Rock Creek (Siletz) Watershed Assessment Final Report

Prepared for the MidCoast Watersheds Council, Siletz Watershed Group
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LIST OF ACRONYMS

AHI	Aquatic Habitat Inventory
BLM	Bureau of Land Management
CLAMS	Coastal Landscape Analysis and Modeling Study
DEM	Digital Elevation Model
DLG	Digital Line Graph
DOQ	Digital OrthoQuad
FEMA	Federal Emergency Management Agency
GIS	Geographic Information System
MCWC	MidCoast Watershed Council
NPDES	National Pollutant Discharge Elimination System
ODFW	Oregon Department of Fish and Wildlife
ODF	Oregon Department of Forestry
USGS	United States Geological Survey

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1 Executive Summary

Rock Creek is a tributary of the Siletz River; its watershed occupies about 43 square miles and ranges in elevation from 160 ft to 2880 ft, with about 36% of the land area lying above 1000 ft elevation (**Figure 7.1**). Rock Creek flows into the Siletz River between river miles 48 and 49 at Logsden, Oregon, about 13 miles inland from the Pacific Ocean. The watershed provides habitat for three threatened species (the marbled murrelet, the Northern spotted owl, and the coho salmon) and two candidate species, which may be listed under the Endangered Species Act (searun cutthroat trout and steelhead trout) (**Figure 3.14**). The residents of Rock Creek are interested in developing a science-based management and monitoring plan to conserve the resources of the watershed. The purpose of this report is to summarize and synthesize existing information so that such plans can be developed.

This assessment was performed using a geographic information system (GIS). We used existing GIS data and developed new GIS data sets to assess watershed conditions in the Rock Creek watershed. Based on the needs of the Rock Creek work group and recommendations contained in the Governor's Watershed Enhancement Board (GWEB) manual, we conducted the assessment using data at a scale of 1:24,000. This is the scale of a 7.5 min USGS topographic map.

Land use in the watershed is primarily timber production (> 85% of the watershed area), with large blocks of state, federal and private industrial land ownership (**Figure 3.2**). Residential development is very limited and is located mainly in the lower valleys of Rock Creek and its tributaries.

The landscape in the watershed is dynamic. The geologic formation underlying most of the watershed, the Tyee formation (**Figure 3.4**), is a sedimentary formation derived from sand and silt deposits, which weathers to form landslide-prone soils. In addition, many valleys of the watershed are steep-sided (**Figure 6.1**), yet only two landslides have been mapped. Both landslides recorded in the watershed originated at quarries located on the flanks of Steer Divide. A rapid, shallow landslide reportedly originated at the hatchery quarry in T10S R8W Sec. 7, and a second landslide and debris torrent originated at the quarry at the headwaters of Beaver Creek (T10S R8W Sec. 4) (**Figure 3.5**). It is likely that other landslides have occurred recently in the watershed, but they may be in more remote locations or hidden under the tree canopy.

In keeping with a GIS-based approach, we divided the watershed into 347 catchments (**Figure 3.3**), which were defined using 10 m digital elevation model GIS layers; average catchment size was about 80 acres. Division of the Rock Creek watershed into catchments was designed to provide information on watershed conditions at an appropriate scale for site-specific land management decisions while maintaining a watershed approach.

We characterized the vegetation in each of the catchments using satellite imagery from the CLAMS88 (Coastal Landscape Analysis and Modeling Study). This information is at least 10 years old and indicates that the majority of land surface in the watershed is occupied by forests containing **no** large conifers (over 2 ft dbh). About 5.5% (621 ha) of the area was open (fields, pastures, recent clear-cuts, etc.). We queried the data for the proportion of conifers in each catchment's riparian area and found that only 10 catchments had riparian vegetation consisting of a few large conifers within predominantly broadleaf forest (i.e., > 70% "Mixed Forest/Large Conifers"), and 39 catchments had more than 5% cover of "Large Conifer Forest" in a 200 ft riparian buffer area.

We found that 3,983 ha (35.6%) of the Rock Creek watershed had an elevation of more than 1000 ft and 211.8 ha (about 2% of the total watershed area) in the Rock Creek watershed were both open and above 1000 feet. According to the 1997 Draft GWEB watershed assessment manual, these areas may experience hydrologic impact from rain-on-snow events.

All streams in the Rock Creek watershed are classified as confined channel types (**Figure 3.15**), despite the presence of broad, flat areas (possibly former floodplains) adjacent to the lower reaches of major streams. This combination of features may indicate downcutting of the watershed's streams, possibly related to recent changes in peak flow characteristics.

To determine in-stream conditions, we analyzed data from Aquatic Habitat Inventory (AHI) stream surveys. AHI surveyed reaches total 77 mi (124 km) and represent 62.1% of total stream length in the watershed. Instead of using a subset of that data which was available as a 1:100,000 scale GIS data layer directly in this analysis, we evaluated and summarized all of the AHI data from original database files on a per-catchment basis. We did this for two reasons: (1) to allow us to compare multiple sources of AHI data in various states of data development, and (2) to link results of our other GIS summaries to AHI data at an appropriate scale.

Analysis of AHI data shows that large conifer cover and large woody debris levels are very low in the Rock Creek watershed. This is consistent with our interpretation of the CLAMS88 landcover data. Fifty-nine of the 116 surveyed catchments showed desirable shading of the stream channel, 23 had medium shading, and 34 had undesirably low shading (**Figure 5.7**). Very few catchments had streams containing desirable wood volume of large woody debris, and none had a desirable number of pieces or key pieces of woody debris (**Figures 5.8 - 5.10**). Only nine out of 136 surveyed catchments had desirable wood volume; three catchments had medium wood volume; and 124 catchments had undesirable wood volume. Only one pool in the Rock Creek watershed had a complex woody debris accumulation. All of the other pools surveyed had no woody debris, or single pieces of wood, or small accumulations that would not provide cover at high discharge rates. All surveyed catchments had undesirably low levels of riparian conifers, based on AHI data. Analysis of CLAMS88 (Coastal Landscape Analysis and

Modeling Study) satellite imagery supports this conclusion; based on this satellite data, large conifer cover is very low in the watershed, both for catchments as a whole (**Figure 3.8**) and for riparian areas within catchments (**Figure 3.10**).

Most catchments had intermediate pool frequency (**Figure 5.3**), variable pool depth and pool area (**Figure 5.2**); and highly variable stream width-to-depth ratio. Instream fine sediment levels were undesirably high in most streams (**Figure 5.5**); and instream gravel levels were desirable or medium in most catchments (**Figure 5.6**). A high proportion of catchments in the Steer Creek and Little Rock Creek subbasins contained actively eroding banks (**Figure 6.3**). The proportion of AHI survey units containing actively eroding banks was over 80% in many of these catchments. Proportion of AHI survey units containing actively eroding streambanks in the rest of the watershed was generally under 40%.

We found information on fish populations to be generally lacking. Based on knowledge from other areas and a limited number of studies, we found that like coho (*Onchorhynchus kisutch*) in all of western Oregon, coho populations in the Siletz River basin as a whole are considered dangerously depleted and unstable. Juvenile surveys (snorkel surveys) conducted in the watershed in 1998 showed very low numbers of coho juveniles, in general. The highest coho juvenile densities in the watershed (marked on **Figure 4.1**) were at William Creek, where coho juvenile density averaged 1.5 coho/m^2, in a portion of upper Steer Creek (0.8 coho/m^2), and in a tributary of Little Steer Creek (0.6 coho/m^2) (Steve Trask, personal communication, 1999).

Fish hatcheries undoubtedly play an influential role in current patterns of coho abundance. The hatchery on Rock Creek is currently being refurbished by the Confederated Tribes of the Siletz Indians. To meet its commitment to the Siletz Tribal fishery, the Oregon Department of Fish and Wildlife continues to release coho smolts into Rock Creek at the hatchery site. The number of smolts released was between 200,000 and 1 million from 1970 to 1995. Between 1996 and 1998, 25,000 smolts were released each year, and ODFW plans to release 50,000 in 1999. Scale analysis indicates that the majority of adult spawners returning to the watershed are of hatchery origin. Because of this strong hatchery influence over the local coho run, the approach used to manage the hatchery will be critical to the success of the coho run in the Rock Creek watershed

We found very little information on populations of other salmonid species; a useful source was the Siletz River Basin Fish Management Plan (ODFW 1997a). Fall Chinook runs in the Siletz River Basin as a whole are considered healthy, although commercial harvests in the Siletz earlier in the 20th century showed a steady, sharp decline, and sport catch has also declined. Steelhead populations also appear to be declining. Scale analysis for steelhead caught in Drift Creek (Siletz) and the Siletz basin show strong hatchery influence in recent years. To address concerns over wild steelhead survival, recent hatchery releases have been produced from local native stock. Little is known of populations of resident, fluvial and searun cutthroat trout in the Siletz Basin; however, angler information seems to indicate a recent decline in searun populations.

Lamprey are a species of special concern in the watershed. The Oregon Department of Fish and Wildlife notes that lamprey throughout Oregon have undergone pronounced declines in recent years; therefore, Pacific lamprey has been designated as a sensitive species in the State of Oregon. Anecdotal information suggests that the once abundant lamprey harvests that existed until the 1980's have disappeared during the past decade.

Little information is available on the status of aquatic invertebrates in the watershed. Local residents described sharp declines in the once large beds of river mussels that were once found through out the watershed. AHI survey crews reported mussel beds in only two catchments (**Figure 4.1**).

Nearly all the wetlands shown within the watershed on the NWI map are located in riparian areas (**Figure 3.16**), and are classified as intermittently- or seasonally-flooded palustrine forested, scrub-shrub and emergent wetland types.

The nine culverts which were surveyed and compiled by ODFW, and which are in need of upgrades to improve fish passage, are shown in **Figure 5.11**. All are designated "medium" to "low" priority for upgrades, and all carry flow from streams designated by ODFW in the list as "fair" fish habitat. We intersected the USGS DLG roads layer and streams layer to determine 127 other possible culvert locations; these are also shown in **Figure 5.11**.

We found that about 8.9% of all roads in the watershed pass through or near streams (**Figure 6.4**). Of roads mapped in the Rock Creek watershed, there are 7,110.8 m of roads that pass through areas with slopes greater than 60% (approximately 2.9% of all of the roads in GIS roads layer for the Rock Creek watershed). If road density (meters of road/ unit area of catchment) on high slope (>60%) areas indicates risk of slope failure, then the majority of catchments in the Rock Creek are not at risk. Most catchments have road densities on high slopes of 1 m of road ha^{-1} or less. These analyses are based on the best available digital roads layer (USGS digital line graphs). Measurements in 10 randomly selected catchments showed that the DLG roads layer was missing an average of 33% of roads visible in digitized aerial photographs (see **Development of base layers** above).

The Siletz Watershed Group is concerned about water quantity and water quality. In region that can receive 200 inches of rain a year it may seem unlikely that water quantity can be an important issue. Yet, in the past, people foresaw increasing demands for water in the mid-coast region and a proposal was developed for a water supply dam on Big Rock Creek. This proposal was supported in a U.S. Department of the Interior Appraisal Report; however, the appraisal report did not consider any possible negative impact to salmonid populations from the proposed dam. Presently, 19 water users in the Rock Creek watershed have water use permits from the Oregon Water Resources Department. Although ODFW designates all of the Rock Creek watershed as low priority for streamflow restoration, impacts from low flow reductions could still exist within the watershed. The demand for high quality water is great because many of the valued resources (wildlife) and primary water uses in the watershed are water-quality sensitive.

None of the streams in the watershed are listed as water-quality limited by the Oregon Department of Environmental Quality (**OR303STR**). There are no permitted wastewater discharge sites (NPDES sites) within the watershed (**NPDES**). Likely nonpoint sources of water pollution include cattle wastes from pastured areas, and application of biosolids (sewage sludge) on the Howard Farm at the confluence of Rock Creek and the Siletz River.

Little long-term information on water quality was available for the watershed. Continuous temperature recording devices were placed at two locations in Little Rock Creek and one location on Rock Creek during August - September 1997. We analyzed output from these devices and found a 7-day moving average daily maximum temperature of under 62° F at the Little Rock Creek locations, and under 63° F at the Rock Creek location. These temperatures are considered moderately impaired. Monthly sampling at 10 locations in the watershed during 1996-1998 showed pH values were within the expected range for the Coast Range; somewhat low concentrations of dissolved oxygen; and low turbidity.

Volunteer organizations, state agencies, and the timber industry have conducted a number of restoration projects in the watershed, including riparian fencing, riparian plantings, placement of large woody debris for in-stream structure, construction of off-channel habitat, road and culvert upgrades, and retention of conifers in riparian zones.

The last sections of this report provide recommendations for further information gathering in the watershed, and suggestions on how the Siletz Watershed Group could focus efforts to enhance watershed conditions and learn more about the valuable resources in the Rock Creek watershed.

2 Goals and methods

2.1 Goals for this watershed assessment

The primary goals of this assessment were to inventory and characterize watershed components and to evaluate watershed processes that influence abundance and distribution of salmonids and other valued wildlife. Products from this work include: a series of monitoring and management action recommendations; summary and base map geographical information system data layers; and identification of important data gaps and recommendations for filling those gaps.

In this assessment, we want to emphasize that watershed processes themselves, such as landslides and sediment transport, cannot be characterized as either good or bad. Instead, we need to address the likely impact of these processes on valued resources within the watershed through detailed study. For example, landslides are a natural component of Pacific Northwest watersheds. The same landslides and debris flows that choke streams with fine sediments and silts are also an important source of gravel necessary for salmon spawning. Landslides may be a concern wherever human actions have altered their frequency, magnitude, and position in the watershed.

