Turbidity in a stream will increase naturally during storm and runoff events. This high variability makes it difficult to establish a simple, meaningful criterion.

The Oregon Water Quality Standards specify a criterion that compares an activity relative to background. This criterion is only useful in comparison to a specific pollutant source where paired samples have been collected; finding this information in routine data collections would be rare. For this assessment we recommend using an evaluation criteria of 50 NTU. Turbidity at this level interferes with sight-feeding of salmonids and therefore provides a direct indicator of biological effect. Turbidity at this level is not lethal to fish, but, it does provide a useful red flag for screening turbidity and suspended sediment.

Action: Compare turbidity values to the 50 NTU evaluation criteria using the procedure in Appendix VIII-B and transfer the results to Form WQ-2.

Step 5: Draw Inferences from the Water Quality Assessment

The data assessments completed in Step 4 result in a percentage of criteria exceedance. The next step is to make an inference about water quality conditions based on the assessment and summarize the information. Because water quality data are normally very limited, the forms are set up to record water quality by subwatershed rather than by **Channel Habitat Type** (CHT). If there is sufficient information to break the subwatershed into smaller units, then the segment breaks should be at transitions between CHTs.

Water quality varies seasonally as the watershed experiences the process of erosion and pollutant transport associated with rain and snowmelt events. Aquatic biota integrate the variability in water quality over time. If water quality conditions are unfavorable during critical periods then the population will either be reduced or eliminated from the waterbody. For this reason, it is not useful to evaluate water quality on an average annual condition; this would tend to mask the effect on the aquatic life. Instead, you need to consider how seasonal extremes or short-duration events effect the organisms living in the stream.

To capture this concept of seasonal effects, we suggest using a fairly conservative assessment of the data. However, the procedure provides some allowance for limited excursions above the criteria that may be attributed to natural variability and to which aquatic organisms are adapted. These factors are balanced by setting a low percentage of criteria exceedance (15%) as the criterion for impairment. Analysts should recognize that these are subjective breakpoints.

To apply the information from the Water Quality Assessment component to the Watershed Condition Evaluation component, summarize water quality using the last column (Summary of Miles Impaired) in Form WQ-3, Summary of Water Quality Impairment. If any water quality category is rated "Moderately Impaired" or "Impaired" (Table 3), the summary should be recorded as "Impaired." This approach is based on the concept of limiting factor: If one water quality factor is limiting the beneficial use, then this needs to be noted in Form WQ-3 so that the condition can be addressed in stream restoration.

Finally, the information is summarized by number of miles impaired. The number of miles each **water quality station** represents is evaluated based on the land use and stream course maps. A water quality station represents stream miles between stations. Where only one station is located at the mouth of the tributary, the distance represented by the station is a judgement call. If the land use is uniform within the subwatershed, then the station could be considered representative of the entire length. Where there is an obvious land use change, (e.g., from crop land to forest land), then that distance to the change in land use should be used.

ADDITIONAL RESOURCES

The Water Quality Assessment component describes a screening-level procedure that accomplishes the purpose of flagging potential problem areas in the watershed. In many situations, this cursory analysis may not be sufficient for making critical decisions about restoration projects, and additional data collection or data analysis may be desired. Information on more detailed analytical methods are maintained by state and federal agencies that have generally made an effort to provide this information via the Internet. The information detailed on the following pages provides links to more detailed analytical procedures and further reading on cause-and-effect relationships.

Table 3. Criteria for evaluating water quality impairment.

Percent Exceedance of Criteria	Impairment Category
(<15%)	**No Impairment** No or few exceedances of criteria.
(15-50%)	**Moderately Impaired** Criteria exceedance occurs on a regular basis.
(>50%)	**Impaired** Exceedance occurs a majority of the time.
Date lacking/insufficient	**Unknown**

EPA Publications

EPA publications can be ordered on the Internet (http://www.epa.gov/OWOW/info/PubList/comments.html) by filling in an on-line Publication Order Form. The order form requires the EPA document number. Publication requests can also be made by mail, fax, or phone (see NCEPI address below). EPA Region 10, Seattle, maintains a toll-free number (800-424-4372) for requesting documents that are available at the Seattle office. Most documents are available to the public at no cost.

> NCEPI (National Center for Environmental Publications and Information)
> 11029 Kenwood Road, Building 5
> Cincinnati, OH 45242
> (800) 490-9198
> Fax: (513) 489-8695

Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls, EPA 841-B-96-004 (EPA 1997) provides detailed guidance on developing nonpoint-source monitoring plans, biological monitoring, data analysis, quality assurance, and reporting. This publication replaces several other documents that were previously available from EPA, and is therefore a valuable desktop reference.

Environmental Indicators of Water Quality in the United States – Fact Sheet, EPA 841-F-96-001. (EPA 1996) describes in detail the set of core water environmental indicators used by EPA to track water quality progress. The document is useful as a more detailed introduction to understanding the indicators used in this assessment manual. It is also available on line at http://www.epa.gov/OW/indic.

Volunteer Stream Monitoring: A Methods Manual, EPA-841-B-97-003, EPA (1997) provides step-by-step methods for use by volunteer programs for monitoring biological health, water quality conditions, and habitat in wadeable streams. The document includes a chapter on watershed surveys. Similar manuals are available on volunteer monitoring for lakes and estuaries. See the Publications Order Form Internet address listed above.

BASINS (Better Assessment Science Integrating Point And Nonpoint Sources) (EPA 1998) is a software package that evaluates water quality at a watershed level using national databases, water quality and point-source loading, GIS data layers, and water quality models. BASINS uses GIS ArcView to integrate spatial information on the watershed with water quality data. This is a tool for the advanced watershed assessment with emphasis on pollutant load evaluation. BASINS is available for downloading at http://www.epa.gov/OST/BASINS.

Ecological Restoration: A Tool to Manage Stream Quality, EPA 841-F-95-007 (EPA 1996) provides a good explanation of the relationship between restoration techniques and water quality parameters– altered stream geomorphology, sedimentation, flow alteration, nuisance algal growth, dissolved oxygen, pH, and toxic elements. It includes a chapter on cost-effectiveness and case studies.

Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen (Carpenter et al. 1997) provides the scientific foundation for the nontechnical reader on phosphorus and nitrogen input, output, and transport processes in a watershed. This is one of a series of papers in the EPA Watershed Academy, an on-line information series, that provide basic technical information useful to watershed councils. You can download the publication at http://www.epa.gov/OWOW/watershed/wacademy/acad2000.html or order from NCEPI.

US Geological Survey

The USGS is a primary source for water quality and quantity data collection and analysis techniques. Reports can be requested via the addresses listed below. Current prices can be obtained when contacting Information Services.

US Geological Survey
Branch of Information Services
Box 25286, Federal Center
Denver, CO 80225
(303) 202-4700
Fax: (303) 202-4693
http://wwworegon.wr.usgs.gov/pubs_dir/twri-list.html

The following three manuals are examples of the technical documents that are in the *Techniques of Water-Resources Investigation Series*. The manuals describe detailed procedures for collecting and analyzing data from surface- and groundwater for the advanced technical user.

- Wilde, F.D., and D.B. Radtke. 1998. Field Measurements. TWRI Book 9, Chapter A6.
- Myers, D.N., and F.D. Wilde. 1997. Biological Indicators. TWRI Book 9, Chapter A7.
- Britton, L. J., and P.E. Greeson. 1989. Methods for Collection and Analysis of Aquatic Biological and Microbiological Samples. TWRI Book 5, Chapter A4.

The USGS operates two national water quality networks. The Hydrologic Benchmark Network collects data on small, minimally disturbed watersheds, and provides information on water quality and quantity under natural conditions. The National Stream Quality Accounting Network tracks trends in water quality in larger watersheds. Nearby stations can be useful in understanding reference or benchmark conditions at the river basin scale. Refer to *Data From Selected USGS National Stream Water-Quality Monitoring Networks*; information available at http://wwwvares.er.usgs.gov/wqn96cd/

The Oregon Plan

This water quality analysis evaluates water quality based on existing data and reports. One of the potential outcomes of the analysis is that information is lacking on an important water quality issue. Watershed councils will likely wish to initiate a monitoring program to fill data gaps identified during the assessment.

Fortunately, a state interagency group has developed a guidebook (*Water Quality Monitoring Guide Book*, *Oregon Plan for Salmon and Watersheds* [Water Quality Monitoring Team 1998]) that will assist watershed councils in developing a monitoring program for water quality. The council should obtain a copy of the document and contact one of the mentors listed in the document for assistance in developing a monitoring plan. Also, refer to the Monitoring Plan component of this document for general guidance on developing a monitoring program.

REFERENCES

Boyd, M. and D. Sturdevant. 1998. The Scientific Basis for Oregon's Stream Temperature Standard: Common Questions and Straight Answers. Oregon Department of Environmental Quality, Water Quality Bureau, Portland.

Dissmeyer, G.E. 1994. Evaluating the Effectiveness of Forest Best Management Practices in Meeting Water Quality Goals or Standards. Misc. Publication 152. USDA Forest Service, Atlanta, Georgia.

EPA (US Environmental Protection Agency). 1997. Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls. US EPA, Nonpoint Source Control Branch, EPA/841-B-96-004. Washington, D.C. EPA. [Comprehensive technical guide for monitoring plans, data analysis, and quality assurance.]

Helsel, D.R., and R.M. Hirsh 1995. Statistical Methods in Water Resources. Studies in Environmental Science 49, Elsevier Science Publishing, New York. [Applied statistical methods for professional hydrologists.]

Hansen, R.N., H.M. Babcock, and E.H. Clark. 1988. Controlling Nonpoint Source Pollution: A Citizen's Handbook. Conservation Foundation, Washington, DC. [An overview of nonpoint source pollution, assessment, and management for the citizen.]

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluating Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. U.S. Environmental Protection Agency, EPA 910/9-91-001, Region 10, Seattle, Washington.

GLOSSARY

beneficial uses: Uses of water specified in Oregon Water Quality Standards.

channel confinement: Ratio of bankfull channel width to width of modern floodplain. Modern floodplain is the flood-prone area and may correspond to the 100-year floodplain. Typically, channel confinement is a description of how much a channel can move within its valley before it is stopped by a hill slope or terrace.

Channel Habitat Types (CHT): Groups of stream channels with similar gradient, **channel pattern**, and **confinement**. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

channel pattern: Description of how a stream channel looks as it flows down its valley (for example, braided channel or meandering channel).

criteria: Elements of Oregon Water Quality Standards expressed as concentrations or narrative statements representing a quality of water that supports a particular use.

dissolved oxygen: Oxygen present in water. Dissolved oxygen is absorbed by fish and other aquatic organisms through gills and membranes.

E. coli: The *Escherichia coli* bacterium is an indicator of human or animal feces.

evaluation indicator: A numerical value used to judge water quality impairment. The numerical value is based on the literature and is not a water quality standard.

exceedance: When a measure of water quality exceeds the criteria. The exceedance needs to be evaluated with respect to natural or human causes.

fecal coliform: Bacteria group used as an indicator of human or animal feces.

fry: The early life stage of salmon and trout after the yolk sac is absorbed.

hardness: A measure of the calcium and magnesium concentrations in water; used to select the appropriate criteria for heavy metals.

impairment: An interpretation of criteria exceedance which indicates that the beneficial use is harmed.

juvenile: The early life stage of salmon and trout, usually the first and second years.

nonpoint source: Sources of pollution from diffuse sources such as storm runoff from farming, logging, and roads.

NTU: nephelometric turbidity unit. A unit of turbidity measurement that is defined by its relationship to an original measurement method. Synonymous with JTU and FTU.

pH: A measure of the relative acidity or alkalinity of water.

salmonid: Fish of the family *Salmonidae*, including salmon, trout, char, whitefish, ciscoes, and grayling. Generally, the term refers mostly to salmon, trout, and char.

screening-level assessment: An initial evaluation of information using simplified methods.

stream reach: A section of stream possessing similar physical features such as gradient and confinement; usually the length of stream between two tributaries.

stream segment: Contiguous stream reaches that possess similar stream gradient and confinement, and which can be used for analysis.

surrogate measure: An indirect measure of a pollutant; for example, the use of turbidity to measure suspended sediment.

suspended sediment: Fine soil particles (e.g., silts and clays) that do not readily settle out. Compare to "fine sediment" – which is sand-sized particles that readily settle to the bottom of a stream and fill in the substrate.

Total Maximum Daily Load (TMDL) plan: A TMDL is a plan for pollutant reduction required under the authority of Section 303(d) of the Clean Water Act for waters designated as water quality limited. See the Start-Up component for further information.

total nitrate: A measurement form of nitrogen in surface- and groundwater that is composed of nitrate and nitrite.

total phosphorus: A commonly used measurement of phosphorus that includes most forms of phosphorus which are biologically available (or can be readily converted to available forms) to algae and aquatic plants.

turbidity: An optical measure of the murkiness of water. An indirect measure of the affect of suspended sediment in water.

mg/l: Milligrams per liter. Unit of chemical concentration that is essentially equivalent to parts per million (ppm).

µg/l: Micrograms per liter. Unit of chemical concentration that is essentially equivalent to parts per billion (ppb).

water quality station: A designated location on a stream at which water samples are collected

.

Appendix VIII-A
Watershed Characterization of Temperature—Umpqua Basin

Appendix VIII-B
Data Assessment

DATA ASSESSMENT

1. List the data by collection date.
2. Rank the data from the lowest to the highest number.
3. Calculate summary statistics and compare to water quality criteria.
4. Compare stations where appropriate and interpret results.

Example: Total Phosphorus (μg/l)
Situation: This data is based on a real example that illustrates the value of comparing stations. An allotment is grazed by cattle in a section of an industrial private forest. Grazing is season-long within the allotment, but is restricted in an adjacent subwatershed. Data from Stream A within the grazing allotment is compared to Stream B, where forestry is the predominant land use.

1. *Data are listed by collection date.*

Date	Stream A	Stream B
Mar 10	24	45
Apr 11	37	51
Apr 24	30	47
May 08	34	51
May 24	23	32
Jun 08	24	43
Jul 05	30	76
Aug 01	32	74
Sep 12	37	78
Oct 10	31	52

2. *Data are ranked in order form lowest to highest.*

Stream A	Stream B
23	32
24	43
24	45
30	47
30	51
31	51
32	52
34	74
37	76
37	78

3. *Calculate summary statistics and compare to water quality criteria.*

Number: The count of data points.

Minimum: The lowest data point in the list.

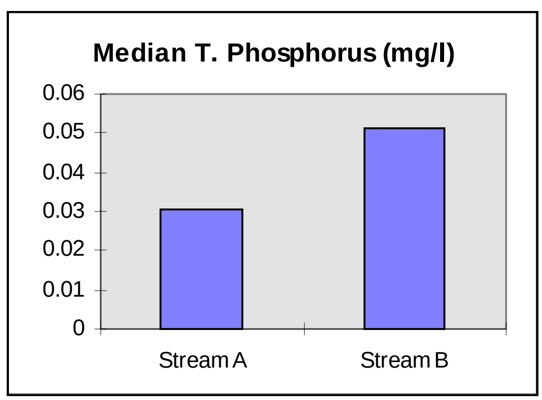
Maximum: The highest data point in the list.

Median: The middle number in the ranked list. In this example, the median for Stream A is between the 5th and 6th number in the list - between 30 and 31 - the median is therefore 30.5.

The evaluation criteria for total phosphorus is 0.05 mg/l or 50 μg/l. The number of data points that exceed 50 μg/l are counted and the percent of exceedance is calculated. E,g., six values exceeded 50 in Stream B; therefore, the percent exceedance is equal to 6 out of 10, or 60 percent.

Statistic	Stream A	Stream B
Number	10	10
Min	23	32
Max	37	78
Median	30.5	51
Number (> 50)	0	6
% exceedance	0	60

A bar chart of the median values provides a visual illustration of the results.



Appendix VIII-C
Blank Forms

Form WQ-1: Beneficial Uses and Water Quality Issues

Watershed:____

Analyst's Name:____

Beneficial Uses in Watershed:______________________________________

Beneficial Uses	Check Uses that Apply
Aesthetic quality	
Fishing	
Domestic water supply	
Resident fish and aquatic Life	
Salmonid fish rearing	
Salmonid fish spawning	
Water contact recreation	
Other (list)	
Other (list)	

303(d) Stream Segment: (Y / N) _____

Parameters	303(d) List	Details from 303(d) List
Temperature		(e.g., summer)
Dissolved oxygen		(e.g., salmonid spawning)
pH		
Nutrients		(e.g., phosphorus summer)
Bacteria		
Toxics		(e.g., tissue pesticides)
Turbidity/suspended sediment		
Habitat modification		Refer to Fish and Fish Habitat component
Flow modification		Refer to Hydrology and Water Use component

Form WQ-2: Summary of Percent Exceedance Criteria

Subwatershed:____

Analyst's Name:____

Percent Exceedance of Water Quality Evaluation Criteria:

Monitoring Site	Temp.	Dissolved Oxygen	pH	Nutrients	Bacteria	Turbidity	Toxics
(Example) Hill Creek #1	no data	0 %	0 %	60%	50%	no data	no data

Form WQ-3: Summary of Water Quality Impairment

Subwatershed:____

Analyst:____

Analyst's rating of confidence in water quality assessment (from Form WQ-4)__________

____

____

____

Fill in the columns as None, Moderately Impaired, Impaired, or Unknown.

Monitoring Site	Temp.	Dissolved Oxygen	pH	Nutrients	Bacteria	Turbidity	Summary of Miles Impaired*
(Example) Hill Creek #1 4.5 miles	Unknown	None	None	Impaired	Mod. Impaired	Unknown	Impaired 4.5 miles

* Summary of Miles Impaired: If any box is rated as Moderately Impaired or Impaired, the Summary is rated as Impaired. Miles in columns are not additive.

Form WQ-4: Confidence Evaluation

Watershed:____

Analyst's Name:____

Analyst's Experience / Expertise____

____

____

Note: Where the availability or quality of information varies by subwatershed, fill out a separate form for each subwatershed.

Use the following table to summarize your confidence in the conclusions about water quality conditions.

Category	Potential issue?[1] (Yes, No, Unsure)	Information sufficient?[2] (Yes, No, Unsure)	Confidence in conclusions?[3] (High, Moderate, Low)
Temperature			
Dissolved Oxygen			
pH			
Nutrients			
Bacteria			
Toxics – Organic			
Toxics – Metals			
Turbidity			
Overall Evaluation			

1 Potential issue? Answer this question based on the Start-Up and Identification of Watershed Issues component.

2 Information sufficient? Evaluate data or conclusions of reports by considering the following questions.

a) How old, or how applicable, is the information to the current watershed condition?

b) Have watershed conditions changed in a significant way since the data was collected?

c) Was the data coverage (over time and geographic extent) sufficient to assess conditions?

d) Is the information based on observations or on more rigorous studies (primarily measurement)?

3 Confidence in conclusions? This conclusion is based on the analyst's opinion regarding the sufficiency of the information and the analyst's confidence in completing the evaluation.

Recommendations for additional water quality monitoring:

Component X Watershed Condition Evaluation

Table of Contents

Component X
Watershed Condition Evaluation

INTRODUCTION

The Watershed Condition Evaluation will help you summarize the information collected in the other components of the assessment process. Using the process outlined in this component, you will accomplish all of the following:

1. Identify missing or unavailable information.

2. Summarize information collected for each of the manual components.

3. List issues that may require additional assessment or data-gathering.

4. Evaluate the condition of the aquatic–riparian system, fish populations, and water quality.

5. Describe watershed areas and issues that should be the focus for action, including habitat restoration / protection opportunities.

The condition evaluation process links summaries from each assessment component to the fish distribution and Channel Habitat Type (CHT) information. The final products will include a table summarizing key findings from each of the manual components and a map showing the distribution of factors limiting productive aquatic habitat, fish populations, and water quality. Appendix X-B provides an example of products from a completed watershed conditions evaluation.

The watershed condition evaluation process will help the watershed council understand how past and current resource management and land uses are impacting aquatic resources. This process will conclude with a list of general issues and specific areas in the watershed that should be priorities for action, including protecting key areas and restoring areas of degraded habitat. For example, actions that will protect existing healthy fish populations or high-quality habitat will typically be ranked as a higher priority than activities to restore degraded habitats in other portions of the watershed.

Critical Questions

1. What are the information and data gaps identified in the assessment process?

2. What were the historical conditions of the aquatic–riparian areas within the watershed?

3. What are the historical changes (legacies), and land uses and resource management trends, that have contributed to impacts in habitat quality, and fish presence and abundance?

4. What ongoing resource management / land use activities are contributing to continued impacts on the watershed resources?

5. What are important issues and key aquatic–riparian areas that need to be addressed to restore and protect watershed resources?

Assumptions

- The cumulative effects of human activities across the watershed and through time have had an impact on the aquatic habitat, fish populations, and water quality (see What Are Cumulative Effects? sidebar, below).

Materials Needed

- Project Base Map or Mylar overlay the size of the Base Map (from Start-Up and Identification of Watershed Issues component)

- Sharp pencil, colored pencils, thin permanent markers (optional: colored adhesive dots)

- The summary tables and maps from the assessment components

Necessary Skills

Evaluating the condition of a watershed is not an easy or straightforward process. It will take time to review and understand the products from each assessment component. It takes careful consideration to integrate the assessment results and determine how resource use through time is interacting with watershed processes. It is important to keep in mind that there is no easy way to complete this evaluation and it will, at times, be difficult to interpret the results. Watersheds are complicated systems, and you can never fully understand how all of the processes and management activities will interact. This complexity makes it important to involve a wide range of perspectives when evaluating the conditions in a watershed. In addition to all of the analysts directly responsible for the assessment components, the project manager should include in the evaluation process a range of key individuals, including watershed council representatives, landowners, and resource management personnel. **It is recommended that technical specialists who have expertise in each of the assessment components review the assessment results and the watershed condition evaluation.**

WHAT ARE CUMULATIVE EFFECTS?

Cumulative effects can be defined as the changes to the environment caused by the interaction of natural ecosystem processes with the impacts of human activities, distributed across the watershed and through time. According to this definition, individual actions that are relatively minor in isolation may disrupt the function of the watershed when coupled with other impacts depending on where and when they occur.

This assessment addresses the location of human activities through a mapping process. The map products illustrate the relationship between factors limiting productive habitat/water quality and the CHTs. The assessment addresses how the watershed has been affected by changes through time by identifying and mapping the following: (1) historical activities that may have resulted in ongoing channel habitat modification (for example, splash dams and channelization), and (2) current activities that limit productive fish populations or habitat (for example, riparian management that is resulting in reduced wood inputs to stream channels).

Final Products of the Watershed Condition Evaluation

- Summary of data and missing assessment pieces (Form CE-1)
- A table summarizing important assessment results, and recommended further assessment or monitoring needs for each subwatershed (Form CE-2)
- A map showing resource condition and management/land use impacts associated with fish use and CHTs
- A table describing key issues for each subwatershed, and listing recommended restoration actions and monitoring needs (Form CE-3)
- A map depicting the locations of recommended restoration actions

METHODS

The watershed condition evaluation is completed with the steps illustrated in Figure 1. The final evaluation focuses on summarizing the key historical and current factors that influence fish habitat and water quality. This information is used, in consultation with key stakeholders in the watershed, to identify opportunities for habitat protection and restoration.

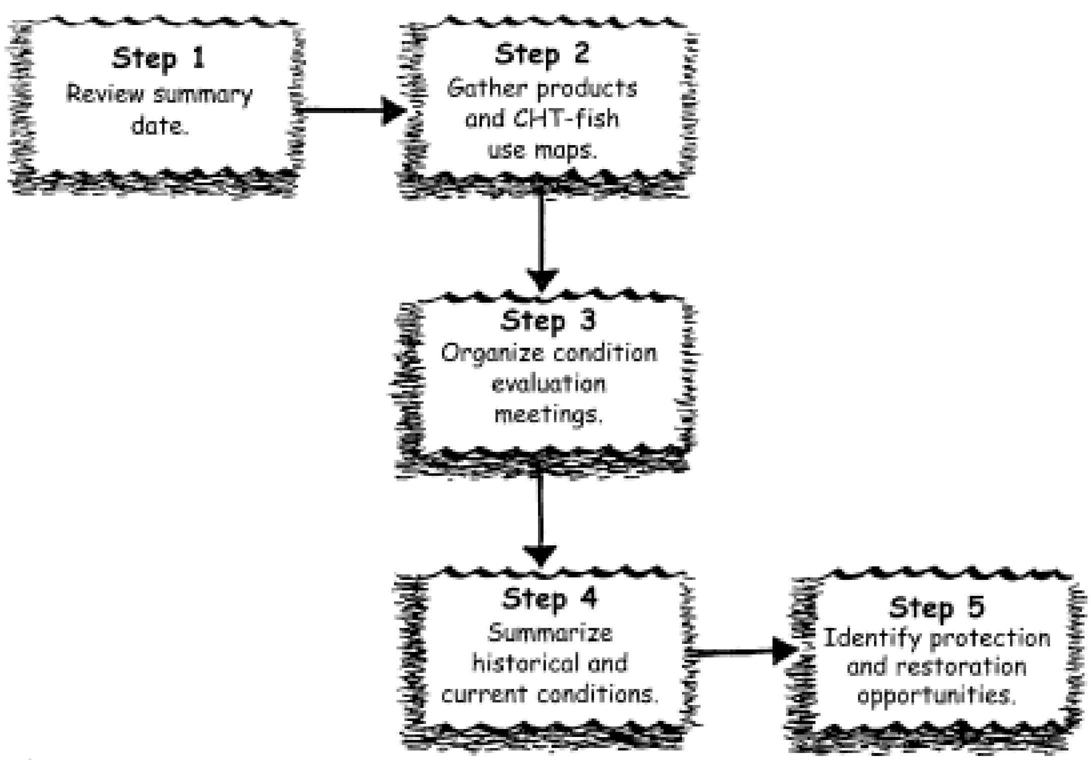


Figure 1. This flow chart illustrates the steps used to complete the watershed condition evaluation, which focuses on summarizing the key historical and current factors that influence fish habitat and water quality.