In this assessment, we address important issues within the Rock Creek watershed that were identified by the Siletz Watershed Group in 1997 (SWG 1997). These issues include water quality and quantity; aquatic and fish habitat; slides and erosion control; and land use. All of these issues are key to this assessment, and are also components of the 1997 GWEB Draft Watershed Assessment Manual (Non-Point Source Solutions 1997).

2.2 Methodology for this watershed assessment

In conducting this assessment, we used methods that had the following characteristics:

- **GIS-based**, using base maps developed from Geographic Information Systems data and terrain information derived from Digital Elevation Models (DEMs). We elected to use ArcView and ArcView Spatial Analyst as our principal tools in this analysis. Both of these software packages are relatively low in cost and can be run on most modern personal computers. We performed this entire analysis, with the exception of the merging of the DEM files and the reprojection of new layers, in ArcView;
- **Integrative**, synthesizing the many factors influencing watersheds and the interactions of those factors;
- **Quantitative**, making use of numeric data as much as possible while still incorporating supplementary qualitative information;
- **Scientific**, using existing data in a scientifically valid way. Wherever possible, we used quantitative and documented data sets;
- **Model-driven**, using conceptual models of watershed processes to guide analyses and interpretation of results.

2.2.1 Models and GIS

Models can be important tools in developing an understanding of how watershed components are linked to one another and to watershed processes. Models can be symbolic (box and arrow-type diagrams) or mathematical representations of complex structures and processes that occur in the real world. The purpose of a model is to simplify a complex set of components and their interrelations (Proctor et al. 1980).

A map is a type of model that describes the spatial relationship between features. The map describes reality: reality and the map are not identical. An important point is that maps describe features; they do not provide explanations or interpretations (Muehrcke 1986). Geographic information systems can be used to produce maps. However, the strength of GIS is that once built, GIS data sets can be used to perform spatial analysis and produce models. That is, unlike simple maps, GIS can be used to develop explanations of how watersheds may work. An important consideration is that, if GIS data are to be used for analysis, those data must not only be up to mapping standards, but they must be collected and stored in such a way that they can withstand the rigors of analysis. In other words, GIS data have at least two major components the spatial location (i.e., the map part) and the actual phenomenon or characteristics that is mapped (i.e., a value or name, etc.) (Dangermond 1990).

GIS models can help resource managers and scientists to develop an understanding of the components and intricate interactions that occur at widely ranging temporal and spatial scales. GIS is useful in developing this understanding, because it forms a framework that can be used to identify hidden relationships between ecosystem components or knowledge gaps.

All watersheds, regardless of size, have two or more interconnected ecosystem subcomponents: terrestrial and aquatic (see Appendix 1). In this study, we have developed and used existing GIS data sets that describe components of both terrestrial and aquatic components of the Rock Creek watershed. We have used these datasets to allow spatially explicit analysis of the relationships between land cover and aquatic resources. These relationships can be used by watershed managers to link land use activities with important watershed components, such as salmon, water quality, and sediment transport.

2.2.2 Development of base layers

Development of GIS data was a major part of this project. Some digital data were already available for the watershed, but the scale of nearly all available digital data was too coarse for analysis at the 5th field watershed level. On the MidCoast Watershed Council (MCWC) CD-ROM Ver. 4.0 only 16.1% of the 150 or so data layers were at 1:24,000 scale or larger (Garono 1999). The first step in this project was to develop a base layer to which all other information would be mapped.

We constructed a digital base map for the watershed consisting of roads, streams, and landscape information at a scale of 1:24,000, the scale recommended by the GWEB manual (Non-Point Source Solutions 1999). Digital data for roads and streams present on the MCWC CD-ROM were either too coarse-scale (scale greater than or equal to 1:100,000), or had been constructed from mixed-scale data and therefore presented a misleading picture of the watershed (i.e., they were not suitable for some types of analysis). Therefore, we acquired 1:24,000 scale digital line graph (DLG) files from the U.S. Geological Survey. These data layers had known positional accuracy and met our needs for a base layer.

The USGS DLG roads layer we used is based on USGS 7.5 minute topographic maps, which are based on aerial photographs taken in the 1970's. Perhaps because so many logging roads have been constructed since the 1970's, the USGS DLGs do not include many small logging roads in the watershed. Therefore, the extent of the roads portrayed in the DLG files probably underestimates the actual number of roads. Digital orthoquads (DOQ's) are aerial photographs that have been converted to GIS layers. These DOQ's are useful for confirming the location of features on the GIS layers. We acquired DOQ's for the study area (***Eddyville, Nortons, Summit and Valsetz***), which were based on 1994 aerial photographs. We used the DOQs for two main purposes: to assign Aquatic Habitat Inventory data to catchments (see **Aquatic Habitat Inventory data** below), and to assess the completeness of the USGS DLG roads layer. For the roads layer assessment, we randomly selected ten catchments within the watershed and overlaid the DLG roads layer over the DOQ image. We found that an average of about 33% of roads visible on the 1994 digital orthoquad images were missing from the USGS roads layer. The percentage of roads missing was highly variable among the randomly selected catchments; three catchments had no roads missing, while one had no roads shown on the DLGs and about 3 km of roads visible on the DOQs. The lack of good roads information is a major data gap (see **Data recommendations** below), which should be filled to provide an accurate basis for watershed management decisions.

2.2.3 How to use this report

We used the following conventions in preparing this report:

- All data layers from the MCWC CD-ROM are referenced by file name, which appears in caps and bold.
- References to sections appear in bold.
- Highlights appear in bold and are underlined.
- Units appear in both metric and English.
- Figures are numbered sequentially within a section.

3 Introduction to the Rock Creek Watershed

The goal of watershed assessment is to review and synthesize existing data to provide recommendations for watershed management decisions. Our approach is to examine the features, conditions, and processes in the Rock Creek watershed, and to assess the likely impact of management actions on the watershed resources we value. We summarized existing information on the many interacting components of ecosystems in the Rock Creek watershed, we hope to help resource managers understand the complex linkages and interactions between these components and processes. Through this understanding of the ecosystem as a whole, science can help us manage and enhance the watershed resources we all value.

Resource managers frequently manipulate the environment in ways that are expected to enhance a particular resource of interest. Because of the complexity of biological interactions in the environment, the connections between management actions and the target resources are not always apparent: a management action intended for one resource may even have unexpected, negative effects on another. To understand the ecological trade-offs of management decisions, three types of knowledge are needed: (1) an understanding of ecosystem components (organisms and structure), what they do (processes and functions), and how they interact; (2) an idea of the current conditions or status of the ecosystem; and (3) a set of methods for measuring the success or failure of management actions. A brief discussion of ecosystem components, processes and function is provided in each chapter, with a more detailed discussion in **Appendix 1 (Ecosystem Processes in Watershed Development)**.

3.1 Setting

The Rock Creek watershed is a fifth field watershed within the Siletz River basin of the Oregon Coast Range. It is located partly in the southwest corner of Polk County, and partly on the east edge of Lincoln County, with a small area in Benton County. The watershed lies between 13 and 23 miles (21 km to 37 km) inland from the Pacific Ocean (**Figure 3.1**). Rock Creek flows into the Siletz River between river miles 48 and 49 at Logsden, Oregon. The watershed's western portion is narrow where Rock Creek joins the Siletz, but widens eastward and extends northward towards Valsetz, Oregon along Big Rock Creek. Total land area in the watershed is about 43 sq mi (11,150 ha). Elevation ranges from about 160 ft (50m) at the mouth of Rock Creek, to about 2880 feet (880 m) on Green Mountain in the northeast portion of the watershed. The primary economic land use in the watershed is timber harvest with some pasture land and rural residences in the broader stream valleys. Named tributaries to Rock Creek are shown in **Figure 3.1**. The data layer for streams within the watershed contains a total of 124.8 stream miles (200.8 km).

The Rock Creek watershed is an example of a coastal watershed within the Mid-Coastal Sedimentary ecoregion (see **Ecoregion** below). Watersheds can be large or small and are defined as the entire land area draining to a specified body of water (or the lowest point, in the case of watersheds in arid regions, Non-Point Source Solutions 1999). Therefore, watersheds are nested, with large watersheds containing smaller watersheds (or catchments). Water eventually reaching the ocean passes through the components of the Rock Creek watershed: water filters through upland forests and cleared lands, passes over logging roads, travels within numerous streams, creeks, and culverts, and through pastures and residential areas. Larger streams are located at the terminal end of the watershed; therefore, larger streams experience the cumulative effects of all processes and activities occurring throughout the entire watershed (**Appendix 1**). Natural resource management decisions must be based on an understanding these linkages in order to sustain the quality and productivity of coastal watersheds.

3.2 Ecoregion

The Rock Creek watershed is located in the Mid-Coastal Sedimentary ecoregion (Watershed Professionals Network 1999). Ecoregions are relatively large areas that share similar physical and biological characteristics (Omernik 1987). The concept of the ecoregion is useful because knowledge of certain processes and characteristics can be applied throughout the entire region.

The Mid-Coastal Sedimentary ecoregion is located in the central Coast Range of Oregon, extending from the upper South Fork Coquille River north to the upper Yamhill River, east to the Willamette Valley foothills and west to within 20 miles of the Pacific Ocean. Watersheds in the ecoregion share a number of characteristics, including: 1) the active subduction of the Juan de Fuca Plate; 2) a moderate climate regulated by the oceanic California Current; 3) an average annual precipitation around 100 inches (254 cm) in lower elevations and 200 inches (508 cm) higher in the watershed; 4) peak flows ranging from 200 to 250 cfs per square mile; 5) underlying geologic formations consisting of easily-eroded siltstone and sandstone; 6) high landslide frequency; 7) high density stream networks with steep headwaters, low-gradient mainstems, and separate, small estuaries; 8) low levels of streamside conifer regeneration; 9) dense coniferous forests; and 10) land use consisting mainly of timber production. These conditions support the production of valued natural resources native to the area, such as Pacific salmon and large conifers.

3.3 Human history

Native Americans have lived in the watershed since prehistoric times. When Europeans first explored the area, Indians in the area subsisted by fishing, hunting, gathering and trading. The past few generations of the Siletz Tribe also lived off natural resources in the watershed. They gathered a variety of plants, hooked and trapped lamprey, caught salmon, collected freshwater mussels, and hunted deer. However, recent declines in lamprey and salmon populations have reduced access to these two important traditional food sources (Downey et al. 1993).

The primary economic use of land in the watershed today is timber harvest, which occupies approximately 85% percent (**OWN_RC**) of the Rock Creek Watershed. Extensive timber harvest began in the area in the 1940's and 1950's. Reports from stream surveys at that time describe impact to streams from logging activity nearby (Willis and Best 1949, Clutter and Jones 1949), and most likely large trees were cut from riparian zones early during this period (BLM 1996).

In the past, most people living in the watershed subsisted at least partly on food and other resources they gleaned directly from the land through hunting, fishing, raising livestock, harvesting timber, and agriculture. In recent times, this has changed. Increasingly, people settling in the watershed live in this rural setting by choice, but work or derive income from sources outside the watershed. This lack of connection between the watershed's quality and productivity and the well being of its inhabitants is of concern for the current residents of the Rock Creek watershed.

Today, rural Oregon faces increases in development, with associated changes in direct use of water and in use of resources dependent on water. Choices made by present-day inhabitants of Rock Creek will determine how water resources are used and how the watershed will change. These choices will undoubtedly affect the quality of life in the watershed. This watershed assessment may be a useful tool in re-developing an understanding of the interconnectedness of watershed components. With this understanding, we can balance needed resource use with possible impacts to the watershed, so that we can successfully enhance and restore the watershed.

3.3.1 Land ownership

There are nine major landowners in the Rock Creek watershed (**Table 3.1**). Most of the land holdings (**Figure 3.2**) are managed for timber production.

TABLE 3.1. Summary of Major Landowners in the Rock Creek Watershed (Source: RC_OWNERSHIP)

Owner	Sq. Miles	Percent of Total Rock Creek Watershed
BLM	2.1	5.0
BOISE CASCADE	8.1	18.7
DIAMOND	0.1	0.1
GEORGIA PACIFIC	6.0	14.0
CONFEDERATED SILETZ TRIBES	1.0	2.2
PRIVATE NON-INDUSTRIAL	6.2	14.4
SIMPSON	6.3	14.6
STARKER	2.9	6.7
STATE OF OREGON	10.5	24.3
Total	**43**	**100**

3.4 Topography and catchment derivation

Topography of coastal watersheds in Oregon ranges from deeply incised canyons in the upper watershed to flat floodplains and gently rolling dunes near the coast. Events and processes within the Rock Creek watershed affect other ecosystems downstream, including the Siletz River estuary. Along the Pacific Northwest Coast, the formation and development of estuaries and their watersheds is the result of long-term geologic processes. Long-term climatological and geological processes (i.e., sea-level rise, erosion, uplift and subsidence events) have influenced and continue to influence the physical and biological components of these watersheds. These watersheds continue to change at various temporal and spatial scales: they are dynamic systems. Organisms have adapted to natural processes on this changing physical template.

An understanding of topographic patterns is important in watershed analysis. The movement of water is greatly affected by the slope or gradient in a watershed. As the speed of water increases, so does its capacity to erode soils and move sediments. Therefore, knowledge of topographical patterns can lead to an understanding of sediment and debris transport patterns to the stream network.