Step 1: Review Summary Data and Identify Missing Pieces

The project manager will be responsible for compiling and reviewing all of the assessment information. Form CE-1 (Appendix X-A) lists the summary products from each assessment component, which are necessary to complete the watershed condition evaluation. Check that each form from the assessment has been completely filled out, and then check off the form in the checklist. If there are notes on any of the forms, be sure to read these and determine if there are any problems or circumstances that need to be considered in this overall evaluation. Pay special attention to the Confidence Evaluation forms—these should identify data gaps, additional information that may be collected, and recommended monitoring. Information gaps and recommendations for further analysis/monitoring will be summarized and used in the Monitoring Plan component. Complete Form CE-2, which summarizes the assessment results, data gaps, and monitoring recommendations. This information will help you develop a monitoring plan.

Step 2: Gather Assessment Products and Produce Channel Habitat–Fish Use Map

The completed assessment provides two types of information that will be used to evaluate the condition of the watershed. Sort out the information gathered from the assessment components into these two categories:

1. A *characterization* of resources and human uses that describes the watershed, how it functions, asnd how it has changed through time.

2. An *assessment* of the current status of important watershed resources.

The characterization and assessment products are as follows:

Characterization Products

- Watershed Setting—ecoregion information
- Watershed Description—land uses, tributaries, stream miles, watershed hydrology
- Channel Habitat Types and Distribution
- Historical Characterization
- Channel Modification Map
- Location of Wetlands
- Fish Distribution
- Road Network
- Landslide Maps

Assessment Products (listed on Form CE-1)

- Channel Modification—degree of impact interpretation
- Riparian Conditions
- Fisheries Habitat Data Summaries
- Fish Migration Barriers
- Water Quality Status
- Water Use Impacts
- Land Use Impacts on Hydrology
- Sediment Sources

It is important to come to the watershed condition evaluation meeting with all of the results from the assessment components, including summary tables and maps. Maps will help illustrate the issues in the watershed and show where possible impacts may be associated with areas of fish use and important aquatic–riparian habitat.

To provide an overview of channel habitat and fish use associations, combine the information from the Channel Habitat Type and Fish Use Distribution maps on the Base Map. This "Channel Habitat–Fish Use Map" will provide the base for mapping issues that are impacting fish habitat/water quality, and will show proposed watershed action opportunities.

Step 3: Organize Watershed Condition Evaluation Meetings

The assessment information and maps will be used to summarize the condition of the watershed. The final evaluation of the watershed's condition should be done through extensive consultation with key stakeholders, including all of the individuals responsible for the assessment, council members, landowners, resource managers, and government agency personnel. It is suggested that the assessment team organize a meeting (or series of meetings) at which the assessment results can be discussed. These meetings provide an interactive opportunity for analysts to tell what they learned about the watershed, for them to ask questions of each other, and for others who live and work in the watershed to provide their insights. These meetings will take one to several days; be sure to keep the meeting format informal and allow plenty of time for discussion.

Step 4: Summarize Historical and Current Watershed Conditions

The condition evaluation meetings will provide the information to fill out Form CE-2. This table is used to concisely summarize the results from each assessment component, including information gaps that will require further assessment or monitoring. You should make copies of this form and fill it out for each subwatershed; in this way you will obtain information on how one subwatershed differs from other subwatersheds in the entire watershed. The form includes the questions from each assessment component to help guide the discussions and highlight areas that should be summarized.

The questions on Form CE-2 provide guidance on issues that should be placed on the Channel Habitat–Fish Use Map. The condition evaluation meetings will provide a forum for participants to discuss and map historical resource management and land use issues that are impacting aquatic–riparian habitat, fish populations, and water quality. Placing these impacts on the Channel Habitat

Type–Fish Use Map provides an overview of where and how activities through time may be limiting habitat quality, fish productivity and ranges, and the maintenance of water quality.

The watershed condition evaluation process will provide information that will characterize conditions that are not conducive to supporting native fish and the maintenance of water quality. It is important to examine the different subwatersheds to identify the range of issues. For example, some subwatersheds will have limited fish use and water quality, while other subwatersheds will support a high diversity of fish species and high water quality. While it is important to examine all areas in the watershed, special emphasis should be placed on stream channels that are responsive to inputs of sediment and wood (See the Channel Habitat Type Classification component). For example, low-gradient stream channels with floodplains provide critical habitat for salmonids; these habitats are sensitive to watershed-wide disturbance.

Step 5: Identify Watershed Protection and Restoration Opportunities

The summarized watershed conditions are used to identify issues and areas in the watershed that should be priorities for action. By using the guidance outlined below, you will be able to place the watershed condition evaluation results into three groupings:

1. Areas with relatively high-quality aquatic–riparian habitat, fish populations, or water quality conditions

2. Areas with low-quality aquatic–riparian habitat, limitations on fish presence or production, or water quality concerns; the impacts and sources are identified

3. Areas where the aquatic–riparian condition, fish populations, or water quality cannot be accurately determined and/or the links to impacts are not clear

All of this information can be used in the development of a watershed action plan that describes how your council will address issues identified in the assessment. The following guidance provides a framework that can help you plan for watershed restoration actions. The assessment results will give you an idea of the issues that are important in your watershed and general areas in which to focus projects. Implementing watershed protection or restoration projects will require more detailed evaluation, usually involving field investigations.

Action Opportunity 1

Protect stream reaches that are in relatively good condition.

Protecting aquatic–riparian habitat that is supporting good habitat, healthy fish populations, and has good water quality is an excellent strategy. It is usually much more efficient and less costly to protect an area that is functioning in a healthy way than it is to restore conditions once they have been degraded. Protection of watershed resources can be accomplished through many different approaches, including encouraging good stewardship of private lands. Other methods that watershed councils have employed to protect high-quality habitat include conservation easements and land acquisitions.

Determining what portions of the watershed warrant protection is based on a synthesis of information on water quality, fish populations, and channel habitat condition, and requires answering a number of questions. Is the area of interest:

1. Meeting or exceeding water quality standards?
2. Supporting healthy populations of native fish?
3. Characterized by high-quality channel and/or riparian habitat?
4. Protected by existing planning or regulatory requirements?

Action Opportunity 2

Restore stream reaches with habitat or fish populations that are currently in degraded condition but have the potential to support high-quality habitat and fish populations.

This category provides a working list of stream reaches for which passive and active restoration should be considered. Passive restoration involves stopping an action that is contributing to limited fish populations (such as using culverts that do not support fish passage) or poor channel habitat, or is linked to water quality problems. An example of a passive restoration strategy is limiting grazing in a riparian area where there are obvious impacts on the vegetation and the stream reach has elevated water temperatures. Over time, with the removal or reduction of grazing, the riparian vegetation should recover. Active restoration involves manipulating or modifying stream or riparian habitat. An example of an active restoration strategy is planting riparian trees to increase shade and placing logs in the channel to improve habitat complexity.

Determining the type of restoration project for each watershed location requires answering some key questions:

1. Where is the location of the stream reach with fish population limitations, or degraded habitat or water quality?

   Information on the location should include important data for interpreting the potential quality of the site, such as CHT.

2. What is the habitat or water quality issue for the reach?

   Issues can include, for example, one or a combination of factors, such as high-quality fish habitat that is blocked by barriers, high water temperatures, limited wood in the channel, limited riparian shade, excessive sediment, and others.

3. What are the factors that are contributing to degraded habitat or water quality?

   Factors can include, for example, culverts, streamside roads, vegetative removal, urbanization, and others. It is important to note whether the issue contributing to the impact is adjacent to the area, upstream (for example, water pollution contributed by a source several miles upstream), or up the hill slope (for example, a road that is contributing excessive sediment to the stream).

4. What is the best strategy for addressing the factors that are contributing to the problem?

For example, the restoration strategy should evaluate whether to pursue passive or active restoration, or some combination of the two. Whether to adopt a passive or active restoration approach requires that you think about the rates of recovery for the system. For example, a riparian area impacted by grazing may recover in a decade, while a stream channel that has lost boulders from log drives and blasting will probably take centuries to recover habitat-forming structures. There will be conditions (e.g., some urban situations) in which the factors contributing to the problem are so severe and pervasive (e.g., extensive pavement of riparian areas) that restoration should not be pursued in that area, especially if there are other opportunities for restoration in the watershed.

Action Opportunity 3

Survey stream reaches where there is insufficient data to assess stream habitat quality or fish population status.

It is important to identify those areas where more investigation is necessary to provide a clear picture of fish population limitations, habitat conditions, or water quality for a stream reach. Additional information should be collected for those stream reaches where conditions are known but the factors contributing to the problem are not. For example, information should be collected for those stream reaches that have potentially high-quality habitat (for example, low-gradient, unconstrained reaches) but where there are no data on fish populations and/or habitat quality.

Identifying portions of the watershed with limited information can help in developing a plan for implementing monitoring projects and field assessments.

Step 6: List Action Issues and Map Watershed Protection and Restoration Opportunities

The information from Step 5 should be used—in consultation with technical specialists, the watershed council, and key stakeholders—to help guide the initial listing of issues and restoration action opportunities for your watershed. Use Form CE-3, Identification of Watershed Issues and Action Opportunities, to describe watershed issues and list protection and restoration needs for each subwatershed. The form also includes space for listing areas that require field monitoring or assessment in order to gage aquatic–riparian habitat quality, fish populations, or water quality. Appendix X-B contains examples of completed forms describing watershed issues and action opportunities.

Use the following guidance when filling out Form CE-3.

Subwatershed: Name of the subwatershed.

Location: Describe the location of the area or steam segment that is the focus of the summary.

Map symbol: It is important to locate and draw the action opportunity area on a base map for the watershed. This map will provide a general overview of action opportunities in the watershed and can be used for guiding the field investigations that are necessary for developing the detailed project plan.

Channel Habitat Type: If appropriate, list the Channel Habitat Type (or types) for the stream area summarized in the form.

Stream size: If appropriate, list the stream size (or sizes) for the stream area summarized in the form.

Fish use: If appropriate, list the resident and anadromous fish use for the stream area summarized in the form.

Summary: In one sentence, concisely summarize the watershed issue or opportunity.

Habitat / water quality concerns: Concisely describe the issues and concerns for the area or stream reach summarized by the table. Describe all of the relevant factors, such as resource management over time, characteristics of the hydrology, erosion and sediment sources and impacts, floodplain and riparian conditions, historical fish use, fish passage issues, channel habitat quality, water quantity, water quality, and others.

Contributing factors: List the factor (or factors) that are limiting fish production, aquatic / riparian habitat, or the maintenance of water quality. If the factors are not known, list "unknown," which will provide guidance for further investigation.

Recommendation: Describe any recommended actions that will address the factors limiting fish production, aquatic–riparian habitat, or the maintenance of water quality. If there is insufficient information to make a recommendation on a protection or restoration approach, then describe the need for further investigation.

Monitoring / assessment needs: Describe any field monitoring or assessment work that should be completed to understand the nature of the issue or contributing factors. This information will be used to plan field investigations necessary to guide detailed project planning, or to provide background information that will be used in the Monitoring Plan component.

REFERENCES

Anonymous. 1998. Oregon Aquatic Habitat Restoration and Enhancement Guide. Oregon State Government, Salem.

Kauffman, J.B., R.L. Beschta, N. Otting, and D. Lytjen. 1997. An Ecological Perspective of Riparian and Stream Restoration in the Western United States. Fisheries 22(5):12-24.

Federal Interagency Stream Restoration Working Group. 1999. Stream Corridor Restoration: Principals, Processes, and Practices. USDA, Natural Resources Conservation Service, Washington, DC Pacific Rivers Council. 1996. A Guide to the Restoration of Watersheds and Native Fish in the West. 2nd edition. Pacific Rivers Council, Eugene, Oregon.

Williams, J.E., C.A. Wood, and M.P. Dombeck, editors. 1997. Watershed Restoration: Principles and Practices. American Fisheries Society, Bethesda, Maryland.

Appendix X-A
Blank Forms

Form CE-1: Checklist of Assessment Component Summary Products

Form/ Map	Title	√
Historic Conditions		
	Historical Condition Report	
CHT Classification		
Form CHT-1	Channel Habitat Type Field Verification	
Form CHT-2	CHT Summary Sheet	
Form CHT-3	Confidence Evaluation for the CHT Classification	
Map CHT-1	Channel Segments	
Map CHT-1	Preliminary Channel Habitat Types	
Map CHT-1	Final Channel Habitat Types	
Hydrology and Water Use		
Form H-1	General Watershed Characteristics	
Form H-2	Land Use Summary	
Form H-3	Annual Peak Flow Summary	
Form H-4	Forestry Worksheet	
Form H-5	Agriculture and Range Land Worksheet	
Form H-6	Forest and Rural Road Worksheet	
Form H-7	Urban and Rural Residential Worksheet	
Form H-8	Hydrologic Issue Identification Summary	
Map H-1	Potential Risks of Land Use on Hydrology	
Form WU-1	Water Rights Summary	
Form WU-2	Water Availability Summary	
Form WU-3	Consumptive Use Summary	
Map WU-1	Water Rights and In-Stream Flow Rights	
Form HW-1	Confidence Evaluation for Hydrology and Water Use	
Riparian/Wetland Conditions		
Form R-1	Riparian Condition Unit Information: This will be most helpful at this point of the process if it is in a spreadsheet format that can be queried as the team develops the Watershed Condition Evaluation Summary.	
Form R-2	Riparian Recruitment Situation Description	
Form R-3	Confidence Evaluation for Riparian Conditions	
Map R-1	Riparian Condition Unit map	
Map R-2	Riparian Recruitment Situations Map	
Map R-3	Riparian Shade Map	
Form W-1	Wetland Attributes	
Form W-2	Confidence Evaluation for Wetlands Assessment	
Form W-3	Wetland Functions Table (optional)	
Map W-1	Wetland Locations	
Sediment Sources*		
Form S-1	Screen or Sediment Topic Sources in a Watershed	
Form S-2	Information on Existing Road-Related Instability	

* Review the sediment source screen to determine which potential sources were evaluated in the sediment source assessment; also obtain the associated maps.

Form CE-1: page 2.

Form/ Map	Title	√
Sediment Sources* (continued)		
Form S-3	Culvert Capacity and Risk for Large Amounts of Sediment Entering Stream	
Form S-4	High-Risk Road Segments for Existing Roads	
Form S-5	Summary of Information on Road Instability	
Form S-6	Current Landslides Not Related to Roads	
Form S-7	Potential for Debris Flows	
Form S-8	Summary of Information on Slope Instability (not related to roads)	
Form S-9	Basic Information on Road Segments Close to Streams With Steep Slopes	
Form S-10	Summarized Runoff-Related Information for a Single Road	
Form S-11	Summary of Information on Road Runoff - Basic Assessment	
Form S-12	Information on Urban Runoff Polygons	
Form S-13	Database for Tracking Field Observations and Mapped Information on Crop Land and Range Land	
Form S-14	Summary of Crop Land and/or Range Land, Grazing Erosion Observations	
Form S-15	Database for Tracking Field Observations and Mapped Information on Burned Areas	
Form S-16	Summary Of Areal Extent Of Erosion Classes Within Burns	
Form S-17	Confidence Evaluation for Sediment Sources Assessment	
Channel Modification		
Form CM-1	Channel Modification Inventory Form	
Form CM-2	Channel Modification Summary	
Form CM-3	Confidence Evaluation for Channel Modification Assessment	
Map CM- 1	Channel Modification Map (showing current and historic modifications)	
Water Quality		
Form WQ-1	Beneficial Uses and Water Quality Issues	
Form WQ-2	Summary of Percent Exceedance Criteria	
Form WQ-3	Summary of Water Quality Impairment	
Form WQ-4	Confidence Evaluation for Water Quality Assessment	
Fish and Fish Habitat		
Form F-1	Fisheries Information Summary	
Form F-2	Habitat Condition Summary	
Form F-3	Fish Passage Summary	
Form F-4	Confidence Evaluation Form for Fisheries Assessment	
Map F-1a	Resident Fish Distribution	
Map F-1b	Anadromous Fish Distribution	
Map F- 2	Migration Barrier Identification Map	

Form CE-2: Summary of Key Findings by Assessment Component

Watershed: **Page _____of_____**

Analyst's Name: **Date:**

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Historical Conditions • What were the characteristics of the watershed's resources at the time of European exploration/settlement? • What are the historical trends and locations of land use and other management impacts in the watershed? • What are the historical accounts of fish populations and distribution? • Where are the locations of historic floodplain, riparian area, channel, and wetland modifications, and what was the type and extent of the disturbance?			

Form CE-2: page 2.

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Channel Habitat Type Classification • What is the distribution of CHTs throughout the watershed? • What is the location of CHTs that are likely to provide specific aquatic habitat features, as well as those areas which may be the most sensitive to changes in watershed condition?			

Form CE-2: page 3.

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Hydrology and Water Use • What land uses are present in your watershed? • What is the flood history in your watershed? • Is there a probability that land uses in the basin have a significant effect on peak flows? • Is there a probability that land uses in the basin have a significant effect on low flows? For what beneficial use is water primarily used in your watershed? • Is water derived from a groundwater or surface-water source? • What type of storage has been constructed in the basin? • Are there any withdrawals of water for use in another basin (interbasin transfers)? Is any water being imported for use in the basin? • Are there any illegal uses of water occurring in the basin? • Do water uses in the basin have an effect on peak flows? • Do water uses in the basin have an effect on low flows?			

Form CE-2: page 4.

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Riparian/Wetlands • What are the current conditions of riparian areas in the watershed? • How do the current conditions compare to those potentially present or typically present for this ecoregion? • How can the current riparian areas be grouped within the watershed to increase our understanding of what areas need protection and what the appropriate restoration/enhancement opportunities might be? • Where are the wetlands in this watershed? • What are the general characteristics of wetlands within the watershed? • What opportunities exist to restore wetlands in the watershed?			

Form CE-2: page 5.

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Sediment Sources • What are important current sediment sources in the watershed? • What are important future sources of sediment in the watershed? • Where are erosion problems most severe and qualify as high priority for remedying conditions in the watershed?			

Form CE-2: page 6.

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Channel Modification • Where are channel modifications located? • Where are historic channel disturbances, such as dam failures, splash damming, hydraulic mining, and stream cleaning, located? • What CHTs have been impacted by channel modification? • What are the types and relative magnitude of past and current channel modifications?			

Form CE-2: page 7.

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Water Quality • What are the designated beneficial uses of water for the stream segment? • What are the water quality criteria that apply to the stream reaches? • Are the stream reaches identified as water quality limited segments on the 303(d) list by state? • Are any stream reaches identified as high-quality waters of Outstanding Resource Waters? • Do water quality studies or evaluations indicate that water quality has been degraded or is limiting the beneficial uses?			

Form CE-2: page 8.

Assessment Component Questions	Summary of Key Findings (impacts/changes in ecosystem, processes affecting habitat quality/quantity, fish populations, water quality)	Missing or Incomplete Information	Locations of Impacts Currently Constraining Habitat, Populations, or Water Quality (add locations to map)
Fish and Fish Habitat • What fish species are documented in the watershed? Are any of these currently state- or federally listed as endangered or candidate species? Are there any fish species that historically occurred in the watershed which no longer occur in the watershed? • What is the distribution, relative abundance, and population status of salmonid species in the watershed? • Which salmonid species are native to the watershed, and which have been introduced to the watershed? • Are there potential interactions between native and introduced species? • What is the condition of fish habitat in the watershed (by sub-basin) according to existing habitat data? • Where are potential barriers to fish migration?			

Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: **Page ____of_____**

Analyst's Name: **Date:**

Subwatershed:	
Location:	
Map symbol:	
Channel habitat type:	
Stream size:	
Fish use:	
Summary	
Habitat/water quality concerns	
Contributing factors	
Field observations	
Recommendation	
Monitoring/ assessment needs	

Appendix X-B
Examples of Watershed Issues and Action Opportunities

EXAMPLES OF WATERSHED ISSUES AND ACTION OPPORTUNITIES

The Big River watershed is a 60,000-acre watershed characterized by forest management in the headwaters and agricultural land uses along the river and the lower tributary valleys. The valley areas along Big River and most of the larger tributaries were cleared of trees in the 1880s when the area was homesteaded. There is one small town, Elk City, in the upper portion of Big River and some growing suburban developments in the lower watershed. Most of the stream channels start in steep headwater areas, with the tributary streams occupying low-gradient narrow valleys with limited floodplain development. Anadromous fish use in the watershed includes chinook salmon in the Big River and lower tributaries, coho salmon, and steelhead trout in most of the larger tributaries. Resident fish include rainbow and cutthroat trout.

Figure X-1 (page 2) is a map illustrating the Big River watershed, including subwatersheds, channel habitat types, and example stream segments used to illustrate watershed issues and opportunities (see the Example Form CE-3).

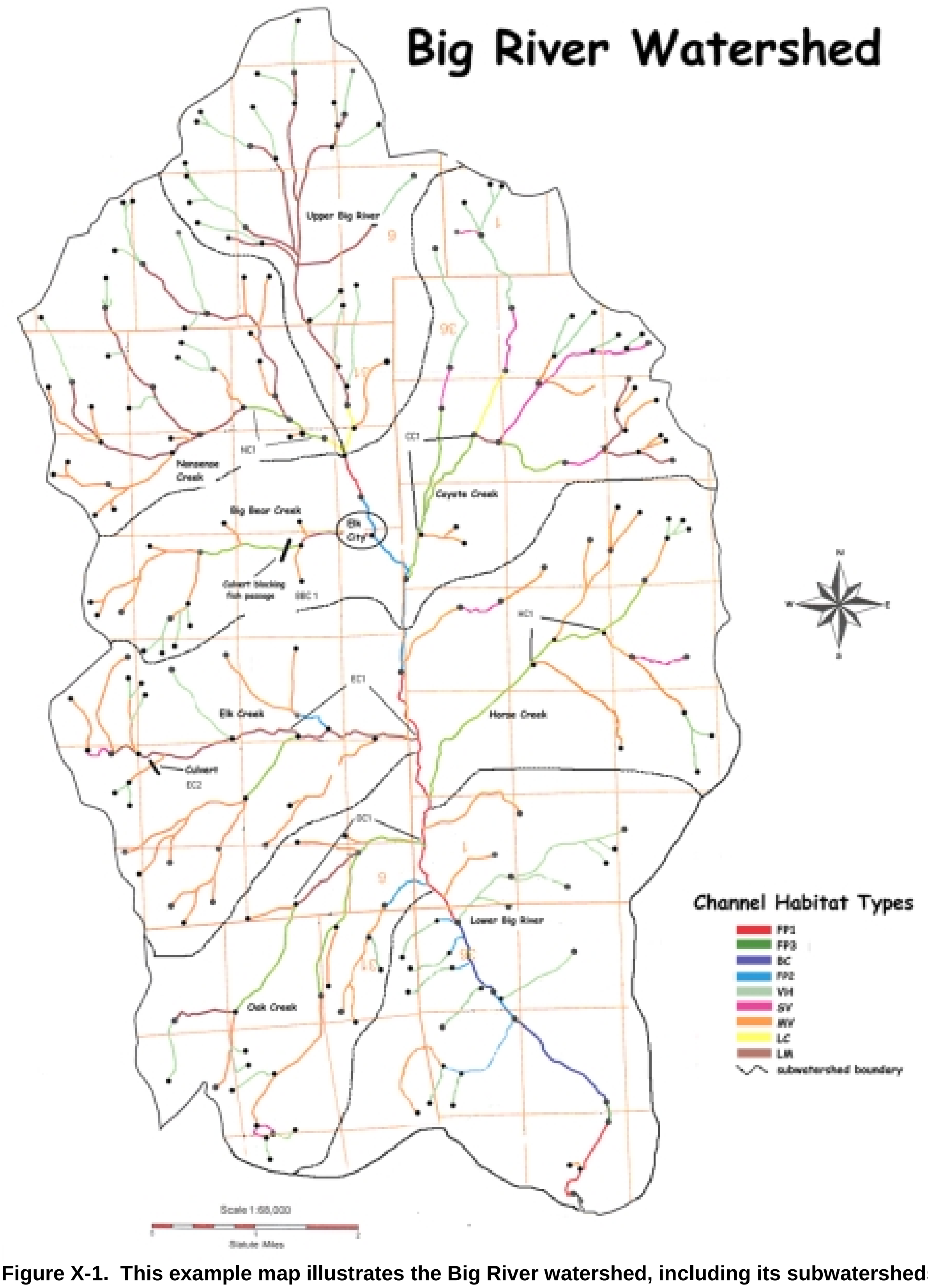


Figure X-1. This example map illustrates the Big River watershed, including its subwatersheds and CHTs. Example stream segments show watershed issues and opportunities.