The first step in our analysis was to divide the Rock Creek watershed into smaller basins that would serve as the basis for our characterization. Watersheds can be divided in a variety of ways depending on purpose. For example, political boundaries (counties, cities and states), ownership, and forest stands are ways in which watersheds have been divided in past studies. In this study, we used GIS to divide the Rock Creek basin into topographically defined catchment basins.

We felt that a ‘catchment’ would be useful in characterizing the Rock Creek watershed at a level of detail necessary to guide monitoring and restoration actions. Furthermore, the movement of water, which connects the land's surface with the stream network, is embodied in this topographically defined characterization scheme. Understanding the connection between land use and important resources, such as salmon, Pacific lamprey, and water quality, is necessary for "watershed" management.

We acquired provisional 10 m digital elevation model (DEM) files from the Forest Science Laboratory at Oregon State University. These files describe the topography of the Rock Creek basin as a grid or mesh, which covers the entire watershed. In this grid, each cell describes the elevation above sea level and is 10 X 10 m (approximately 30 X 30 feet) in size. The DEM files were available for each of the six USGS quadrangles in the study area (Eddyville, Euchre Mountain, Fanno Ridge, Nortons, Summit, and Valsetz). Before we could use the DEM files to derive catchment basins, we had to combine the six DEM files into one DEM file. The process of combining separate ‘raster’ files, in this case the six DEM files, into one file is called mosaicing. Raster files can be images (i.e., digital photographs or satellite images) or grid files (e.g., DEM files).

We used ERDAS Imagine® software to mosaic the six DEM files into one image. We derived catchment basins from the resulting merged DEM file following methodologies developed by D. Maidment, University of Texas (Center for Research in Water Resources (CRWR) 1998). We chose the CRWR method because the scripts were developed to run with the ARCView Spatial Analyst (software). The script is an automated procedure that will define catchments from the DEMs after the user selects an initial stream threshold. After trying several initial threshold values, we defined each catchment basin as having an initial threshold of 1500 grid cells. That is, each cell that we "defined" as a stream had to have at least 1500 grid cells (37 acres or 15 ha) feeding into it. This is simply the computer's way of modeling where a stream would be, based on the DEMs and the initial conditions supplied by us (stream threshold). It is a model of the stream network: how good or bad the computer representation is depends on the questions that we are asking of the model. This process resulted in the definition of 2,542 catchment basins for the six-quadrangle area. To reduce the computer processing time and the size of the data files, we extracted, or clipped, the catchment basins for the Rock Creek basin from the six-quadrangle area. We selected a stream threshold of 1500 cells because it produced a manageable number of catchments and it produced a stream network that was comparable to the stream network depicted in the 1:24,000 scale DLG layer (our base streams layer).

Developing a catchment boundary and stream network is one common use of DEM files. What is new, in this particular case, is that we are using procedures developed by Dr. Maidment's group for the ArcView Spatial Analyst. In the past, these procedures were only available with more expensive software and hardware. For more information, see the Tillamook Bay NEP or the CRWR web pages.

Elevations from 11,138,375 points (grid cells) were used to generate 347 catchment basins for the Rock Creek study area (**Figure 3.3**). The average size of each catchment was 79.5 acres (32.2 ha), the maximum size was 341.2 acres (138.1 ha) and the minimum size was 0.15 acres (0.1 ha). In general, most catchment basins in the study area were between 50 and 100 acres (20 and 40 ha). These catchment basins are topographically defined areas that can be used to link land use to individual stream segments. The catchments were used as a frame through which the characteristics of the watershed were viewed. For example, we characterized land cover, slopes, road densities, etc. for each of these catchment areas.

3.5 Climate

The climate of the Rock Creek watershed is typical of the coastal zone of Oregon. Temperatures are mild year-round at lower elevations; winters are wet, with most precipitation falling as rain except at higher elevations.

A weather station in Otis, OR (elevation 150 ft, about 19 mi. or 30 km north of Logsden), provides nearby precipitation and temperature data over a period of several decades. Between 1961 and 1990, this station received monthly mean precipitation ranging from a July low of less than two in. (5 cm), to a December high of nearly 16 in. (40 cm), for a mean annual rainfall of 97 in. (246 cm: Oregon Climate Service, http://www.ocs.orst. edu/pub/ftp/ reports/ zone/Zone_1_TPCP.html). The mean monthly low and high temperatures for January were 36° F (2.2° C) and 47° F (8.3° C); mean monthly low and high for August were 50° F (10.0° C) and 71° F (21.6° C).

The Oregon Climate Service also reports data from two stations located further inland and closer to the Rock Creek watershed, but these two stations (Alsea Fall Creek Hatchery and Summit) lack the continuous data provided by the Otis station. These stations generally receive less rainfall in summer months, with winter rainfall slightly less than that at Otis.

Winter temperatures at high elevations in the Rock Creek watershed would be much colder than those recorded at coastal stations. At these high elevations, much of the winter precipitation falls as snow, and rain-on-snow events can produce rapid peak flows in the watershed's streams and have a profound impact on instream resources (see **Rain on snow** below, and **Figure 7.1**).

3.6 Geologic processes

The Oregon Coast Range is a geologically active region located on a continental margin. In this region, the North American plate is overriding the Juan de Fuca plate. Subduction of the North American plate is associated with the volcanic eruptions in the Cascade Range, and with the tilting of the continental crust. As a consequence of this tectonic plate movement there has been an uplift of the continental shelf along the coastal regions of Oregon and Washington. The Oregon coast has changed rapidly during the past several million years and the organisms that live here have adapted to these changes. This changing terrain ultimately influences riverine and estuarine physical processes, and controls sedimentation on geologic time scales (after Creager et al. 1984).

The Rock Creek watershed is dynamic: change has occurred in the watershed since the retreat of the glaciers 20,000 years ago. For example, weathering and erosion were responsible for sediment delivery to the rivers that eventually drained in to what is now Siletz Bay. At the time of European settlement, the Oregon coast was in a state of slow change punctuated by catastrophic events such as storms, landslides and tsunamis. For approximately 6,000 years the sea level was nearly constant and during this time erosion and deposition preceded at a relatively uniform rate (Dicken et al.1961); however, land use dramatically changed within the watershed after European settlement.

Although the Rock Creek watershed is many miles from the Siletz estuary, it has direct influence on the estuary. Streams, rivers and estuaries integrate the cumulative effects of both natural and human-influenced watershed processes. For example, rates of sediment delivery to aquatic ecosystems are a direct result of watershed processes, which transport sediments overland in surface runoff from the uplands into the stream channels, and eventually to estuary and ocean. These processes are affected in the long term (hundreds of thousands to millions of years) by geologic processes such as land subsidence and uplift, and in the short term (decades to centuries) by land use practices, weather events, and short-term geomorphic processes.

Important short-term geomorphic processes (see **Appendix 1**) within the watershed include: soil creep, the movement of individual soil particles downslope; rock slides, the rapid movement of a mass of rocks down hillslopes; landslides, the rapid movement of a mass of soil and rocks downslope; earthflow, the movement of a mass of soil and rock downslope (usually less than one meter per year); and debris torrents, masses of logs, boulders and smaller sediments which rapidly move down tributary streams during winter storms (Nehlsen and Dewberry 1995).

3.7 Geologic formations

3.7.1 Introduction

Understanding the geologic formations that underlie the watershed helps us understand watershed processes. The bedrock geology determines how groundwater moves and thus impacts base flows of streams. In addition, geologic formations weather in characteristic ways that can help predict stream channel morphology, landslide risks, and other factors that directly impact salmonids (Hicks 1990).

The earth's crust in northwest Oregon is probably thin (less than 10 mi, or 16 km) and may be part of an ancient sea floor (Eocene) that has welded to the continent. Rocks of the Coast Range consist of Tertiary volcanics and marine sediments (Aviolio 1973).

3.7.2 Tyee Formation

The Tyee formation is the predominant formation in the Coast Range (Franklin and Dyrness 1988) and is the predominant underlying geologic formation in the Rock Creek watershed (**Figure 3.4**) (**GEO62500.SHP**). This formation consists of sedimentary rock formed from sands and silts deposited on the continental shelf during the middle Eocene (about 50 million years ago). The sandstones and siltstones of the Tyee formation weather relatively easily to form fine-textured soils. Streams formed in the Tyee formation may lack instream structure (large woody debris, boulders, etc.). This lack of instream structure, whether due to the underlying geologic formation or to land management practices, may lead to instability of gravel beds, thus limiting the availability of suitable spawning areas for salmonids.

3.7.3 Igneous intrusions

Igneous formations are more resistant to weathering and erosion than softer sedimentary rock. Therefore, many of the prominent mountains and ridges in the Rock Creek watershed and important salmonid spawning gravels are of igneous origin. In addition, several igneous rock quarries are present in the Rock Creek watershed. The watershed contains three high ridges of igneous rock protruding from the more easily weathered Tyee formation. The rock that makes up these ridges (Mafic intrusions of Tertiary igneous origin, **Figure 3.4**) originated from undersea volcanic activity. Green Mountain contains the highest point in the watershed (2,833 ft, or 863 m), and is formed from these igneous rocks. Another landscape feature formed from igneous rock is Steer Divide, the northeast-southwest trending ridge that separates the Steer Creek drainage from the Big Rock Creek drainage.

The same massive ridge of igneous rock that forms Green Mountain continues west across Big Rock Creek, as does a smaller, parallel ridge to the south. When Big Rock Creek flows across these igneous rock formations, its gradient is much steeper than in other parts of its basin, and the large, resistant rocks have created several waterfalls. The largest and steepest of these waterfalls is located about five miles upstream from the mouth of Big Rock Creek; it forms one of the natural barriers to fish passage in the watershed. These falls were described in Oregon Fish Commission surveys from 1949 and 1953 (Willis and Best 1953, Clutter and Jones 1949). At that time, a fish ladder around the falls was proposed as a means of providing salmonid access to potential habitat upstream. This ladder was apparently never constructed.

USGS 7.5 minute quads (dating from 1974 and 1984) show four quarries and two borrow pits in the watershed. All of these rock removal locations are located on igneous rock ridges in the watershed (**Figure 3.4**). In this watershed, landslides have occurred near quarries. Both of the landslides shown in the Oregon Department of Forestry's GIS system originated at quarries [**LANDSLIDE.SHP**] (**Figure 3.5**). A rapid, shallow landslide originated at the hatchery quarry in T10S R8W Sec. 7, and a landslide and debris torrent originated at the quarry at the headwaters of Beaver Creek (T10S R8W Sec. 4). Locations of these two landslides are shown on the soils map (**Figure 3.5**).

3.7.4 Quaternary sediments

The broader stream valleys in the watershed are underlain by alluvial sediments, materials deposited by streams in these valleys during the Quaternary epoch (**Figure3.4**). This alluvial material consists of both materials located on terraces above the current floodplain, located at the mouth of Rock Creek and materials deposited during more recent stream flow at or near the current floodplain level. These deposits are found along the main stem of Rock Creek and lower Big Rock Creek, along Fisher Creek, and in parts of upper Little Rock Creek.

One of the more recent geologic formations in the watershed consists of landslide debris from large, prehistoric landslides (**Figure 3.4**). Two such areas are the north flank of Green Mountain, and the northwest flank of Steer Ridge. Underlying geology here consists of poorly sorted, unconsolidated colluvium (material weathered from underlying rock and moved by slide activity). This formation may also include some blocks of igneous rock moved during the ancient landslides.

3.8 Soils

Soils and watershed processes are interrelated in many ways. Soils that have poor structural strength, high erodibility, and impermeable subsurface layers are at greater risk for landslides than strong, less-erodible, highly permeable soils. Therefore, landslide risk is partly a function of soil type; soils with high risk of slides are described below. Areas with hydric soils (soils formed under conditions of frequent, prolonged inundation or saturation) have high potential for wetland and riparian restoration.

Soils data for this assessment came from Natural Resources Conservation Service soil surveys. The Lincoln County Soil Survey (Shipman 1997) has been digitized (**LINCSOIL.SHP**), but the Polk County Soil Survey (Knezevich 1982) is not yet available digitally. Soils in the Lincoln County portion of the watershed are shown in **Figure 3.5**.

Soils associated with the watershed's igneous rock formations (**Figure 3.4**) are shallow stony loams and deep gravelly clay loams derived from igneous rock. These soils are shallow over igneous bedrock; stony outcrops of bedrock are common. Common map units include Trask shaly loam, the Kilchis-Klickitat complex, and Klickitat gravelly clay loam. Roads built on the Trask soil are considered prone to landslides, but that is not the case for the other two series (Knezevich 1982).

Soils associated with Quaternary alluvial deposits in the watershed's broader stream valleys include Eilertsen silt loam and the Nekoma-fluvaquents complex; and a few small areas of Elsie silt loam. All three soils formed in silty alluvium derived from mixed sources (Shipman 1997). Eilertsen and Elsie are deep, well-drained soils found on stream terraces. The Nekoma-fluvaquents complex consists of deep soils of mixed drainage and variable composition, found on floodplains. Most of the watershed's wetlands appear to be associated with the fluvaquent component of the Nekoma-Fluvaquents complex, in poorly drained depressions that flood frequently (see **Figure 3.16**) (U.S. Dept. of Interior NWI maps, date unknown). These fluvaquents are the watershed's only hydric soils (soils formed under conditions of frequent and prolonged inundation or saturation) (Shipman 1997, Knezevich 1982).