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 1 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Elk Creek***
Location:	Cedar Creek upstream from FS road 1292
Map symbol:	EC2
Channel habitat type:	MV: Moderately steep narrow valley channel
Stream size:	Small
Fish use:	Cutthroat trout
Summary	Impassable culvert is preventing upstream movement of cutthroat trout.
Habitat/water quality concerns	The culvert has a 3-foot drop onto bedrock with no jump pool. It appears that fish cannot move upstream, although there is a population (perhaps isolated) of cutthroat trout above the culvert. The stream above the culvert has about 0.25 miles of marginal fish habitat (shallow pools, little wood) and then the gradient of the stream increases to 10 percent and fish use ends. The culvert appears to be adequately sized to pass peak flows.
Contributing factors	Culvert on FS Road 1292 is a fish passage barrier.
Field observations	Culvert information, including fish habitat data above and below, were collected by a forest service crew on Aug. 23, 1996. The upper-extent fish use information was collected by an ODFW crew on May 2, 1997.
Recommendation	Because there is very little fish habitat above this culvert, this is not a high priority for council action at this time. The council should encourage the landowner to replace the culvert next time there is forest management in the area.
Monitoring/ assessment needs	None

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 2 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Big Bear Creek***
Location:	Upstream from county road 33
Map symbol:	BBC1
Channel habitat type:	FP3: Low gradient small floodplain, unconfined channel
Stream size:	Medium
Fish use:	Cutthroat trout and sculpin, potential coho
Summary	Impassable culvert is preventing passage of coho salmon into this section of stream.
Habitat/water quality concerns	The culvert has a 3 foot drop onto bedrock with no jump pool. It appears that fish cannot move upstream, although there is a population (perhaps isolated) of cutthroat trout above the culvert. The stream above the culvert has about 0.25 miles of marginal fish habitat (shallow pools, little wood) and then the gradient of the stream increases to 10 percent and fish use ends. The culvert appears to not be adequately sized to pass peak flows.
Contributing factors	Impassable culvert on county road 33 at mile post 14.
Field observations	Culvert information, including fish habitat data above and below, were collected by a county crew on Sept. 10, 1997.
Recommendation	Consider consulting with agency personnel to replace this culvert with a bridge or another culvert that is appropriate for peak flows and fish passage.
Monitoring/ assessment needs	If possible, monitor fish passage after the culvert is replaced.

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 3 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Elk Creek***
Location:	Lower 2 miles
Map symbol:	EC1
Channel habitat type:	LM: low gradient moderately confined channel
Stream size:	Large–medium
Fish use:	Steelhead and rainbow trout
Summary	Large amounts of sediment have been deposited on the channel bottom throughout this section.
Habitat/water quality concerns	Elk Creek passes through farms for the first mile and then drains private forest lands. In comparison to similar streams in this area, there appears to be large amounts of fine sediments deposited on the channel bottom, sometimes filling up shallow pools. Historically, this was a very productive steelhead stream, with population counts decreasing dramatically over the last 10 years. This section of stream has fair fish habitat, though somewhat entrenched. It is not known where the sediments are coming from; the increase in sediments has been noted to corresponded to the increased truck traffic over the last two years. There may be increased turbidity associated with the sedimentation.
Contributing factors	Not know at this time, although road-related sediment is suspected.
Field observations	Sediment deposits were noted in the 1997 ODFW stream habitat survey.
Recommendation	Assess the roads in the area to determine if they are contributing fine sediments.
Monitoring/ assessment needs	Monitor turbidity levels, especially during wet-weather truck traffic on the roads. Assess roads for delivery of sediment. (*See turbidity parameter in Appendix XI-A, Component XI.*)

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 4 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Oak Creek***
Location:	Lower 2 miles
Map symbol:	OC1
Channel habitat type:	LM-FP3: low gradient moderately confined, and small floodplain, unconfined
Stream size:	Large–medium
Fish use:	Cutthroat trout and juvenile chinook salmon rearing
Summary	Land uses in the area contribute to lack of wood in the channel and increases in peak flows, which is resulting in channel entrenchment.
Habitat/water quality concerns	This section of Oak Creek passes through a suburban area, with many homes bordering the stream. Channel simplification due to the channel incision caused by the various land uses (suburban along the stream and urban in the tributaries) and lack of wood in the channel have resulted in this section being very sensitive to increases in peak flows. The channel cannot dissipate stream flow energy during storms, resulting in further confinement of the channel. Historically, this channel was moderately confined. Planned housing developments in the watershed will result in further increases in peak flows more removal of riparian vegetation.
Contributing factors	Lack of wood in the channel due to removal of riparian trees and increases in peak flows resulting in channel incision.
Field observations	Channel entrenchment, stream wood counts, and riparian vegetation noted in 1998 student survey.
Recommendation	Work with the city to control future storm water discharges; identify areas for riparian improvement projects.
Monitoring/ assessment needs	None

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 5 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Coyote Creek***
Location:	Lower 1.5 miles
Map symbol:	CC1
Channel habitat type:	FP3: Low gradient small floodplain, unconfined channel
Stream size:	Large–medium
Fish use:	Coho salmon, cutthroat and steelhead trout
Summary	There is very little information on the habitat quality and fish use for this stream section.
Habitat/water quality concerns	According to 1939 Fish Commission reports, Coyote Creek supported large numbers of spawning coho salmon and some steelhead. There are no recent surveys of stream habitat or fish use in this stream. The assessment information, based on maps and aerial photographs, appears to indicate the potential for high-quality fish and wildlife habitat: low-gradient channel, with a small floodplain and some large riparian conifers. This area was recently proposed for a recreational development, including building small cabins in potential floodplain habitat.
Contributing factors	No information.
Field observations	There are no recent fish or habitat surveys of the area. Floyd Jones, a landowner on Big Bottom Creek, said that he saw spawning coho in this section of the stream in 1997.
Recommendation	This area should be a high priority for field assessments of habitat quality and fish use.
Monitoring/ assessment needs	Assess channel and riparian habitat using ODFW protocols. Determine the upper extent of fish use and conduct snorkel surveys to assess use by salmonids, including juvenile coho and steelhead.

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 6 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Big River***
Location:	Lower 10 miles between the mouth and Elk City
Map symbol:	Red line along lower Big River
Channel habitat type:	Variable
Stream size:	Large
Fish use:	Cutthroat trout, rainbow trout, steelhead, coho and chinook salmon
Summary	There are indications that of *E. coli* bacteria levels may exceed state standards.
Habitat/water quality concerns	During a rainstorm in 1996, the high school collected water quality grab samples from Big River at the mouth and just above Elk City. All of the water quality parameters were normal with the exception of *E. coli* bacteria. The *E. coli* counts were 30/100 ml above Elk City and 800/100 ml at the mouth. No other samples have been collected. The land uses in the watershed, especially below Elk City, are primarily farms and pastures with livestock. There are increasing numbers of homes and hobby farms. A recent Council of Government study found that the soils in the lower watershed have a high potential for septic tank failure and recommended limits on new septic tanks.
Contributing factors	Not determined at this time, although a combination of septic tanks and farm animals may contribute to the increased *E. coli* counts.
Field observations	The only known *E. coli* samples were collected in 1996.
Recommendation	Monitor *E. coli* counts and assess possible causal factors such as leaky septic tanks and/or contributions from livestock.
Monitoring/ assessment needs	Using DEQ protocols, monitor *E. coli* counts during rain events at a range of sites along Big River and at key tributaries to assess major source areas. (*See E. coli parameter in Appendix XI-A, Component XI.*)

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 7 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Horse Creek***
Location:	The 1-mile section between Fly Creek and Knot Creek
Map symbol:	HC1
Channel habitat type:	FP3: Low gradient small floodplain, unconfined channel
Stream size:	Medium
Fish use:	Cutthroat trout and coho salmon
Summary	This section, which has the potential for high quality habitat, lacks habitat complexity, especially wood in the channel.
Habitat/water quality concerns	Horse Creek supports relatively large numbers of spawning coho salmon, with most of the production in the upper watershed on Forest Service land. Historically (based on a 1939 Fish Commission survey), this section of the stream had good habitat, with a low-gradient channel, abundant side-channels, and large amounts of wood in the stream. Wood was removed from this section of channel in repeated operations between 1946 to 1972. Aerial photos from this period show that almost all of the trees along the stream were removed, which limited recruitment of wood to the stream. Information from recent habitat surveys in this section show that there is very little complex habitat, with few deep pools and almost no side-channels, which limits winter rearing habitat for juvenile coho salmon. The riparian trees are mostly 25-year-old conifers, so there is little riparian vegetation improvement potential.
Contributing factors	Wood removal from the channel and little potential for short-term recruitment of large trees into the channel.
Field observations	Stream and riparian habitat information is from a 1995 ODFW survey. There are annual spawning surveys on the Forest Service land in the upper portion of the watershed.
Recommendation	Investigate, in consultation with ODFW and other agencies, the potential for placing large wood in the channel to improve habitat.
Monitoring/ assessment needs	Field assessments will be necessary to assess restoration potential.

Example Form CE-3: Identification of Watershed Issues and Action Opportunities

Watershed: Big River **Page 8 of 8**

Analyst's Name: Steve Jones **Date: 3/19/99**

Subwatershed:	***Nonsense Creek***
Location:	Lower 1.3-mile section
Map symbol:	NC1
Channel habitat type:	FP3: Low gradient small floodplain, unconfined channel
Stream size:	Large – medium
Fish use:	Cutthroat and rainbow trout
Summary	There is very little riparian vegetation along this section and high water temperatures have been observed.
Habitat/water quality concerns	This portion of Nonsense Creek flows through farm lands, with a mixture of crops and grazing. The upper watershed is forested. This stream has a good population of rainbow trout. Historical information indicates that the lower watershed was densely forested until land was cleared for homesteads in the 1880s. Information from current aerial photos and a recent stream habitat survey all indicate that there is very limited cover over the stream and few riparian trees. The stream habitat survey noted water temperatures in this section of stream as high as 72 degrees F in August. There is no other water temperature information. As far as can be determined, there is limited water removal from the stream, with most of the water rights in the lower 0.5 miles of the stream.
Contributing factors	Not determined at this time, but limited riparian cover over the stream (and possibly water removal) may be contributing to increases in water temperatures.
Field observations	Stream and riparian habitat information and water temperature data are from a 1997 ODFW survey.
Recommendation	Characterize current water temperature patterns in the watershed and assess riparian canopy cover over the stream. Assess possible grazing and other management impacts on riparian vegetation. Use this information and data on to determine the potential for riparian restoration projects with willing landowners. The riparian projects can use, where appropriate, riparian fencing and tree planting.
Monitoring/ assessment needs	Using DEQ monitoring protocol, monitor water temperatures at key locations in the watershed and assess water use patterns. *(See temperature parameter in Appendix XI-A, Component XI.)*

Component XI
Monitoring Plan

Table of Contents

Component XI
Monitoring Plan

INTRODUCTION

The primary purpose of this Monitoring component is to describe approaches for collecting information to answer questions that may arise during the watershed assessment. A second objective is to briefly discuss ways to measure success of restoration efforts that may come out of the assessment. The Monitoring component is intended to address the questions of What and Why to monitor, not to describe detailed monitoring procedures. Monitoring procedures are being developed by an interagency team of the Oregon Plan for Salmon and Watersheds (OPSW). To date, the OPSW monitoring team has completed a *Water Quality Monitoring Guidebook* (OPSW 1999). We refer the reader to this guidebook and other monitoring documents being prepared by this team for specific monitoring procedures.

This component will focus on the approach to filling data gaps discovered during the watershed assessment, because this will be the type of monitoring activity that watershed councils will most likely be involved in. The second objective of monitoring, measuring the success of restoration efforts, is discussed briefly in the sidebar, Monitoring Restoration Activities. This sidebar also briefly reviews the various types of monitoring to acquaint the reader with the terminology that is commonly encountered in monitoring guidebooks. The main portion of this component will present the following information:

1. A description of the process of cataloging data gaps identified during the watershed assessment

2. A description of the stages to follow in developing a monitoring plan

3. An outline of a written monitoring plan

4. A list of the sources of potential monitoring methods and other resources that may be used to implement the monitoring plan

The stages in developing a monitoring plan and the monitoring methods apply as well to measuring the success of restoration actions. The emphasis of this component is on linkages to more detailed procedures rather than a self-contained methods manual. Guidance on monitoring is contained in a number of good references that should be consulted when developing a monitoring program (see References section).

Necessary Skills

Developing a monitoring plan requires specific knowledge of the monitoring techniques related to that issue, data analysis, statistics, and quality assurance. Once a plan and data collection protocol are established, trained volunteers can often implement the field work (the fun part !) under the direction of professionals or agency mentors. Watershed councils should obtain help when developing a monitoring program from agency resource specialists, monitoring consultants, or university faculty.

Final Products of the Monitoring Component

The monitoring component provides linkages between the watershed assessment and monitoring programs being developed by the OPSW. An outcome of the watershed assessment is a list of information needs that are the basis for developing a watershed monitoring program. This list of needs can then be used in communications with state and federal agencies that may be able to fill these data gaps or to develop monitoring initiatives at the watershed council level. A second potential outcome of this component is the development of a monitoring plan to address specific data gaps or to evaluate the success of restoration activities.

Filling Data Gaps

Typical monitoring activities that watershed councils may use to follow up the watershed assessment are categorized as *filling data gaps.* As a part of the watershed assessment, data gaps and other information needs are identified. These information needs should be addressed before pursuing more costly restoration activities (see sidebar, Monitoring Restoration Activities). The potential mix of data-gap monitoring and field-verification activities varies for each component of the watershed assessment. Some components such as assessing riparian condition or verifying the location of wetlands are best completed using field observations. Other components, such as water quality monitoring, require collection of samples with an emphasis on standard operating procedures and quality control. Lastly, other components, such as evaluation of hydrologic impacts, cannot be readily monitored and rely on use of models that require a high degree of professional expertise.

Since the watershed assessment was primarily designed to use existing data, field studies to verify assumptions are an excellent follow-up activity to watershed assessment. Field verification is a type of follow-up activity that primarily uses visual observation with few measurements. In many cases observers can be trained by a resource professional to use standard methods and collect information that will be very useful to the watershed improvement goal. To be useful, the field verification needs to be completed using standard protocols and documentation. Potential field-verification activities are listed in Table 1 for the Channel Habitat Type Classification, Riparian/Wetlands, Sediment Sources, Channel Modification, and Fish and Fish Habitat assessment components.

Intensive monitoring activities that include collection of field samples are more costly and require more detailed planning to be successful. Monitoring activities may be undertaken for a number of purposes. Some common purposes are to: (1) evaluate the existing condition or status of the resource, (2) identify the cause-and-effect relationships, and (3) determine trends in water quality or habitat conditions in response to specific actions. The first objective is undertaken if little or no information exists about an important issue or to evaluate a series of potential causative agents at a cursory level. The second objective, cause-and-effect studies, are designed to pinpoint the major cause of an impact or geographic focus to be able to prioritize restoration. For example, it may be known that nutrients are high in a mixed land use watershed, but no specific source has been identified. A cause-and-effect study would try to identify the relative contribution from agricultural runoff from urban runoff by bracketing these land use areas with monitoring sites. The third type, trend studies, requires intensive monitoring over a long time period because of the natural change in conditions that may occur from year to year or decade to decade.

It is important to be very clear about the objective for intensive monitoring before planning data-collection efforts. The monitoring objective ultimately determines the location, duration, and frequency for sample collection. Evaluating current conditions may be accomplished by making measurements during one season, and constitutes a snapshot in time. (For an example, see Appendix VIII-A in the Water Quality component). Trying to evaluate a trend over time requires a greater level of effort and a commitment of resources over several years or decades. For these reasons, watershed councils should focus on monitoring efforts that address specific data gaps in watershed assessment rather than long-term monitoring efforts.

MONITORING RESTORATION ACTIVITIES

Once restoration actions are taken, the council will want to know if they were installed correctly (if the action involves structures) and if they are going to be successful. Monitoring methods that evaluate restoration activities have been described as *implementation* and *effectiveness monitoring*. Documents that describe monitoring methods often refer to these terms, so it will be useful to understand this terminology.

Implementation monitoring asks: **Was the management practice or restoration activity implemented properly?** This monitoring should be a part of every project and is normally performed during or shortly after restoration. Monitoring during the project can lead to mid-course corrections that save the project from failure. Implementation monitoring after the project is necessary to report the success of the restoration effort to the watershed council and the funding agency. Implementation monitoring can be as simple as counting the number of structures installed and evaluating if the structures were installed as designed. The actual monitoring activity consists of visual inspections, field notes, and photographs. For example, if improved road maintenance was the restoration action, implementation monitoring would consist of checking to see if ditches and culverts were cleaned and functional, and if cut and fill slopes were seeded, or to determine if seasonal road closures were installed in time.

Implementation monitoring is simple, and it is a cost-efficient form of monitoring. This essential part of any monitoring effort is often taken for granted: assuming that the best management practice (BMP) was undertaken and completed as planned. Before we measure the effectiveness of the restoration activity, we must ensure that the planned action was completed as designed. Although this may seem to be an obvious part of restoration, taking the time to document what was completed is easily overlooked.

Effectiveness Monitoring asks: **Were restoration actions effective in meeting the restoration objectives and in attaining the desired outcome?** This kind of monitoring is more complex than implementation monitoring because we need to connect some action with an outcome in the riparian area or stream channel. In the road maintenance example, we may want to determine if ditches and culverts plugged during a storm, if the vegetation seeded on the slope was established in time to prevent erosion, and if the road closures prevented rills on the road surface. With stream restoration projects, some actual evidence of an improved condition may not be become evident until several cycles of high flows or after many years.

Other types of monitoring that are commonly described include *validation*, *baseline*, and *trend monitoring*. *Validation monitoring* is a research level of monitoring that addresses basic scientific questions about watershed processes and will generally not be undertaken by watershed councils. *Baseline monitoring* is undertaken to establish conditions prior to management activities or in a paired watershed or reference site. Baseline monitoring in a less-disturbed drainage is important to calibrate the effects of natural disturbance such as mass wasting, floods, and fire. *Trend monitoring* tracks conditions in streams and watersheds over years and requires a long-term commitment of resources. While all types of monitoring might be used, watershed councils will likely focus on filling data gaps and on the implementation and effectiveness of restoration activities.

IDENTIFYING DATA GAPS

The first stage in developing a monitoring program is to identify the list of data gaps and prioritize the potential list of monitoring studies. The potential list of information needs is compiled from the watershed assessment and should be completed as part of the Watershed Condition Evaluation. Based on this list we might categorize the potential list of monitoring activities as field-verification activities, short-term monitoring activities, and long-term monitoring activities. The second consideration at this stage is to determine which of these activities are within the jurisdiction of other entities and should be completed by them. For example, you may want to encourage an agency to add new stations to its monitoring program, request a major landowner to take the lead in a study, or recruit the interest of a research organization at a state or federal agency. An example of a potential list of data gaps and monitoring activities is provided in Table 1.

Table 1. Examples of data gaps identified from the watershed assessment.

Manual Component	Potential Data Gaps
Channel Habitat Type Classification	Field verification of channel habitat types gradient, cross-sectional shape, or valley shape
Hydrology & Water Use	Streamflow gaging stations Land use mapping
Riparian	Field verification of recruitment condition and shade Field measure of stream shade and canopy Riparian plant communities Width of riparian areas Breaks in riparian areas and causes
Wetlands	Type, location, and size of wetlands Wetland functions and conditions Connectivity Restoration opportunities
Sediment Sources	Field verification of sources Road stability Culvert survey Erosion – crop-land areas Erosion – range conditions
Channel Modification	Field verification of channel modifications
Water Quality	Temperature and dissolved oxygen pH and heavy metals Nutrients Turbidity and suspended sediment Bacterial sources and impacts
Fisheries	Distribution of fish in the watershed Location and severity of migration barriers Condition of spawning and rearing habitat Fine-sediment impacts

Data gaps can be listed and compared to watershed issues and their influence on future actions. Follow-up monitoring activities should be prioritized on the basis of moving forward on potential restoration options. For example, temperature and riparian conditions are often a major issue in a watershed. The watershed assessment may have indicated that temperatures at the mouth of tributaries were in excess of state water quality standards. Riparian conditions based on aerial photographs indicated potential areas of insufficient shade. A 1-year intensive data-collection effort of temperature data loggers (monitoring activity) and riparian condition (field-verification observations) may answer landowners' questions about specifically where the canopy cover is insufficient and how it is affecting temperature.

DEVELOPING A MONITORING PLAN

Once the data gaps and monitoring needs are identified, a monitoring plan can be developed to answer specific questions. A written monitoring plan is a necessary tool to conduct any monitoring program. The monitoring plan is like a set of blueprints for building a new home. Once finalized, the blueprints and materials list provide the basis for a contract between the homeowner, the builder, and subcontractors to ensure that there is always a basis for clear communication. The monitoring plan performs the same function—it lays out the objectives, identifies the people and equipment needed, and describes what and where the monitoring activities will take place. Like a set of blueprints, the monitoring plan will need to go through several drafts and peer reviews before there is agreement that the plan makes sense and can be completed with the resources available.

The process that should be followed to complete a monitoring plan is illustrated in Figure 1. We refer to these as stages, because they are part of a decision process and may vary depending on the type of monitoring; they are not steps in a to-do list as described in other components. The monitoring plan should be viewed as an iterative process. The best-designed monitoring program may not work for a variety of reasons, such as access limitations, unanticipated high flows, inadequate equipment, or higher variability than anticipated. For that reason, data should be evaluated frequently and the monitoring plan revised as needed to ensure a successful project.

Stage 1: Objectives

The first stage in developing a monitoring program is to establish a clear set of objectives. These objectives start with a statement of the data gap or the question to be answered. Examples of data gaps are listed in Table 1. Examples of questions are: "Does this stream meet the Oregon Department of Environmental Quality water quality standards for temperature and dissolved oxygen?"; and "Are BMPs effective at reducing sediment inputs to the stream channel?". Data gaps and questions such as these are the beginning point for developing the set of monitoring objectives.

Once the data gap or question is identified, a helpful procedure is to briefly outline the potential study design as shown in Table 2. Briefly specify the objective, the question to be addressed, parameters to be sampled, monitoring method, study design, potential sample locations, duration, and sample frequency. This brief outline connects the objective to the other stages in developing a monitoring plan and should raise critical implementation questions. What resources are needed? What kind of expertise is needed? And specifically, what potential monitoring equipment, methods, and funding will be needed?

Three of the *Watershed Issues and Action Opportunities* discussed in the Watershed Condition Evaluation (Component X) can be used to illustrate this initial stage in developing a monitoring plan. Please refer to Appendix XI-A for an outline of these examples. The three examples address temperature, bacterial contamination, and fine-sediment sources. The temperature study is designed initially as a one-season study to evaluate where potential problem areas are and if they are related to lack of shade. The bacterial contamination study combines storm-event monitoring to locate the sources of bacteria and a 1-year-long study to evaluate the severity and duration of the bacterial contamination. The sediment source study is planned for completion in a few weeks or months by monitoring turbidity during several runoff events.