The main soils associated with the watershed's predominant geologic formation (the Tyee formation) are the Preacher and Bohannon series. These soils are found on most of the higher ground in the watershed. Both series formed in colluvium weathered from sedimentary rock. Associations of these series are mapped in Lincoln County (Shipman 1997; **LINCSOIL.SHP**), but only the Bohannon series is mapped in the part of the watershed lying in Polk County (Knezevich 1982). Another mapping unit associated with the Tyee formation is Apt-McDuff silty clay loam. Like the Preacher and Bohannon series, Apt and McDuff soils were formed in colluvium weathered from sedimentary rock. Roads built on Bohannon, Apt and McDuff soils are considered prone to slips and slides (Knezevich 1982).

The soils associated with the Quaternary landslide formations include Blachly silty clay loam, Klickitat gravelly clay loam; Marty gravelly loam; Astoria silt loam, and Hembre gravelly silt loam. Roads built on all of these soils except for Klickitat are considered prone to landslides (Knezevich 1982).

3.9 Land cover

3.9.1 Introduction

Land cover is an important watershed component. Land cover refers to the vegetation, houses, roads, and other materials that cover the surface of the earth. Land cover can affect (and is in turn affected by) climate, biogeochemistry, hydrology, and the diversity and abundance of terrestrial species (Turner et al. 1993). Accurate land cover information is needed in many of the assessment modules of the GWEB Manual. For example, knowledge of current land cover conditions is important in developing an understanding of sediment sources, riparian conditions, water quality, hydrologic patterns and overall watershed condition. A spatially explicit representation of land cover (i.e., a map or data layer) can be used by watershed managers to link land use activities with important watershed components, such as salmon, water quality, and sediment transport.

For this assessment, we used a geographic information system (GIS) to characterize land cover in the Rock Creek watershed. We addressed three land cover topics using the GIS: (1) prevalence of large conifers in the watershed and in riparian buffer zones; (2) prevalence of open areas; and, (3) management areas for rare, threatened and endangered species.

The best available information for land cover for the Rock Creek watershed comes from CLAMS88.   The CLAMS (Coastal Landscape Analysis and Modeling Study) data set is based on interpretation of a satellite image that was acquired in 1988 by researchers at Oregon State University. The image was classified into 14 categories, twelve of which occurred in the Rock Creek Watershed (**Table 3.2**) for the Rock Creek watershed (**Figure 3.6**). We used this land cover data source because it is based on interpretation of a satellite image (i.e., it is quantitative) and available for the entire study area. This satellite image was acquired in 1988 and represents the land cover of Rock Creek as it was 10 years ago. We considered using an updated version of the CLAMS data; however, availability and characteristics of the 1995 land cover data (**CLAMS95**) limited its utility for this analysis.

We found that most of the watershed is covered by Broadleaf Forests. Approximately 25% of the watershed is occupied by forested cover of the Large and Very Large cover class. We explored the spatial distribution of conifers in the following sections.

TABLE 3.2. Twelve categories of land cover for the Rock Creek watershed present in the CLAMS88 data set. Shown are the number of square miles and proportion of the watershed occupied by each cover class. Categories 0 = background, 2= water, and 5= cloud are not shown.

Class	**Cover Type**	**Description**	**mi^2**	**Proportion (%)**
1	Shadow	Background (portions of the data file that do not contain image information)	0.02	0.0
3	Open	Open (0-40% vegetation cover)	2.45	5.7
4	Semi-Closed	Semi-Closed (41-70% vegetation cover)	8.29	19.2
6	Broadleaf	Broadleaf (>=70% broadleaf cover)	12.1	28.0
7	Mixed, Small Conifers	Mixed broadleaf/conifer: <70% broadleaf cover, small conifers (<=1 ft [25cm] DBH)	2.94	6.8
8	Mixed, Medium Conifers	Mixed: <70% broadleaf cover, medium conifers (1-2 ft [26-50cm] DBH)	3.6	8.3
9	Mixed, Large Conifers	Mixed: <70% broadleaf cover, large conifers (2-3 ft [51-75cm] DBH)	6.04	14.0
10	Mixed, Very Large Conifers	Mixed:<70% broadleaf cover, very large conifers (>3 ft [75cm] DBH)	1.54	3.6
11	Conifer, Small	Conifer: >70% conifer cover; conifers small (<=1 ft [25cm] DBH)	1.26	2.9
12	Conifer, Medium	Conifer: >70% conifer cover; conifers medium (1-2 ft [26-50cm] DBH)	2.9	6.7
13	Conifer, Large	Conifer: >70% conifer cover; conifers large (2-3 ft [51-75cm] DBH)	1.76	4.1
14	Conifer, Very Large	Conifer: >70% conifer cover; conifers very large (>3 ft [75cm] DBH)	0.24	0.6
		Total	**43.1**	**100.0**

3.9.2 Large conifers

Conifers dominated the coastal forests of Oregon prior to European settlement (Franklin and Dyrness 1988). Human actions, especially during the past 150 years, have dramatically altered the amount and age structure of present-day forests. Remaining large conifers continue play a number of roles in the Rock Creek watershed by stabilizing soil and providing habitat for wildlife. Conifers also shade streambanks and provide large woody debris and other organic material to streams; therefore, spatial patterns of existing coniferous forests are important to fisheries managers. Resource managers need to know which catchments contain a high proportion of large conifers, and which catchments lack large conifers.

We created several different summaries from the CLAMS data. We used the ArcView command 'Tabulate Areas' to summarize the 14 land cover classes for each catchment basin. The first step was to create new cover classes by combining classes from the interpreted satellite image. We combined CLAMS cover classes to get an accurate picture of the location of large conifers within the watershed because multiple classes contained large conifers (i.e., classes 8-14).

The first combined class, "**Mixed Forest/Large Conifers"**, contains CLAMS land cover classes 9 + 10 + 13 + 14. These classes include all classes with any proportion of large conifers, even if cover is dominated by broad-leaved trees. Classes 9 and 10 contain some large conifers (>50 cm DBH), but are dominated by broad-leaved trees (i.e., have less than 70% total conifer cover). Classes 13 and 14 are dominated by large conifers (over 51 cm DBH).

The second combined class, "**Large Conifer Forest"**, contains only Classes 13+14, because these two classes are actually dominated by large conifers (>70% conifer cover). Compared to Classes 9 + 10, the environment represented by Classes 13 + 14 is much closer to the original coniferous climax forest of the Coast Range (Franklin and Dyrness, 1988). We ranked each catchment based on the calculated proportion of total cover consisting of large conifers classes. The proportion of "Mixed Forest/Large Conifers" was calculated as the area occupied by classes 9 + 10 + 13 + 14 in each catchment basin divided by the total catchment area. Second, we calculated the proportion of "Large Conifer Forest" as the area occupied by classes 13 + 14 divided by the total catchment area.

We found that most catchments in the Rock Creek basin have 10 to 40% of their area occupied by "Mixed Forest/Large Conifers" (classes 9, 10, 13 and 14 from the 1988 CLAMS data). Only 22 out of 347 catchment basins had more than 60% land area in "Mixed Forest/Large Conifers" (**Figure 3.7**). **This indicates that the majority of land surface in the watershed is occupied by forests containing <u>no</u> large conifers.**

Since categories 9 and 10 contained large conifers, but were not conifer-dominated, we also analyzed catchments for proportion of "Large Conifer Forest" (classes 13 and 14).

These two conifer-dominated classes are more indicative of mature timber, which in this part of the coast range is dominated by Douglas-fir (*Pseudotsuga menziesii*), western hemlock (*Tsuga heterophylla*), and western redcedar (*Thuja plicata*) (Franklin and Dyrness 1988). To determine the proportion of Large Conifer Forest in each catchment, we interrogated the **CLAMS88** data set as described above.

As expected, **we found the proportion of each catchment occupied by "Large Conifer Forest" to be much smaller than the proportion occupied by "Mixed Forest/Large Conifers."** In fact, only 42 out of 346 catchments had more than 5% of their area dominated by large conifers. (We chose a lower threshold for this analysis, 5% instead of the 60% used for "Mixed Forest/Large Conifers", because a higher threshold would have resulted in no catchments depicted.) The locations of these catchments are shown in **Figure 3.8**. The total land area covered by large conifers is about 2,633 ac (1,066 ha) out of the watershed's total 27,500 ac (11,150 ha).

3.9.3 Large conifers in riparian areas

Interestingly, if a 200 ft. riparian buffer zone were constructed around each stream on our base map, it would cover approximately a quarter of the land area in the Rock Creek watershed. (If this buffer zone were constructed only around fish-bearing streams, the area covered would be far less. Unfortunately, digital data on the limits of fish use were not available for this study.) The **RIPVEG6** layer on the MCWC CD-ROM was derived from the CLAMS88 data set and described the land cover in a 200 ft riparian buffer zone around the streams in our base map. We summarized "Mixed Forest/Large Conifers" and "Large Conifer Forest" for this stream buffer area as described above.

We found that very few catchments had large conifers in the riparian area. Only 10 catchments had more than 70% "Mixed Forest/Large Conifers" in the 200 ft riparian buffer area. Thirty-nine catchments had more than 5% cover of "Large Conifer Forest" in the riparian buffer area. The positions of these catchments within the Rock Creek basin are shown in **Figures 3.9** and **3.10**.

Catchments shown in **Figures 3.7- 3.10** are areas in the Rock Creek watershed that are likely to have large woody debris recruitment to streams, and cooler stream temperatures due to riparian shading. It is important to keep in mind that the information in the CLAMS data set is based on a "snapshot" of the watershed as it was in 1988. Current conditions may be different and should be verified.

3.9.4 Large Conifer Index

A "Large Conifer Index" was created in order to rank each catchment on the basis of large conifer cover, within the entire catchment and within the 200 ft. buffer zone. An index is useful because it summarizes the results presented in **Figures 3.7-3.10**.

The Large Conifer Index was created in the following manner. If 70 to 80% of the catchment had Mixed Forest/Large Conifers, the index score was set at 2. If 60 to 70% of the catchment had Mixed Forest/Large Conifers, the index was set at 1. If more than 5% of the catchment had Large Conifer Forest, 2 points were added to the index score. For catchments with 1 to 5% of their area occupied by Large Conifer Forest, 1 point was added. For catchments with Mixed Forest/Large Conifers in more than 70% of the 200 ft riparian buffer, 2 points were added to the index. For catchments with Mixed Forest/Large Conifers in 60 to 70% of the riparian buffer, a 1 was added. Finally, if more than 5% of the riparian buffer had Large Conifer Forest, a 2 was added to the index score. If the riparian buffer had between 1 and 5% Large Conifer Forest, then 1 was added. The resulting index scores ranged between 0 and 6.

We found that most catchments had a Large Conifer Index score of 0, indicating that most catchments have low proportions of large conifer cover. Only 6 catchments received a score of 4; one received a score of 5 and one received a score of 6. These areas should be verified and considered for future management actions. The locations of these catchments are shown in **Figure 3.11.**

3.9.5 Open Areas

In addition to the presence of large conifers in the watershed, we were also interested in locating catchments that were relatively open. These open areas represent meadows and pastures, as well as recently harvested timberland. Open areas also play a role in rain-on-snow events and in slope failures (see **Climate**, above, and **Landslides**, below). We considered open areas to be Class 3 (open) of the **CLAMS88** layer. We calculated the proportion of open area as Class 3 divided by the total area of each catchment basin (**RCOPEN&1000-2.SHP**). **We found that 621 ha were classified as being open (5.5% of the total Rock Creek watershed).** The locations of catchments with more than 10% open area are shown in **Figure 3.12**.

3.9.6 Discussion: CLAMS data

The CLAMS88 data provide a picture of which catchments in the Rock Creek watershed had large conifers in 1988. The categories used in the CLAMS88 classification are useful, since they show which forest areas had large conifers in mixed forest, not just which forest areas were dominated by large conifers. Even if a forest is dominated by broadleaves, large conifers present in the mixed forest can provide important wildlife habitat, large woody debris, and other functions to the watershed.

Additional metadata for the CLAMS88 layer would be desirable. For instance, a description of the methods used to interpret the satellite images would be helpful. Also, more detailed interpretation of non-forest cover would be helpful for watershed assessment purposes. For example, the nature of the vegetation in the "open" and "semi-closed" categories is left unspecified. Hydrologic assessment of these catchments depends on the nature of this vegetation: e.g., peak flows and runoff rates are different for grasslands versus shrub-dominated land (NonPoint Source Solutions 1997).

3.9.7 Historic forest age classes

Fire and logging (generally clear cutting in this region) are two important ecological forces that have a direct impact on successional patterns and, therefore, land cover. Fire opens the forest canopy by removing trees and allows herbaceous and shrubby vegetation to become established, often in irregular (heterogeneous) patterns (Franklin and Dyrness 1988). Consequences of the conversion of forest to non-forest may include changes to hydrology (water movement: Jones and Grant 1996) and to the abundance of wildlife that depend on forested areas. Gradually, over time, the herbaceous and shrubby plants are replaced by trees and the forest becomes re-established. The effects of fire and tree removal can last for many years. Re-establishment of a "characteristic" understory and important forest processes (e.g., gap dynamics) generally begin 100 to 150 years following a disturbance (Franklin and Dyrness 1988). In addition, sediments entering the stream network following a forest fire, may take decades to work their way to the receiving estuary.

Maps of forest stand age classes from 1850 to 1940 (BLM 1991) and 1914 (**TIMBER1914.SHP**) (**Figure 3.13**) show that widespread forest fires burned most of the watershed during the last half of the 19th century and the first half of the 20th century. [The 1850 to 1940 maps are not included in this report because they were compiled from surveyors' notes at a scale of 1:850,000, and therefore lack the spatial accuracy needed for this watershed assessment.] The proportion of trees killed by these historic forest fires cannot be determined from the data available.

In the Upper Siletz watershed, just north of the Rock Creek watershed, historic wildfire disturbance most likely caused only partial stand destruction in most areas (BLM 1996). Fires in the Upper Siletz watershed may therefore have served to thin the forest stands. These stands may have different present-day conditions than areas where crown fires killed all trees and resulted in a dense, even-aged stand.

3.9.8 Rare, threatened and endangered species

There are a number of rare, threatened and endangered species that do and could potentially exist in the Rock Creek watershed. The National Marine Fisheries Service (NMFS) has listed coho salmon populations on the Oregon coast as threatened and the USFW has listed the Northern spotted owl and marbled murrelet as threatened. In addition, steelhead and coastal cutthroat trout are listed as candidates for listing (Table 3.2).

TABLE 3.3. Summary of the current status of Oregon Coast Salmonid Evolutionarily Significant Units. (Source: http://www.nwr.noaa.gov/1salmon/salmesa/index.htm).

Fish	Status	Notes
COHO	Threatened	Oregon Coast Evolutionarily Significant Units (ESU) were listed as a threatened species on August 10, 1998. The ESU includes all naturally spawned populations of coho salmon in Oregon coastal streams south of the Columbia River and north of Cape Blanco. Major river basins containing spawning and rearing habitat for this ESU comprise approximately 10,606 square miles in Oregon.
CHINOOK	None	On March 9, 1998, NMFS determined that listing was not warranted for the Oregon Coast CHINOOK ESU. The ESU includes all naturally spawned populations of Chinook salmon in Oregon coastal basins north of, and including, the Elk River. Major river basins containing spawning and rearing habitat for this ESU comprise approximately 10,604 square miles in Oregon.
CHUM	None	On March 10, 1998, NMFS determined that listing was not warranted for this Pacific Coast Chum ESU. The ESU includes all naturally spawned populations of chum salmon from the Pacific coasts of California, Oregon, and Washington, west of the Elwha River on the Strait of Juan de Fuca. Major river basins containing spawning and rearing habitat for this ESU comprise approximately 10,152 square miles in Oregon and Washington.
STEELHEAD	Candidate	On March 19, 1998, NMFS determined that listing was not warranted for the Oregon Coast Steelhead ESU. However, the ESU is designated as a candidate for listing due to concerns over specific risk factors. The ESU includes steelhead from Oregon coastal rivers between the Columbia River and Cape Blanco. Major river basins containing spawning and rearing habitat for this ESU comprise approximately 10,604 square miles in Oregon.
COASTAL CUTTHROAT	Candidate	On April 5, 1999, NMFS determined that listing was not warranted for the Oregon Coastal Cutthroat ESU.

Fish	Status	Notes
		However, the ESU is designated as a candidate for listing due to concerns over specific risk factors. The ESU includes populations of coastal cutthroat trout in Oregon coastal streams south of the Columbia River and north of Cape Blanco (including the Umpqua River Basin, where cutthroat trout were listed as an endangered species in 1996). Major river basins containing spawning and rearing habitat for this ESU comprise approximately 10,606 square miles in Oregon.

The occurrence of one rare plant species also has been reported in the watershed; others may exist. *Filipendula occidentalis*, a Species of Concern in Oregon (Oregon Natural Heritage Program 1998), has been reported from the western portion of the watershed. This identity of this plant should be confirmed by the Oregon State University herbarium staff, and general areas where it occurs should be recorded.

The Endangered Species Act requires protection of forests in and near habitat used by threatened and endangered species. There is a strong tie between the occurrence of many rare species and land cover. For example, loss of late-successional forests may be accompanied by declines in important species such as the northern spotted owl, marbled murrelet, and salmon (Tuchmann et al. 1996). Therefore, an understanding of the patterns in land cover can lead to a better understanding of factors necessary to conserve these important organisms.

Large government and industrial landowners in the watershed are preparing plans for habitat conservation to help protect these rare species. The Oregon Department of Forestry is developing a Habitat Conservation Plan (HCP), expected to be completed in 1999 (Rob Nall, personal communication, 1999), which will detail forest management practices within habitat used by rare species. For the time being, ODF has provided rough outlines of management areas for threatened and endangered species in the Rock Creek watershed. There are two such management areas located within the Rock Creek watershed (**Figure 3.14**). One of the two management areas is located just northeast of Logsden; the other is along the steep section of Big Rock Creek between Fall Creek and Lucas Creek. These management areas provide nesting areas for threatened marbled murrelet (*Brachyramphus marmoratus*) and/or northern spotted owl (*Strix occidentalis*) (Rob Nall, ODF, personal communication 1999).

3.9.9 Timber harvest plans

Information on timber harvest plans is not available from private industrial landowners. However, ODF provided data layers containing sales since 1994, and planned sales as of 1999. These sale areas are shown in **Figure 3.14**. Knowing where timber harvests are planned can help the Siletz Watershed Group make decisions on where to locate watershed enhancement and monitoring activities (see **Data recommendations** below).

Land in the watershed owned by the Bureau of Land Management (BLM) is mostly designated as Late-Successional Reserves (LSR) (Bureau of Land Management 1995). LSR areas are generally managed to maintain late-successional and old-growth forest conditions. According to BLM personnel (Randy Gould, personal communication, 18 June 1999) there have been 548 acres of timber harvest in this watershed during the past 30 years. In Section No. 27, 303 acres have been pre-commercially thinned and 323 acres fertilized. Some smaller areas in the watershed are Adaptive Management Areas; harvest strategies for these areas are intermediate between Matrix lands (managed primarily for timber harvest) and LSRs (Bureau of Land Management 1995). On BLM administered lands an additional 240 acres can be pre-commercially thinned, 124 acres commercially thinned, and 118 acres can undergo hardwood conversion during the next 10 years (Randy Gould, personal communication, 18 June 1999). No regenerating harvest is planned for the next 10 years (Randy Gould, personal communication, 18 June 1999).

3.10 Channel types

The current condition of the stream channels in Rock Creek is the result of interactions between geology, climate, terrain, disturbance (past and present), and biological factors, particularly beaver (see Appendix in Non-Point Source Solutions 1997). For example, the geology determines how resistant bedrock is to weathering and whether gravel will be present in stream channels (***see Geology***). The climate, in part, determines what type of vegetation could potentially cover the watershed and the amount of precipitation and its timing (seasonality). Disturbances, like fire, road building, and logging, determine which areas of the watershed are forested or not. The duration and intensity of flood peaks, in turn, are influenced by patterns in vegetation, precipitation and terrain. Flood peaks are responsible for eroding and down-cutting stream channels, transporting sediments, and ultimately produce the patterns in pools and riffles and the channel types that we recognize. Beaver harvest trees and shrubs within the riparian area and build dams that create salmon habitat such as ponds, backwater wetlands, and overflow channels. The features of streams that we recognize as “good salmon habitat” are the result of the interplay of all of these factors.

Aquatic Habitat Inventory (AHI) data on channel forms and digital elevation models (DEM) were used to place stream channels into types as described in the 1998 Draft GWEB Watershed Assessment Manual (Watershed Professionals Network 1999). [AHI data are described in more detail in **Aquatic Habitat Inventory data**, below.] Channel form descriptions from AHI reach-level data describe channel confinement and confining terrain (terraces, hill slopes, or bedrock). We divided these AHI channel forms into the GWEB Manual channel types by incorporating gradient information from **SYA_HYD6.** The results are shown in **Figure 3.15**.

Interestingly, all channels in the watershed met the GWEB Manual criteria for classification as "confined" (stream channel confined by landscape features at a width less than twice the active channel width, see Appendix IIIA in Non-Point Source Solutions 1999). Variability among channel types in the Rock Creek watershed was, therefore, limited to gradient classes and landscape position.

Channel types represented in the watershed are:

Code	Description	Gradient	Confinement
LC	Low-gradient confined	<2%	confined
MC	Moderate-gradient confined	2-4%	confined
MH	Moderate-gradient headwater	2-8%	confined headwater stream
MV	Moderate-gradient narrow valley	4-8%	confined narrow valley
BC	Moderate to steep-gradient, bedrock confined	4-16%	bedrock-confined
SV	Steep-gradient narrow valley	8-16%	confined narrow valley
VH	Steep-gradient headwater	>16%	steep headwater stream, confined

It is important to note that channel characteristics can vary within a given channel type. Channel form was recorded by AHI crews **only** at the reach level (see **Aquatic Habitat Inventory data** below). Habitat units within a given reach can and do vary from the overall reach-level channel form. For example, although all reaches surveyed by AHI crews were assigned to "confined" channel types, lower Steer Creek has areas of backwater wetlands, which flood during high flows, and the NWI wetland map (**Figure 3.16**) shows several other wetlands adjacent to streams. Backwater wetlands are typical of floodplain channel forms, not confined channel forms. By extension, other stream segments in the watershed may have active floodplains despite the "confined" classification of the reaches in which they lie. The biological importance of these segments is magnified when the stream is predominantly confined, because backwater wetlands and floodplain side channels form refuges for fish escaping from high velocity flows in the main channel. In particular, reach-level channel typing may not capture small habitat units like beaver ponds. Beaver ponds appear to be very important winter habitat for juvenile coho (Nickelson et al 1992). So, when considering channel types described in this report, it is important to remember that fish will seek out appropriate habitat in the landscape, even when that habitat is not detected by our data gathering methods.

3.11 Past watershed assessment efforts

A Draft Rock Creek Watershed Assessment/Action Plan was developed by local landowners and members of the Siletz Watershed Group in 1997 (Siletz Watershed Group 1997). This assessment contained narrative commentary and a series of questions on issues of concern to the group. We have used the Draft Rock Creek Watershed Assessment/Action Plan to provide focus for this assessment.

Only one federal watershed analysis has been conducted near the Rock Creek watershed: the Upper Siletz Watershed Analysis (BLM 1996). The Upper Siletz watershed shares many characteristics in common with the Rock Creek watershed, so the BLM analysis provided useful background information relevant to the Rock Creek assessment and is referenced in this report.

3.12 Existing watershed restoration projects

The Siletz Watershed Group has been active in addressing watershed issues. Watershed restoration projects in the Rock Creek watershed have been accomplished by this group, and by several other organizations, including the Hire-the-Fisher program, the Confederated Tribes of the Siletz Indians, the Oregon Department of Fish and Wildlife, and Georgia Pacific (The Timber Company).

Records of restoration projects in Oregon watersheds are maintained by the Governor's Watershed Enhancement Board (GWEB). We obtained restoration project ID numbers, locations of projects, and project types from a GWEB database. **Figure 3.17** shows locations and types of projects in the GWEB database for Rock Creek watershed. GWEB project types in the Rock Creek watershed included riparian (fencing, plantings, riparian hardwood conversion, and retention of riparian conifers in excess of ODF Forest Practices Act requirements), instream (e.g., placement of large woody debris), and road projects. Project numbers shown below refer to GWEB ID numbers.

Projects 96, 99, 1218, 1219: Several areas of active streambank erosion along Rock Creek have been addressed through riparian fencing carried out by the Hire-the-Fisher crew from 1995 through 1998. A total of 6,310 ft (1,923 m) of fencing was installed along Rock Creek, and 3,000 ft (914 m) along Little Rock Creek, for the purpose of keeping livestock off streambanks. Drinking water for livestock was provided through installation of off-stream watering units (nose pumps) where needed. The Hire-the-Fisher crew also did riparian plantings at one location on Little Rock Creek, one location on Big Rock Creek, and one location on Rock Creek. Willows were planted to stabilize streambanks, and shade tolerant conifers such as cedar and hemlock, and some Douglas-fir were planted in riparian areas.

Project 1182: In 1997, Simpson Timber Company upgraded seven culverts and replaced one culvert with a bridge on a road near Little Rock Creek; this project also included 3 miles of ditchline improvement, a log weir, and alcove construction.

Projects 759, 803-805: In 1995 through 1997, Georgia-Pacific applied ODF forestry measures to a series of segments of Fall Creek. Measures included riparian hardwood conversion, retention of conifers in excess of Forest Practices Act requirements, retention of snags and wood along small non-fishbearing streams, and re-allocation of in-unit leave trees.

Project 104: In 1996, Oregon Tree Farms decommissioned 200 ft of road, cleaned 1800 ft of ditches, and upgraded a culvert on a road near Little Steer Creek; this project also included riparian conifer plantings and competition control and ditch cleaning.

Project 423: In 1996, ODFW completed 100 ft of bank stabilization, built a rock weir, and created complex pool habitat by placing a debris jam/habitat structure (4 pieces of large woody debris) in the channel at about Mile 2.5 of Steer Creek.

Project 1310: In 1997, ODFW stabilized 90 ft of streambank using logs and rock, built a 60 ft alcove, and placed large woody debris at 4 sites on Big Rock Creek.

4 Fisheries and aquatic organisms

4.1 Introduction

Watershed processes that impact salmonid habitat are a major focus of the GWEB Watershed Assessment Manual. Streams in which salmonids live are conduits for a large proportion of the energy and materials flowing through the watershed's ecosystem. In addition to watershed processes and instream habitat, a watershed assessment also needs to address the current condition of salmonid populations and those of other valued aquatic organisms. As for many other data categories used in this assessment, only limited data are available on salmonid or other fish populations in the Rock Creek watershed. In this section, we summarize and update available information on fish populations (please see **Data gaps and data limitations).** Filling gaps in our knowledge of fisheries population data is a major focus for the Governor's Coastal Salmon Restoration Initiative. In addition, the Oregon Department of Fish and Wildlife (ODFW) is currently developing statewide monitoring programs to improve our knowledge of these valued species (see the Oregon Plan website at *www.oregon-plan.org* for more details).