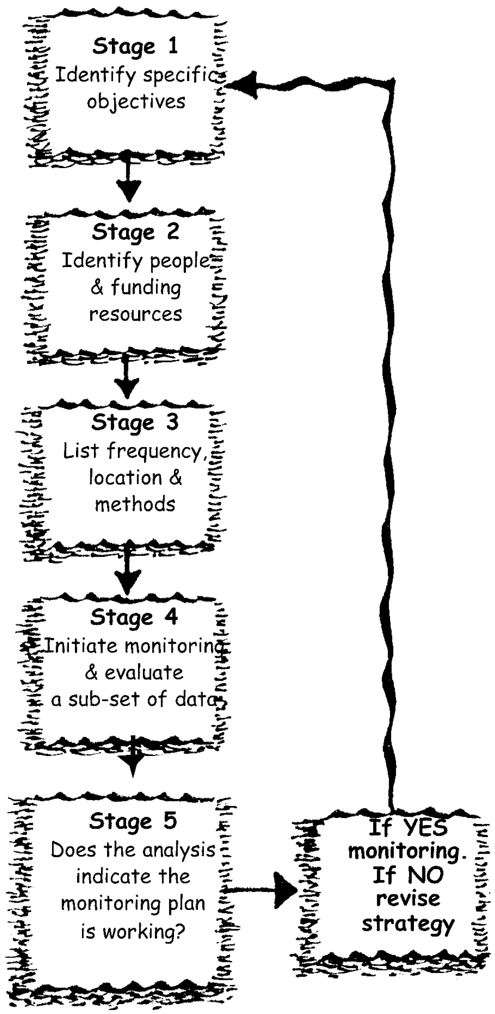


Figure 1. The process that should be followed to complete a monitoring plan is described in stages. The plan should be considered an iterative process, and the stages may vary depending on the type of monitoring.

Table 2. Example of initial monitoring strategy.

	Outline Example
Question/Data Gap	Does the stream meet state standards for temperature and dissolved oxygen?
Objective	Measure temperature and oxygen during critical seasonal periods and times during the day to detect exceedance of criteria.
Parameters	Temperature, dissolved oxygen
Methods	Continuous temperature data loggers, dissolved oxygen meter
Study Design	Upstream/downstream of major canopy openings, reference sites, etc.
Locations	Based on study design, access, vandalism.
Study Duration	At least one season
Sample Frequency	Data loggers—hourly

Stage 2: Resources

After an initial monitoring outline is completed, the next stage is to evaluate resources to carry out the project. This includes the people that are needed, the budget, the field equipment, laboratory analysis, and supplies. If the program is too ambitious, as is often the case, it is better to pare down expectations at this stage than have to deal with problems later. This is a good time to contact a monitoring specialist or mentor and determine if all the resource bases are covered.

Stage 3: Monitoring Details

Identify the specific set of parameters, the methods to be used, the sample frequency required, and the location of potential monitoring sites. This process should provide feedback on costs, equipment needs, and level of skill needed. Equipment and supplies for water quality studies such as temperature are listed in the *OPSW Water Quality Monitoring Guidebook*.

Stage 4: Pilot Project

Conduct field reconnaissance of all monitoring sites to be sure that access is secured and that conditions are safe throughout the monitoring period. It is a good idea to plan on conducting a pilot project for a short period or complete some trial runs prior to committing to a long-term monitoring program.

Stage 5: Review and Revise

Review the data collected after a short pilot period to determine if the information being collected will answer the overall monitoring objective, and that it meets the quality assurance objectives. Any bugs in the monitoring program can be worked out before more effort is expended. For temperature data loggers, for example, a standard procedure is to check the data logger against a standardized thermometer before installation in the stream.

WRITTEN MONITORING PLAN

Once you have gone through the iterative process of developing a monitoring approach, it is important to document these decisions in a written monitoring plan. The monitoring plan documents why, how, when, and where you plan to conduct the monitoring activity. You can return to the monitoring plan throughout the course of a monitoring project to help maintain consistency and provide documentation to others about your efforts. Listed in the sidebar, Monitoring Plan Components, are the topics that should be included in the monitoring plan. A more detailed description is provided in the *OPSW Water Quality Monitoring Guidebook*. Refer to this document for further details on developing the monitoring plan, selecting sites, data quality discussion, and recommendations for data storage and analysis.

MONITORING PLAN COMPONENTS

Background
This information can be summarized directly from the Watershed Condition Evaluation Assessment component. Describe the watershed and the previous studies and data available on the issue. This section, as does the rest of the monitoring plan, communicates to others about your monitoring project. The background section provides the basic context for the study and includes such facts as geology, soils, land uses, channel types, and historical context.

Problem Statement, Goals, and Objectives
Summarize the information derived from Stage 1 to document the statement of the data gap to be addressed or the question to be answered.

Site Description
The site description provides the context of the sampling sites in comparison to other sites in the watershed and provides comparability to potential reference sites in other watersheds. The site description can be based on the information from maps generated during the watershed assessment such as Channel Habitat Type, adjacent riparian condition, and elevation. Monitoring sites need to be located specifically on a topographic map so that the exact location can be described using the latitude and longitude.

Methods
The methods section describes the technical portion of the monitoring project. It documents the techniques that will be used to collect samples or field measurements, equipment and equipment calibration, what specific parameters are to be collected, and target periods. This section documents the decisions made in Stage 3 of the planning process. Quality Assurance and Quality Control (QA/QC) are essential elements of any monitoring plan. They provide you with evidence that your data is accurate and precise enough to address the questions being asked. These elements are addressed in detail in the OPSW Water Quality Monitoring Guidebook.

Data Storage and Analysis
Thinking through this section is critical early in the monitoring process so you have the support necessary to store, transport, or analyze the data. The Oregon Department of Environmental Quality has developed a data storage template that can be used to format data records (see OPSW Water Quality Monitoring Guidebook for details). Planning ahead can save time and money, and spare the agony of lost data.

Timetable and Staff Requirements
Each monitoring project will have a unique schedule of activities that must occur for it to be successful. These planning and implementation activities take time. The OPSW Water Quality Monitoring Guide contains general examples of the sequencing of stages and time requirements for a monitoring project.

MONITORING PROTOCOLS

Typical monitoring activities and methods that may be anticipated to fill data gaps identified in each section of the watershed assessment are shown in Tables 3 and 4. The potential activities cover a technical range from field verification of assumptions made in the office to running hydrologic and erosion models. This range of technical expertise reflects the complexity of natural systems and is not intended to suggest that watershed councils undertake all these activities. Natural resource professionals should guide the selection of potential monitoring activities that can be undertaken.

Some monitoring protocols have been designed for watershed volunteers. These monitoring programs are very useful in increasing involvement from the local community and in providing educational opportunities. Information from these less-specialized procedures may provide valuable information on the watershed. However, it is important to carefully evaluate what can be accomplished by a volunteer program versus what is needed to answer critical questions about the watershed. The US Environmental Protection Agency (EPA) has completed Volunteer Monitoring Guides for estuaries, lakes, and streams (EPA 1991, 1993, and 1997).

ADDITIONAL RESOURCES FOR DEVELOPING MONITORING PLANS

This watershed assessment manual cannot anticipate all the types of restoration activities that watershed councils may undertake. There are, however, some good guidance documents that provide detailed direction in developing monitoring programs for implementation and effectiveness monitoring. The article by Kershner (1998) in *Watershed Principles and Practices* provides a brief review of what is needed in a monitoring plan for restoration activities. The guidance documents by MacDonald et al. (1991) and Dissmeyer (1994) provide detailed monitoring guidelines for assessing forestry activities, and the guidance document by Bauer and Burton (1993) provides specific protocols for assessing effects of grazing management on water quality. The EPA (1997) document, *Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls*, is an excellent reference document available at no cost that addresses the development of monitoring plans, data analysis and statistics, and quality assurance procedures.

Table 3. Monitoring methods for watershed characterization and source assessment.

Manual Component	Monitoring Follow-Up	Monitoring Method
Channel Habitat Type Classification (Component III)	Field verification of CHTs	Described in Channel Habitat Type Classification component (Component III).
	Detailed verification method	Rosgen 1996.
	Reference channel sections	Harrelson et al. 1994.
		TFW Ambient Monitoring Program Manual (Shuett-Hames et al. 1994).
Hydrology and Water Use (Component IV)		See Hydrology (Component IV) section for list of further hydrologic analyses.
Riparian (Component V)	Field verification of recruitment situation and shade	Described in Riparian section, Component V.
	Field measure of stream shade	Described in Riparian section.
	Riparian plant community	Riparian Area Management: Greenline Riparian-Wetland Monitoring (Cagney 1993).
	Riparian evaluation procedure	Integrated Riparian Evaluation Guide (USDA Forest Service 1992).
	Urban riparian inventory	Oregon Urban Riparian Inventory and Assessment Guide (1998)
	Riparian physical processes	Users Guide to Assessing Proper Functioning Condition (Bureau of Land Management 1998).
Wetlands (Component V)	Field verification of wetland attributes	Limited OFWAM Evaluation (Option A) described in Wetland section, Component V.
	Intensive methods	Wetland Functional Assessment (Option B) described in Wetland section.
Sediment Sources (Component VI)	Field verification of sources	Described in Sediment Sources component (Component VI).
	Rural road instability	Forest Road Hazard Inventory Protocol (Oregon Department of Forestry [ODF]).
	Erosion—crop land	Universal Soil Loss Equation (USDA Agricultural Handbook #703).
	Erosion—range land	Monitoring Primer for Rangeland Watersheds (Bedell and Buckhouse 1994).
	Forest management practices	Evaluating the Effectiveness of Forestry BMPs (Dissmeyer 1994).
Channel Modification (Component VII)	Field verification	Described in Channel Modification component (Component VII).

Table 4. Water quality and fisheries monitoring methods.

Manual Component	Monitoring Follow-Up	Monitoring Method
Water Quality (Component VIII)	Intensive monitoring methods	Described in Oregon Water Quality Monitoring Guidebook (OPSW 1999) • Temperature—continuous recorders • Dissolved oxygen—Winkler Method or dissolved oxygen meter • Intergravel dissolved oxygen—field sampling protocol • pH and conductivity meters • Nitrogen and phosphorus—laboratory analysis • Turbidity—field meter or laboratory analysis • Macro-invertebrates—identification and counts • Fecal bacteria—laboratory analysis • Pesticides and toxins—laboratory analysis
	Water quality effects of grazing	Monitoring Protocols to Evaluate Water Quality Effects of Grazing Management in Western Riparian Areas (Bauer and Burton 1993)
	Water quality effects of forestry	Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska (MacDonald et al. 1991)
Fish and Fish Habitat (Component IX)	Fish distribution	Surveying Forest Streams for Fish Use (ODF)
	Migration barriers	Oregon Road/Stream Crossing Restoration Guide (GWEB 1998)
	Pool habitat condition survey	ODFW Stream Habitat Surveys (Moore et al. 1997)
	Large woody debris, spawning gravel, habitat units	TFW Ambient Monitoring Program Manual (Shuett-Hames et al. 1994)

REFERENCES

Bauer, S.B. and T.A. Burton. 1993. Monitoring Protocols to Evaluate Water Quality Effects of Grazing Management of Western Rangeland Streams. US EPA, Region 10, Water Division, Surface Water Branch. EPA 910/R-93-017.

Bedell, T.E., and J.C. Buckhouse. 1994. Monitoring Primer for Rangeland Watersheds. US Environmental Protection Agency. EPA 908-R-94-001.

Bureau of Land Management, Oregon Division of State Lands. 1998. Urban Riparian Inventory and Assessment Guide.

Cagney, J. 1993. Riparian Area Management, Greenline Riparian-Wetland Monitoring. Bureau of Land Management. Tech. Ref. 1737-8.

Dissmeyer, G.E. 1994. Evaluating the Effectiveness of Forestry Best Management Practices in Meeting Water Quality Goals and Standards. US Department of Agriculture Forest Service, Southern Region, Atlanta Georgia.

Governor's Watershed Enhancement Board (GWEB). 1998. Oregon Road/Stream Crossing Restoration Guide: Summer 1998 Draft.

Harrelson, C.C., C.L. Rawlins, and J.P. Potyondy. 1994. Stream Channel Reference Sites: An Illustrated Guide to Field Technique. US Department of Agriculture Forest Service: Gen. Tech. Report RM-245.

Kershner, J.L., 1997. Monitoring and Adaptive Management. Chapter 8 *in* J.E. Williams, C.A. Wood, and M.P. Dombeck, editors. Watershed Restoration: Principals and Practices. American Fisheries Society, Bethesda, Maryland.

MacDonald, L.H., A.W. Smart, and R.C. Wissmar. 1991. Monitoring Guidelines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska. US Environmental Protection Agency, Region 10, Water Division, Seattle, Washington. EPA/910/9-91-001.

Moore, K.M.S., and K.K. Jones. 1997 (in prep.) Analysis and Application of Stream Survey Data for Restoration Planning and Quantification of Change at the Watershed Scale. Oregon Department of Fish and Wildlife Research Section, Corvallis.