Many salmonids have complex life histories and occupy many areas of coastal watersheds at one time or another. Salmonids are also sensitive to natural and man-made changes to watersheds. For these reasons, salmon are often referred to as indicator species (see Non-Point Source Solutions 1997, Tuchmann et al. 1996, Bottom et al. 1998, Wissmar and Simenstad 1998). Knowledge of the abundance and distribution of salmon in the Rock Creek watershed is useful as a quantitative benchmark so that management actions can be evaluated (i.e., are management actions having a positive effect on the condition of the watershed necessary to support desired levels of salmonid populations). Surveys generally conducted to acquire population information.

Generally, the primary objective of a survey is to determine the current status of salmonid populations. In Oregon, juvenile surveys, spawning surveys, harvest records, adult escapement surveys, or hatchery releases are often used to assess salmonid populations. Each of these methods targets a subset of the actual salmon population at any time. In other words, each of these methods attempts to infer characteristics of the entire salmonid population from a smaller sample. Statistics is the branch of science that allows us to draw conclusions from and evaluate the reliability of observations (Zar 1984). How well a particular survey's results reflect the "real" number of salmon can be evaluated using well-established statistical methods. Information on the survey method and the confidence in a particular observation must be reported along with the actual observation for that number to be useful as a quantitative benchmark. Scientists refer to general observations and observations lacking statistical assessments as anecdotal information. Although anecdotal information can be useful, this information cannot be used to establish quantitative benchmarks and has limited value in monitoring the effects of management actions.

For the Rock Creek watershed, information on salmonid populations comes from data collected using a variety of survey techniques, i.e., juvenile surveys, spawning surveys, commercial harvest, hatchery counts, etc. Fisheries managers look at the results from these surveys and the confidence associated with each measurement to determine how well the overall salmon population is doing.

4.2 Coho (Onchorhynchus kisutch)

Like coho (*Onchorhynchus kisutch*) in most of western Oregon, coho populations in the Siletz River basin as a whole are considered dangerously depleted and unstable (ODFW 1997a). Long-term survey data on numbers of spawning adult coho are not available for the watershed, but anecdotal evidence suggests that coho were far more abundant about 50 years ago. In the 1948 run, 5,000 coho (silver salmon) were dipped over the permanent hatchery racks and were later observed in numbers of 10 to 12 individuals per riffle from the hatchery to the head of Little Rock Creek (Clutter and Jones 1949).

Juvenile surveys (snorkel surveys) conducted in the watershed in 1998 showed very low numbers of coho juveniles in general. Juvenile populations were reported as juveniles per square meter of stream; 1.5 coho/m^2 is considered fully stocked for the purposes of the rapid bioassessment. The highest coho juvenile densities in the watershed were at William Creek, where coho juvenile density averaged 1.5 coho/m^2; in a section of upper

Steer Creek (0.8 coho/m^2), and in a tributary of Little Steer Creek (0.6 coho/m^2) (**Figure 4.1**), where the average density was 0.47 coho/m^2 (Steve Trask, personal communication 1999). Steer Creek in general also has relatively high coho densities (Bob Buckman, ODFW, personal communication).

Typical commercial coho harvests in the Siletz River and Siletz Bay in the late 1800s and up to about 1940 ranged from 10,000 to 30,000 fish each year. The commercial fishery declined to near zero by 1956 and was closed in 1957 (Morgan 1964).

Results from randomized spawner surveys for the Siletz Basin as a whole since that time clearly indicate severe declines. Randomized spawner escapement surveys for coho show escapement of 400 to 2500 individuals during the early 1990's, declining to 200 to 800 individuals in the late 1990's, compared to the commercial catch of 10,000 to 30,000 fish per year in the early part of the century (Jacobs 1999).

Sport catch of coho in the main stem Siletz River and Siletz Bay during 1975-77 was around 1600 fish, but averaged around 300 individuals in the late 1970's through the mid-1990's. (Sport catch is considered a less reliable estimate of fish populations than randomized adult escapement surveys.) Sport catch of coho in Rock Creek and Little Rock Creek has been highly variable during the period of record (1975 through 1996). Sport catch averaged 304 fish during three relatively good years (1984-86), but was under 100 fish each year from 1988 through 1994. Most streams were closed to coho angling in 1994. Some coho harvest still occurs in the watershed; ODFW maintains a cultural fishery agreement with the Confederated Tribes of the Siletz Indians, allowing a total annual harvest of 200 salmon per year of any species from sites on Rock Creek and at two other locations on lower Siletz tributaries (Bob Buckman, ODFW, personal communication).

Coho status in the watershed is complicated by the influence of hatchery releases (Stewart 1963; Stickell 1979). The Oregon Department of Fish and Wildlife reared salmon at the Siletz River Hatchery on Rock Creek from 1937 until 1987 (Rousseau 1987). The hatchery collected coho eggs and reared coho (also called "silver salmon" in the hatchery documents) and steelhead. Fall Chinook of Columbia River origin were also transferred to the hatchery in some years (Stewart 1963). A total of 3 million fall chinook fingerlings were released from the hatchery into Rock Creek, but no adults returned as a result of these plants.

Presently, coho eggs used in the Siletz hatchery were both from local breeding stock trapped at the facility, and from stock from other Coast Range runs.

Fingerlings of all species reared at the hatchery were released into Rock Creek; a few were released into the Yaquina River and its tributaries. After 1987, rearing was discontinued at the hatchery, but the facility was used to capture brood stock for the rearing program at the Salmon River hatchery (Rousseau 1987). Recently, the Confederated Tribes of the Siletz Indians received a grant from the Oregon Economic

Development Department to refurbish the hatchery (Bob Buckman, ODFW, personal communication).

To supplement the Siletz Tribal fishery, the Oregon Department of Fish and Wildlife continues to release coho smolts into Rock Creek at the hatchery site. Number of smolts released was between 200,000 and 1 million from 1970 to 1995. Between 1996 and 1998, 25,000 smolts were released each year, and ODFW plans to release 50,000 in 1999. Currently, all 50,000 smolts released in the Siletz River system are released into Rock Creek at the Rock Creek hatchery site. Smolts released have been a mix of stock from Trask River, Alsea River and Siletz River populations. Adult returns from these releases have been poor. The hatchery is being renovated for the purpose of native stock production, education, and research (Bob Buckman, ODFW, personal communication).

Influence of hatchery stock on coho runs in the watershed is high. Scale analysis shows that the majority of adult spawners returning to the watershed are of hatchery origin. Scale analysis was conducted on a total of 112 returning adult coho in the years 1990 through 1997. Of these, 85 were hatchery returns (Borgerson and Bowden 1991 - 1997). Because of this strong hatchery influence over the local coho run, the approach used to manage the hatchery will be critical to the success of the coho run in the Rock Creek watershed (Bob Buckman, ODFW, personal communication).

Land use and stream characteristics in the Rock Creek watershed may relate closely to coho status. Coho "hot spots" (**Figure 4.1**) recorded during snorkel surveys (Trask 1998) are located in middle-to-upper reaches of the major tributaries to Rock Creek. These reaches have narrow channels compared to the Rock Creek mainstem, and the channels are still largely shaded (**Figure 5.7**). Consequently, water temperatures in these upper reaches may still be relatively cool compared to the lower reaches of streams in the watershed, where shading is now limited (unfortunately, comparative water temperature data are not available for these reaches). The upper stream reaches are also more heavily used by beaver, because the narrower streams are more easily dammed. Beaver ponds and alcoves are important winter habitat for juvenile coho (Nickelson et al 1992).

4.3 Fall and Spring Chinook (Oncorhynchus tshawytscha)

Fall Chinook runs in the Siletz River Basin, as a whole, are considered healthy (ODFW 1997a). However, commercial chinook harvest data from the Siletz earlier in this century showed a steady, sharp decline, and sport catch has also declined. Fall Chinook status in the Rock Creek watershed is related to watershed characteristics. Fall Chinook spawn in tributaries like Rock Creek or in the mainstem Siletz River; juveniles rear in the mainstem (Nicholas and Hankin 1988). Fall Chinook juvenile densities are high in the Siletz mainstem, and juvenile size is small, suggesting that competition exists for resources in the rearing areas (Bob Buckman, ODFW, personal communication 1999). Data from regular adult spawner counts at the mouth of Big Rock Creek consist of small numbers, and the counts began only in the 1950's, so they may not reveal trends earlier in the century. Counts ranged from 20 to 40 individuals during the period 1952 to 1974;

counts declined during the 1970's and rebounded in the late 1980's. Recent counts ranged from 40 to 80 adults (ODFW 1997a). Location of the spawner counts is shown in **Figure 4.1**.

Sport catch of Fall Chinook in Rock Creek and Little Rock Creek from 1975 to 1986 was low and variable, generally under 50 fish each year, with no discernible trend. However, sport catch of fall in these streams did decline noticeably after 1989, with an average of under 10 fish caught per year. The significance of this reduced sport catch is unknown; adult spawner counts at Big Rock Creek do not follow this declining trend.

Since sport catch data do not cover the early part of the 20th century, early commercial chinook harvest data are of interest. These data show a steady, sharp decline in commercial chinook harvests in the Siletz River basin, from about 225,000 pounds in 1923 to about 20,000 pounds in 1949 (Smith 1956).
The ODFW Siletz River Basin Fish Management Plan shows Spring Chinook spawning and rearing habitat in Rock Creek up to the mouth of Big Rock Creek. However, no data were available for Spring Chinook populations in the watershed. The Spring Chinook run in the Siletz River Basin, as a whole, is probably only a few hundred fish each year (ODFW 1997a).

4.4 Steelhead (Oncorhynchus mykiss)

Winter steelhead are native to the Rock Creek Watershed, and are not stocked in the watershed (ODFW 1977). Steelhead numbers in the Rock Creek basin are low; this may relate at least partly to bedrock geology of the watershed. Steelhead seem to be best adapted to streams flowing through basaltic (igneous) geologic formations, while coho occupy similar streams in areas of sedimentary geology (Bob Buckman, ODFW, personal communication 1999).

Factors controlling steelhead populations are little known, but sport catch of steelhead in the Siletz Basin as a whole indicates a sharp decline in wild stocks since the mid-1980's. Sport catch in Rock Creek and Little Rock Creek shows a similar trend, with average catch in both streams around 40 fish each year from 1977 through 1986, but dropping to an average of 13 fish each year from 1987 through 1997 (records show zero catch in 4 out of 5 years since 1992).

Scale analysis for steelhead caught in Drift Creek (Siletz) and the Siletz basin as a whole show strong hatchery influence in recent years. To address concerns over wild steelhead survival, recent hatchery releases have been produced from local native stock (ODFW 1997a).

4.5 Cutthroat (Oncorhynchus clarkii)

Cutthroat trout are widely distributed in small streams throughout the Coast Range. The species has resident populations, which do not migrate far from their spawning grounds; fluvial populations which migrate to large rivers to reach maturity; and anadromous (searun) populations which migrate to the ocean after 2 to 4 years of rearing in headwater streams. The population of resident, fluvial and searun cutthroat trout in the Siletz Basin is little known, but angler information seems to indicate a recent decline in searun populations. Declines in both hatchery and wild searun cutthroat populations have been documented in the Umpqua, Siuslaw, and Alsea basins. Due to this decline, ODFW has closed down cutthroat harvest in coastal streams until information collected shows that populations are increasing. Hatchery stocking of searun cutthroat has been discontinued (ODFW 1997a).
A resident population of cutthroat trout has been documented in Big Rock Creek above the falls at Fall Creek and Lucas Creek.

4.6 Pacific lamprey (Lampetra spp.)

Downey et al. (1993) interviewed local Siletz Tribe members and other local residents for information on the history of lamprey populations and harvest in the watershed. Lamprey are known locally as eels, and were a mainstay of the diet for local people growing up in the Rock Creek watershed during the 1930's, 1940's and 1950's. The Oregon Department of Fish and Wildlife has no data on lamprey populations (ODFW 1997a), but notes that lamprey throughout the state of Oregon have undergone pronounced declines in recent years. The State of Oregon has designated Pacific lamprey as a sensitive species.

Interviewees described abundant lamprey and large lamprey harvests up until the 1980's. Fishers described good lamprey runs in the late 1960s and early 1970s, but poor runs in the past decade. Lamprey were hooked from April through July, though some people reported hooking lamprey into the winter.

One favorite lamprey hooking spot was the bedrock platform at the mouth of Rock Creek (just downstream from the Logsden Store), but interviewees said hooking was good in many other spots with good riffles. Hooking was the main method of lamprey harvest, but older people also remember trapping lamprey in basket traps.

There is no regulation of lamprey harvest in freshwater in Oregon. Factors related to lamprey decline are assumed to be similar to factors contributing to salmonid declines. Therefore, ODFW assumes that actions taken to recover salmonid habitat will also benefit lamprey.

In oral interviews (Downey 1993), Siletz tribal members and other local residents attribute the decline of lamprey to several factors, particularly timber harvest practices that removed vegetation along streambanks. They also attribute lamprey decline to siltation in streambeds; water pollution from herbicide spraying; water pollution from nutrients that create algal blooms; water temperature changes; and rumored past government lamprey eradication programs.

ODFW recognizes the cultural importance of the lamprey fishery to the Siletz Indian tribe, and maintains a policy of managing the Siletz River Basin for wild production of Pacific lamprey. Actions recommended in the Fish Management Plan include data collection, habitat protection and restoration, and further research on lamprey life history and habitat requirements (ODFW 1997a).