Moore, K.M.S., K.K. Jones, and J.M. Dambacher. 1997. Methods for Stream Habitat Surveys. Oregon Department of Fish and Wildlife, Portland.

National Resource Conservation Service. Revised Universal Soil Loss Equation (RUSLE). Agricultural Handbook #703. US Department of Agriculture.

Oregon Plan for Salmon and Watersheds. 1999. Water Quality Monitoring Guide Book.

Oregon Department of Forestry. Forest Road Hazard Inventory Protocol.

Oregon Department of Forestry and Oregon Department of Fish and Wildlife. Surveying Forest Stream for Fish Use.

Rosgen, D. 1996. Applied River Morphology. Wildland Hydrology, Pagosa Springs, Colorado.

Shuett-Hames D., A. Pleus, L. Bullchild, and S. Hall. 1994. Ambient Monitoring Program Manual. Washington State Department of Natural Resources, TFW-AM9-94-001, Olympia.

US Department of Agriculture Forest Service. 1992. Integrated Riparian Evaluation Guide, Intermountain Region. Ogden, Utah.

US Environmental Protection Agency. 1993. Volunteer Estuary Monitoring: A Methods Manual. EPA842-B-93-004. http://www.epa.gov/owow/monitor/estusrvm.html

US Environmental Protection Agency. 1991. Volunteer Lake Monitoring: A Methods Manual. EPA440-4-91-002. http://www.epa.gov/owow/monitor/lakevm.html

US Environmental Protection Agency. 1996. The Volunteer Monitor's Guide to Quality Assurance Project Plans. EPA440-4-91-002. http://www.epa.gov/owow/monitoring/volunteer/gappcovr.html

US Environmental Protection Agency. 1997. Volunteer Stream Monitoring: A Methods Manual. EPA841-B-97-003.

US Environmental Protection Agency. 1997. Monitoring Guidance for Determining the Effectiveness of Nonpoint Source Controls. US EPA, Region 10, Water Division, Surface Water Branch. EPA 910/R-93-017.

Appendix XI-A
Monitoring Outline for Selected Issues

APPENDIX XI-A: MONITORING OUTLINE FOR SELECTED ISSUES

Primary Monitoring Issue	***Temperature***
Subwatershed: **Location:** **Map Symbol:**	***Nonsense Creek*** (see Watershed Issue description in Component X). Lower 1.3 mile section NC1
Background	The condition evaluation indicates that water temperatures in late summer are as high as 72°F in the lower portion of Nonsense Creek. Land uses in the lower section of the watershed are farm lands, composed of a mixture of crops and grazing. There is currently very little riparian vegetation along this section of the stream. There is limited water removal from the stream. The upper watershed is forested and has a good population of rainbow trout. The water temperature data was observed during a stream habitat survey; there is no other water temperature information.
Monitoring Question/ Data Gap to be Addressed	Are high temperatures impacting fish populations in the lower section of the stream? If so, are these high temperatures related to lack of riparian canopy cover, water withdrawals, or both?
Study Objectives	1. Identify temperature patterns in the mainstem of the creek and key tributaries. 2. Verify riparian cover findings identified from aerial photos.
Parameters	Primary: Temperature; Secondary: Canopy cover
Methods	Temperature data loggers, (Guidebook for Water Quality Monitoring, OPSW 1998). Densiometers for canopy cover (See Appendix V-B in this manual). QA/QC Issues: Verify accuracy of data loggers prior to field installation; install loggers according to protocols to avoid effects of local warming.
Study Design (& critical period)	Use upstream-downstream approach to bracket areas of high and low canopy cover. Locate data loggers in upper watershed in areas of known fish occurrence to determine temperature zones in which fish appear to be thriving. Install data loggers with sufficient time prior to and after expected warm period (June – August) to document the duration of high temperatures.
Station Locations	Locate stations at mouth of tributaries to document temperature regime in these sub-basins. Locate stations above and below canopy openings, and at land use breaks.
Study Duration	A study during one season provides comparison between locations to identify areas of warming or cooling. Annual monitoring may be needed to verify these results, to note differences between years, or as a follow-up to restoration actions.
Sample Frequency	Temperature data loggers should be set to short intervals (e.g., 15-20 minutes) to capture the daily extremes in temperature accurately.
Analyses	Graphical: Plot the temperature on the X axis against time in days on the Y axis. Look for periods of exceedance of the Oregon water quality criteria of 64°F. (Data logger software usually provides these plots and calculates daily maximum, minimum, and mean.) Evaluate any exceedance of temperature criteria against the canopy cover evident in aerial photos and compared with canopy measurements if these were collected. Other: Calculate the number of days that temperature exceeds the 7-day moving average (64°F) in the Oregon Water Quality Standards.

Primary Monitoring Issue	***Bacterial Contamination***
Subwatershed: **Location:** **Map Symbol:**	***Big River*** (see Watershed Issue description Component X). Lower 10 miles between the mouth and Elk City Red line along lower Big River
Background	The Big River summary indicates that bacterial numbers increase along the reach of stream from Elk City to the mouth of the river. Potential sources of bacterial contamination along this reach include urban/suburban runoff; runoff from pastures, confined animal feeding areas and other livestock and pet wastes; and failing septic systems.
Monitoring Question/ Data Gap to be Addressed	What are the contributing sources and severity of bacterial contamination to Big River below Elk City?
Study Objectives	1. Confirm the degree of severity of the bacterial pollution in Big River. Is there a consistent problem or was the initial finding an anomaly? 2. Locate specific contributing sources of *E. coli* to identify problem areas and potential solutions.
Parameters	*E. coli* bacteria samples
Methods	Grab samples for analysis at certified laboratory QA/QC Issues: Sterilized sample containers, store on ice, transport to lab within specified holding time.
Study Design (& critical period)	To address the first objective, a few selected index stations will be sampled on a monthly basis to determine the severity and duration of the problem. For the second objective, a set of intensive stations will be monitored during representative storm events at key tributaries and river locations to bracket land use areas.
Station Locations	Determined by location of sources, land use, and accessibility. Stations are located above and below major land uses on tributaries and to segregate regions along the river.
Study Duration	Measure index stations over a 6-12 month period to represent both high and low periods. Monitor intensive survey stations 3-4 times during this period.
Sample Frequency	Index stations–monthly basis. Intensive survey stations as needed to sample storm events.
Analyses	Graphical: Plot results of storm-event monitoring with bacterial numbers on X axis and stream miles along the Y axis. Look for a consistent pattern of increases to identify bacterial sources. (Note: Bacterial counts often need to be converted to a different scale such as a logarithmic scale). Other: Tally the percent exceedance of water quality criteria to identify areas that exceed water quality standards.

Primary Monitoring Issue	***Fine Sediment (turbidity)***
Subwatershed: **Location:** **Map Symbol:**	***Elk Creek*** (see Watershed Issues description in Component X). Lower 2 miles EC1
Background	Elk Creek passes through farms for the first mile and then drains private forest lands. In comparison to similar streams in this area, there appears to be large amounts of fine sediments deposited on the channel bottom, sometimes filling up shallow pools. It is not known where the sediments are coming from; the increase in sediments has been noted to correspond to the increased truck traffic over the last 2 years. There may be increased turbidity associated with the sedimentation.
Monitoring Question/ **Data Gap to be Addressed**	What are the contributing source(s) of sediment to this section of Elk Creek? Are roads and truck traffic the primary source of fine sediment?
Study Objectives	1. Determine the severity of fine sediment inputs to Elk Creek. 2. Identify the sources of sediment delivery. 3. Specifically, assess the condition of the adjacent roads during periods of sediment runoff.
Parameters	Turbidity (as a surrogate for suspended sediments. Note that turbidity is useful for very fine soil particles – silts and clays – but, is not generally useful for sand-sized particles.) Road condition
Methods	Turbidity: Portable turbidimeter provides ability to process samples quickly in the field. Samples can also be taken to a laboratory. Road Condition: Detailed Rural Road Runoff Survey (See Component VI for description, Table 12).
Study Design **(& critical period)**	Sample turbidity at locations along the stream and incoming sources during the wet weather period. Repeated surveys should show a pattern of obvious source areas. The road survey provides a detailed assessment by section which will link the sources to road segments needing improvement.
Station Locations	Identify potential source areas prior to sample collection such as road fill that is adjacent to the stream, cross-drain outlets, and other drainage sources. Flag and record these on a map as sample locations.
Study Duration	Several repeated visits should be adequate to identify source areas. The survey can be repeated after road improvements are made (during comparable conditions) to evaluate effectiveness of the treatments.
Sample Frequency	As described above.
Analyses	The turbidity levels during a survey can be plotted on a detailed map in relation to road features and other sources. Areas of higher turbidity may be linked to specific source areas using the Road Runoff Survey.

Watershed Professionals Network (WPN) is an association of water resource consultants. *WPN* was formed to use the diverse skills of independent consultants to complete complex projects.

CONTRIBUTORS

Karen Kuzis—Project Management, Fisheries

Stephen Bauer—Water Quality, Monitoring

John Runyon—Historical Conditions, Condition Evaluation

Bob Denman—Channel Habitat Typing, Channel Modifications

Joanne Greenberg—Hydrology and Water Use

Ed Salminen—Riparian Conditions

Betsy MacWhinney—Wetland Conditions

Chip Andrus—Sediment Sources, Ecoregion Descriptions

Jean Caldwell—Ecoregion Descriptions

Mary Raines—Sediment Sources

Kent Smith—Watershed Fundamentals

Kathy Sitchin, **Pentec Environmental, Inc. —**Technical Editing

Darrel Weiss, **Pentec Environmental, Inc. —**Word Processing

Mike Flinn—Original Artwork

ACKNOWLEDGEMENTS

We have enjoyed the challenge of developing this document and could not have done it without the help and support of numerous people. Ken Bierly of the Governor's Watershed Enhancement Board (GWEB) provided outstanding project management and kept the task on track. GWEB staff was always available to answer questions or help obtain information. The Technical Oversight Committee sat through numerous meetings while developing and testing the approach used in this manual. A special thanks goes to the Watershed Council members who attended the technical committee meetings, listened to our technical discussions, and helped ground us in their real-world issues and problems. Finally, thanks to the Mid Coast Watershed Council for taking time to participate in the test assessment. Our experience actually completing an on-the-ground assessment and working with a Watershed Council helped improve the manual.

PUBLICATION CITATION

This document should be referenced as Watershed Professionals Network. 1999. Oregon Watershed Assessment Manual. June 1999. Prepared for the Governor's Watershed Enhancement Board, Salem, Oregon.

ACRONYMS USED IN THIS MANUAL

3-D	three-dimensional
BLM	US Bureau of Land Management
BMPs	best management practices
cfs	cubic feet per second
CHT	Channel Habitat Type
Corps	US Army Corps of Engineers
CSRI	Coastal Salmon Restoration Initiative
CWA	federal Clean Water Act
DBH	diameter at breast height
DSL	Oregon Department of State Lands
DHSVM	Distributed Hydrologic Soil and Vegetation Model
EPA	US Environmental Protection Agency
ESA	Endangered Species Act
ET	evapotranspiration
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
GWEB	Governor’s Watershed Enhancement Board
HGM	hydrogeomorphic
HSG	hydrologic soil groups
HSPF	Hydrologic Simulation Program in Fortran
HUC	Hydrologic Unit Code
IVA	Indicator Value Approach
LWD	large woody debris
NCEPI	National Center for Environmental Publications and Information
NMFS	National Marine Fisheries Service
NPS	Nonpoint Source Control program
NRCS	Natural Resources Conservation Service
NTU	nephelometric turbidity unit
NWI	National Wetland Inventory
ODA	Oregon Department of Agriculture
ODEQ	Oregon Department of Environmental Quality
ODF	Oregon Department of Forestry
ODFW	Oregon Department of Fish and Wildlife
OFWAM	Oregon Freshwater Assessment Methodology
ONHP	Oregon Natural Heritage Program
OPSW	Oregon Plan for Salmon and Watersheds
OWRD	Oregon Water Resources Department
RCU	Riparian Condition Unit
SCS	USDA Soil Conservation Service
SWCD	Soil and Water Conservation District
SRPA	Streamflow Restoration Priority Area
SSCGIS	State Service Center for Geographic Information Systems
TIA	Total Impervious Area
TMDL	Total Maximum Daily Load
USFS	US Forest Service

Acronym List (continued)

USFWS	US Fish and Wildlife Service
USGS	US Geological Survey
WAB	water availability basin
WARS	Water Availability Reports System
WET	Wetland Evaluation Technique
WRIS	Water Rights Information System