Stan VanDeWetering at the Confederated Tribes of the Siletz Indians is currently investigating lamprey habitat requirements. His research includes characterization of benthic macroinvertebrate populations. Some field data have been collected for this study, and interpretation is underway.

4.7 River mussels

Local residents described large beds of river mussels (species unknown) in the watershed in past decades, but these have declined in recent years (Downey 1993). The only locations where AHI survey crews noted freshwater mussels were along Steer Creek (see **Figure 4.1**). Mussels are filter feeders adapted to higher-order streams, and are sensitive to increased sediment loading. Levels of fine sediment in the sections of Steer Creek with mussels were undesirably high (**Figure 5.5**).

4.8 Beaver

According to journals kept by early settlers, beaver occurred in most of the streams along the Oregon Coast, even in tidewater streams (Guthrie and Sedell 1998). Undoubtedly, beaver are an important component of the Rock Creek watershed. More than any other animal in the watershed (except for man), beaver affect stream morphology and create habitats that appear to be very important to salmon. For example, beaver ponds are preferred winter habitat for juvenile coho, and the availability of winter habitat is considered a limiting factor in production of wild coho smolts in Oregon coastal streams (Nickelson *et al* 1992).

To our knowledge, beaver populations have not been documented in the Rock Creek watershed. Some data on locations of beaver dams is found in the Aquatic Habitat Inventory data; analysis of that data for areas that support beaver populations is recommended (see **Data recommendations** below). Areas that are prime beaver habitat are probably not suitable areas for conifer plantings in the riparian zone (see **Watershed enhancement recommendations** below).

Beaver and humans interact intensively in the watershed. Beaver cut trees and shrubs from the riparian zone and can severely reduce survival of conifer plantings. Beaver dams can block culverts, leading to flooding of roads and subsequent washouts. Some suggestions for managing beaver in the watershed are found in **Watershed enhancement recommendations** below.

4.9 Other vertebrates and invertebrates

Stan VanDeWetering at the Confederated Tribes of the Siletz Indians is currently conducting research on benthic macroinvertebrate populations and diversity in the watershed. The data are not yet compiled, but should provide insight into these organisms that are the major food source for salmonids and other anadromous fish. Because aquatic macroinvertebrates have specific environmental requirements, they are good indicators of environmental conditions within a stream (see **Aquatic and riparian habitats** in **Ecosystem processes in watershed development**, Appendix 1). Monitoring benthic invertebrates could be a good way to evaluate the impact of watershed management activities (see **Monitoring recommendations** below).

5 Aquatic habitats

5.1 Introduction

Many factors can affect the abundance and distribution of salmon. By the very nature of their life histories, salmon populations are affected by factors in rivers, estuaries and the oceans (see McMurray and Bailey 1998). Factors can be either physical or biological and together influence "salmonid habitat." For example, salmon populations can be indirectly affected by the availability nutrients, which determine how well the food web (algae and insects) can support higher trophic levels, like salmon. Salmon populations can also be affected by the availability of suitable spawning beds (which are influenced by the interplay of land cover, climate, geology and terrain, see Section 3.10 and Appendix I), disease, and predators (see Wissmar and Simenstad 1998). To complicate matters, all of these factors can vary in space and time making it difficult to isolate and remedy individual factors. For this reason, many people feel that it is the entire watershed that must be managed to support salmon populations, not just individual components of aquatic habitat.

Watershed alterations by humans have altered the watersheds where the salmon have evolved. Historically, humans have used rivers for food and water sources and the transportation of materials and wastes. Odum (1975) reports that rivers are among the ecosystems most intensively used by humans. Alterations have been both biological and physical. For example, humans have directly or indirectly introduced non-native organisms (e.g., Reed canary grass, Pacific Oysters, dairy cows, etc., see Thom and Borde 1998) into or have otherwise altered the biologic communities (through forest and agricultural practices) of coastal watersheds. Humans have manipulated, directly and indirectly, the physical structure of watersheds (i.e., road building and stream channel modification, altered surface runoff and hydrology). For these reasons, most salmon inventory and restoration work centers on “the altered physical salmon habitat". The Aquatic Habitat Inventory program is an example.

5.2 Aquatic Habitat Inventory data

Much of the data for this section of the assessment was gathered using the Aquatic Habitat Inventory (AHI) procedure. The AHI is a standardized protocol for field stream surveys developed by the Oregon Department of Fish and Wildlife (Moore et al. 1997).

The purpose of the AHI survey is to inventory aspects of the riparian environment as they relate to fish habitat. Data and observations are collected along stream reaches. Reaches vary in length from 0.5 km to more than 8 km and are subjectively defined by observed breaks in topography, land use, stream flow and other riparian characteristics.

Within each stream reach a series of habitat units (also of varying length) are surveyed and the following characteristics are observed or measured: length of habitat unit; land use; riparian vegetation; stream gradient; valley width index; channel form and width; average depth of riffles and pools; average percent gravel, sand and silt; number of pools; average wood complexity; open sky; undercut banks; volume of large wood; temperature; large boulders; conifer size classes in riparian area; beaver dams; culverts; mass failures; and debris jams. As with any environmental data, it is important to note that the observations reflect the condition of the stream at the time of the survey. In the case of the Rock Creek watershed, AHI surveys were conducted by various crews from 1995 through 1997.

AHI surveys have been conducted on Rock Creek (up to Steer Creek); Big Rock Creek; Fall Creek; Steer Creek; Little Rock Creek; Dry Creek; Brush Creek; and William Creek (**Figure 5.1**). These surveyed reaches total 77 mi (124 km) and represent 62.1% of total stream length within the Rock Creek watershed). There are several steps in preparing AHI data: (1) data are collected in the field; (2) data are checked and entered into a database or spreadsheet; (3) data are interpreted, adjusted, and calibrated so that field measured lengths correspond to map-measured lengths; (4) and, data may be incorporated into GIS.

We obtained AHI data from two sources: ODFW and the Hire-the-Fisher program. Little Rock Creek, Steer Creek and William Creek were surveyed by Hire-the-Fisher crews. ODFW crews surveyed Big Rock Creek, Fall Creek, Brush Creek, Rock Creek and a tributary of upper Big Rock Creek. All AHI data were in various stages of data development.

We obtained copies of the Hire-the-Fisher data from former Hire-the-Fisher AHI survey crew members Kip Wood and Mark Stone (who can be reached through the Lincoln County Soil and Water Conservation District) and from ODFW. The Hire-the-Fisher data was in raw form; it was entered into an Excel spreadsheet, but data were unchecked. ODFW data originated from several different survey teams, and had been checked, adjusted, calibrated, and interpreted by ODFW. Materials received from ODFW included adjusted data based on raw data; summary data; and GIS layers. We used both Hire-the-Fisher data and ODFW data for this summary of the Rock Creek Watershed Analysis. However, the data from ODFW had been processed and contained slightly different parameters (for example, ODFW staff adjusted habitat unit lengths to compensate for variability in unit length estimates). **Therefore, data from the two different data sources cannot be directly compared.**

In addition, the ODFW survey data had been mapped to a GIS layer, but the base layer to which they were mapped was a 1:100,000 stream layer that did not fit criteria for this analysis (i.e., a scale of 1:24,000 or better). Recall, that the purpose of this analysis is to identify areas within the Rock Creek watershed for management and restoration actions and that we were interested in using the AHI data to characterize catchments (as described in **Topography and catchment derivation** above). Therefore, instead of directly using GIS layers prepared by ODFW, we used the ODFW GIS layer to attribute our catchments with the data contained in the ODFW GIS layer.

For the Hire-the-Fisher data, we reviewed the original database files containing the habitat unit level data. These data were the most detailed data on stream condition available. One of the problems that we encountered was that because the distance along the stream is estimated rather than measured, the position of each habitat unit observation within the watershed is only an approximation. This uncertainty requires a method for assigning habitat units to geographic locations.

ODFW staff probably had similar problems in mapping AHI data. To solve this problem, ODFW staff interprets, adjusts and calibrates AHI field measurements to map the AHI survey data. ODFW field crews' estimates are adjusted to the habitat unit lengths using an adjustment factor based on verified distance measurements that are taken every 10 habitat units. The AHI data are then mapped onto the GIS streams layer using the adjusted distances.

We followed a similar approach with the Hire-the-Fisher data. We used readily identifiable landmarks, recorded in the Hire-the-Fisher data, to assign each habitat unit to a catchment. Many landmarks such as named tributary junctions and road crossings could be located on the GIS base map, in combination with the digital orthoquads. Where landmarks were far apart or did not match catchment boundaries, we used a combination of measured distances on the GIS base map, and estimated distances in the AHI data, to place habitat units on the map.

To allow comparison of the Hire-the-Fisher data to the ODFW-compiled data, we needed to assign the ODFW data to catchments, too. We accomplished this by comparison of the location of habitat units in the ODFW GIS layer to catchment boundaries using ArcView. The ODFW data were then attributed with catchment numbers, and the value for each AHI parameter was then averaged across each catchment. This single value could then be compared to the value from the Hire-the-Fisher data, which is also averaged for each catchment.

By assigning habitat units to catchments, we were able to characterize the in-stream and riparian conditions for each catchment. Both Hire-the-Fisher data and ODFW data could then be used to assess conditions within the watershed. Although there were still some differences between the data from Hire-the-Fisher-surveys and from ODFW-compiled surveys, using a consistent method to assign the data to catchments at least produces a map on which AHI data are scaled similarly. Consistent scaling is helpful when using the AHI data to assess stream characteristics and watershed processes.

Comparison to ODFW habitat benchmarks provides one way to interpret AHI data and evaluate the condition of streams (Watershed Professionals Network 1999). ODFW habitat benchmarks are shown in **Table 5.1** below. Conditions can be described as desirable (high value habitat), undesirable (lower value habitat), or medium (between desirable and undesirable levels).

ODFW habitat benchmarks were developed for the entire state. For example, a single benchmark, e.g., the number of conifers in the riparian zone, is used for all of Oregon even though conditions in eastern Oregon differ greatly from conditions in the Willamette Valley or the Coast Range. Benchmarks that are more specific might be useful in some cases, and could help resource managers interpret local stream conditions more accurately. For example, different benchmarks for substrate composition have been developed for areas with sedimentary bedrock *versus* volcanic bedrock. Other regional or sub-regional benchmarks might be useful for other parameters. In any case, the ODFW habitat benchmarks are a useful starting point for analyzing the condition of streams in the Rock Creek watershed.

TABLE 5.1. ODFW Habitat benchmarks

Stream characteristic	Undesirable	Desirable
Pools		
Pool area (percent of total stream area)	<10	>35
Distance between pools (# of channel widths)	>20	5-8
Residual pool depth (meters)		
Small streams (<7m width)	<0.2	>0.5
Medium streams (≥7m & <15m width)		
Low gradient (slope <3%)	<0.3	>0.6
High gradient (slope >3%)	<0.5	>1.0
Large streams (≥15m width)	<0.8	>1.5
Complex pools/km (pools w/wood complexity>3)	<1.0	>2.5
Riffles		
Width: Depth ratio (Western Oregon)	>30	<15
Substrate		
Gravel substrate (% area)	<15	≥35
Silt+sand+organic substrates (combined % area)		
Volcanic parent material	>15	≤8
Sedimentary parent material	>20	≤10
Channel gradient <1.5%	>25	≤12
Shade		
Shade (reach average %)		
Stream width <12m (western Oregon)	<60	≥70
Stream width >12m (western Oregon)	<50	≥60
Woody debris		
Large woody debris (15cm X 3m minimum size)		
# of pieces/100m stream length	<10	≥20
Volume/100m stream length (cubic m)	<20	≥30
'Key' pieces (>60cm X 10m) per 100m stream length	<1	≥3
Riparian conifers		
Riparian conifers within 30m of stream		
Number >20in dbh/1000 ft stream length	<150	≥300
Number >35in dbh/1000 ft stream length	<75	≥200

5.3 Stream morphology

5.3.1 Introduction

Stream morphology describes the shape and structure of the stream channel. Stream channel width and depth, pool area, pool frequency, pool depth are examples of stream morphology. These stream characteristics are the result of many formative factors such as stream gradient, surrounding topography, land cover, land use, underlying geology, peak flow characteristics, and presence or absence of woody debris.

In this section, we discuss pool characteristics and stream channel width and depth. Presence or absence of large woody debris in stream channels is discussed in **In-stream structure** below.

5.3.2 Pools

Pools form important habitat for salmonids. Fish use pools as resting areas between high-velocity stream segments; as feeding areas; for protection from terrestrial predators; and as refuges from the higher temperatures often found in shallower water. Several measures of pool suitability of pools for salmonids can be calculated from AHI data, including pool area, pool, and pool depth.

Pool area

Pool area can be expressed as the percent of total stream area occupied by pools. We analyzed the AHI data for pool area within each catchment using the ODFW benchmarks; the results for stream reaches within catchments are shown in **Figure 5.2**. General results for each stream are shown in **Table 5.2** below. **Pool area ranged from undesirable to desirable within Big Rock Creek; Brush Creek and Fall Creek had generally undesirable pool area, and Rock Creek, lower Steer Creek, and Little Rock Creek had generally desirable pool area.**

TABLE 5.2. Overview of stream ratings: pool area*

Stream	Undesirable	Medium	Desirable
Big Rock Creek	X	X	X
Brush Creek	X		
Dry Creek		X	
Fall Creek	X		
Little Rock Creek			X
Rock Creek			X
Steer Creek		X	X

*see **Figure 5.2** for spatial distribution of pool area ratings within stream drainages

Pool frequency

Pool frequency refers to the number of pools per unit distance. Another way to express pool frequency is its inverse, the distance between pools. ODFW benchmarks use the distance between pools to characterize pool frequency, expressed in terms of average channel widths between pools. For the purposes of this assessment, average active channel width was used as the channel width for determining distance between pools.

According to ODFW habitat benchmarks (**Table 5.1**), an average distance of over 20 channel widths between pools is undesirable; an average of 5 to 8 channel widths between pools is considered desirable. Results of analysis of distance between pools is shown in **Figure 5.3**. **A minority of stream reaches within the watershed had desirable pool frequency; most catchments had intermediate pool frequency.** No rating is shown for reaches that had only one pool (distance between pools could not be calculated).

Pool depth

Pool depth is important to salmon because deep pools can provide cooler water, refuge from predators, and more complex, multilayered habitat. ODFW benchmarks for pool depth are complex, based on stream width and gradient as well as pool depth (**Table 5.1**). **Streams with the best pool depths were William Creek, Rock Creek and Little Rock Creek. Streams with the least desirable pool depths were Steer Creek, Dry Creek and Brush Creek. Big Rock Creek and Fall Creek had intermediate ratings for pool depth.** Ratings are shown in **Table 5.3** below.

TABLE 5.3. Catchment ratings by stream: Pool depth

Stream	Undesirable number & %	Medium number & %	Desirable number & %
Big Rock Creek	7 (16%)	18 (40%)	20 (44%)
Brush Creek	10 (63%)	6 (37%)	0
Dry Creek	2 (100%)	0	0
Fall Creek	2 (20%)	6 (60%)	2 (20%)
Little Rock Creek	0	24 (75%)	8 (25%)
Rock Creek	1	9 (39%)	13 (56%)
Steer Creek	8 (47%)	9 (53%)	0
William Creek	0	0	2 (100%)

Pool complexity

The term "complex pools" is sometimes used to refer to pools with complex accumulations of large woody debris. This topic is addressed in **Instream structure** (large woody debris) below.

5.3.3 Active channel width-to-depth ratio

Stream width-to-depth ratio is based on active channel dimensions, which are measured by AHI crews only on every tenth habitat unit. Perhaps because so few measurements were taken (only 10% of units were measured), width-to-depth ratio varied greatly within habitat units, within unit types, and within streams in the watershed.

Moore et al. (1997) have developed a series of benchmarks used by ODFW for quickly evaluating aquatic habitats. According to ODFW habitat benchmarks, desirable salmonid habitat in riffle units in western Oregon has a width-to-depth ratio of less than 15 (no units in a ratio). A width-to-depth ratio of over 30 is considered undesirable. **Table 5.4** shows average width-to-depth ratios for different habitat unit types in various streams in the watershed. The table shows that width-to-depth ratio varied greatly within a given unit type. The average ratio varied from 5 to nearly 40 for riffles, from 5 to 25 for glides, and from 11 to 26 for pools. Because of this variability, we decided to use all units for which active channel measurements were available to calculate and rate stream width-to-depth ratios. By using all available measurements, we hoped to increase the reliability of the average ratio calculation (had we based the calculation on riffles only, we would have been rating catchments based on only 1 or 2 ratio measurements per catchment). ODFW benchmark ratings for active channel width-to-depth ratio within catchments are shown in **Figure 5.4**.

Some catchments are not rated in **Figure 5.4**, because no active channel measurements were available for the catchment (i.e., catchment was less than 10 habitat units in length).

The high level of variability in active channel width-to-depth ratio suggests that as measured using AHI techniques, it may not be a useful parameter for evaluating salmonid habitat in the watershed. However, other survey methods or more detailed studies could reveal patterns in width-to-depth ratio that might increase our understanding of watershed processes in the Rock Creek watershed.

TABLE 5.4. Width-to-Depth ratio for habitat unit types.

Stream	count	width-to-depth ratio average	std dev	95% confidence interval
Riffles: Big Rock Cr.	9	13.8	7.9	5.1
Riffles: Rock Cr.	4	38.7	3.2	3.1
Riffles: Brush Cr.	11	5.0	2.3	1.4
Pools: Big Rock Cr.	8	11.1	4.4	3.1
Pools: Rock Cr.	12	26.0	17.0	9.6
Glides: Big Rock Cr.	2	24.0	17.0	23.5
Glides: Rock Cr.	12	22.0	14.4	8.2
Glides: Brush Cr.	16	5.4	1.8	0.9
Rapids: Big Rock Cr.	3	6.2	7.6	8.7

5.4 Substrates

Salmonids spawn in gravel beds. Sediment loading to a stream can bury gravel beds, eliminating this vital spawning habitat. Sediment delivery to streams is a natural process. In many cases, human actions have altered the rate and magnitude of delivery. Sedimentation in streams affects salmonids by covering gravel beds. Sediment also reduces light penetration and can reduce feeding success. Aquatic invertebrates such as freshwater mussels are also affected by sediment, which may clog their filter-feeding apparatus.

To evaluate the condition of streambeds, AHI teams record the composition of the substrate (materials covering the bottom of the streambed) for each habitat unit surveyed. Materials composing the substrate are categorized as silt and fine organic material; sand; gravel; cobbles; boulders; or bedrock; and the percent area occupied by each category is recorded. ODFW benchmarks (**Table 5.1**) rate percent gravel as follows: less than 15% gravel is considered undesirable, more than 35% gravel desirable. Silt, fine organic materials and sand are rated together as a group (called "fine sediments" in this section). If the underlying parent material is sedimentary (true for nearly all streams in the Rock creek watershed), a desirable level of fine sediments is less than 10%; over 20% is undesirable. If the stream has a gradient of less than 1.5%, higher levels of fine sediments are tolerated (<12% desirable; >25% undesirable).

Only 7 catchments had desirable levels of fine sediments. Steer Creek, Little Rock Creek, Dry Creek, Brush Creek, and the upper portion of Big Rock Creek had undesirably high levels of fine sediments (Figure 5.5)

Most catchments had desirable or medium levels of gravel (Figure 5.6). Only 20 catchments had undesirably low gravel. Interestingly, upper Big Rock Creek showed both undesirable high levels of fine sediments, and desirable high levels of gravel. The sedimentary parent material found throughout most of the watershed may limit the development of cobble and boulder substrates, resulting in generally high percentages for both gravel and fine sediments.

5.5 Riparian conditions

5.5.1 Introduction

Riparian areas are defined as the areas adjacent to water resources such as streams and lakes, where vegetation and soils are affected by, and in turn affect, the water resource. The nature of vegetation in the riparian area greatly influences the water quality and in-stream habitat for aquatic organisms (see Botkin et al. 1994; Beschta 1998). Riparian vegetation is an important component of salmonid habitat because in addition to shade, it provides large woody debris, leaves, fruits, and seeds into the stream, which in turn, provide food for aquatic organisms. In particular, large conifers are vital for providing the large woody debris that persists in streams and provides the structure characteristics to which salmonids are adapted.

Riparian vegetation also provides habitat for terrestrial organisms that feed on (or become food for) aquatic species. Plant roots help stabilize streambanks and improve soil permeability, thereby increasing water infiltration. Better water infiltration means better water quality, because when water entering the stream is filtered through soil instead of flowing over the soil surface, many pollutants and sediment particles are removed. Better water infiltration also means a reduction or delay in peak flows, reducing flood hazards downstream -- particularly when riparian areas include wetlands that act as a "sponge" to soak up rainfall and floodwaters.

In this assessment, we defined riparian areas based on our two main data sources: land cover data from satellite imagery, and data from the Aquatic Habitat Inventory (AHI) project coordinated by ODFW. The AHI method defines the riparian area as a strip of land extending about 100 ft (30 m) from the edge of the stream channel. Data available on the MidCoast GIS (MCGIS, CLAMS88 and CLAMS95) include vegetation within 200 ft (about 61m) of the stream channel. This definition of riparian areas is also used in U.S. Forest Service watershed analyses (USFS 1996 and 1997).

Riparian vegetation along unconfined or moderately confined channels in the Mid-Coastal Sedimentary ecoregion (Watershed Professionals Network 1999) can potentially consist of red alder (*Alnus rubra*) near the stream, with conifers or mixed forest beyond. Along confined channels, a narrow band of red alder might be found along the stream channel, but most riparian forest would consist of coniferous or mixed broadleaf/ coniferous forest (Watershed Professionals Network 1999). In the Rock Creek watershed, all AHI-surveyed channels are classified as confined. Therefore, under natural conditions, riparian vegetation would be dominated by conifers.

5.5.2 Riparian shading

Removal of riparian vegetation reduces shading of the stream channel, potentially resulting in increased water temperature, loss of stream bank stability, loss of sediment filtration, and reduction in organic nutrients delivered to streams through leaf fall.

Timber harvest in the 1940's and 1950's often resulted in loss of riparian vegetation (Clutter and Jones 1949; Willis and Best 1953). In more recent years, forest practices regulations have required improved retention and management of riparian vegetation. This regulatory change should be reflected in improved shading and large woody debris recruitment in future decades.

Agricultural activities in the lower portions of the watershed have reduced riparian shading, both through tree cutting and brush removal for pasture improvement, and through livestock grazing on riparian vegetation.

Moore et al. (1997) have developed a series of benchmarks used by ODFW for quickly evaluating aquatic habitats. According to ODFW habitat benchmarks for the surveys in the Rock Creek watershed, AHI teams recorded percent open sky. We subtracted the percent open sky values from 100 to get percent shade, and then analyzed the average shading per catchment using the ODFW benchmarks. The results are shown in **Figure 5.7**. **Fifty-nine of the 116 surveyed catchments showed desirable shading of the stream channel, 23 had medium shading, and 34 had undesirably low shading.**

5.6 In-stream structure (large woody debris)

Of all habitats in the landscape, riparian areas were impacted earliest and most strongly by European settlement. Historically, removal of conifer and hardwood trees and understory vegetation along stream banks for agriculture and logging has been especially damaging. As late as the early 1970’s, debris removal from streams was a common management technique (see review by Bryant 1983). In the past, managers believed that woody debris in streams lead to decreased oxygen concentrations, potentially release of toxic compounds (primarily leachates from western red cedar), and fish passage issues. Today, however, the ecological roles that large woody debris plays in streams are believed to outweigh any negative effects. In brief, large woody debris adds to the complexity of the stream channel. Channel complexity provides cover for salmon, and reduces water flow to provide refuge for salmon and allow sediments to accumulate (Non-Point Source Solutions 1999). Resource managers must have an understanding of the role that large wood plays in aquatic ecosystems to avoid unexpected outcomes to their management actions (see review by Harmon et al. 1986).

Large wood is redistributed within the watershed by several mechanisms including, mass movement of soil, debris torrents, bank erosion, blow downs, snow and ice, and floods (Harmon et al. 1986, Keller and Swanson 1979). Removal of large conifer trees in the Rock Creek watershed for agricultural or forestry has eliminated the primary source of functional large woody debris. Keller and Swanson (1979) reported that wood greater than 24 inches (10 cm) provides "key pieces" of large woody debris that can modify stream channels. The importance of large woody debris can be quite significant in “small to intermediate size streams with steep valley walls and little or no floodplain” (Keller and Swanson 1979), such as that which occurs in the Rock Creek watershed.

Removal of riparian conifers in Rock Creek portion of the Coast Range probably occurred in the 1940's, 1950's and 1960's (Clutter and Jones 1949; Willis and Best 1953; BLM 1996). It is important to target areas of the watershed that may potentially contribute large woody debris to streams because conifers growing on stream banks do not begin to generate much large woody debris until the stand is 80 years old and decades may pass before woody debris levels can begin to recover. Long term planning and management is required to ensure that large wood will be continually recruited to stream channel.

5.6.1 Current conditions

The AHI procedure evaluates woody debris in streams in detail (Moore et al. 1997). ODFW habitat benchmarks rate these woody debris levels in three ways (Table 5.1). Only woody debris over 15cm dbh and 3m in length is included in ratings. Number of pieces of woody debris per 100m of stream length is rated as follows: less than 10 pieces is considered undesirable; over 20 pieces is considered desirable. Volume of woody debris per 100m of stream length is rated desirable if over 30 m^3, undesirable if under 20 m^3. Number of key pieces of wood (over 60 cm by 10m) is rated desirable if over 3 per 100m of stream length, undesirable if less than 1. **Overall, woody debris levels in streams in the Rock Creek watershed are extremely low. No catchments had a desirable number of pieces (Figure 5.8) or key pieces (Figure 5.9) of woody debris. Only nine out of 136 surveyed catchments had desirable wood volume; three catchments had medium wood volume; and 124 catchments had undesirable wood volume (Figure 5.10).**

Pools with complex woody debris accumulations are considered valuable salmonid habitat. Complex woody debris consists of accumulations of medium and large pieces plus root wads and branches (Moore et al. 1997). These complex accumulations provide shelter and habitat for a variety of organisms and tend to persist through high flow events, providing a stable environment for many seasons. ODFW benchmarks rate frequency of pools with complex woody debris as follows: more than 2.5 pools per km with complex wood accumulations is considered desirable; less than one pool with complex wood per km is considered undesirable. **Only one pool in the Rock Creek watershed had a complex woody debris accumulation. All of the other pools surveyed had no woody debris, or single pieces of wood, or small accumulations that would not provide cover at high discharge rates.**

5.6.2 Recruitment potential

Large conifers in the riparian zone provide large woody debris to the stream. If conifers are absent from the riparian zone, potential for recruitment of LWD is small (though landslides may deliver some large conifers to the stream). If conifers are present in the riparian zone but are small, decades must pass before the trees reach a size adequate to provide "key pieces" of wood. As described above, coniferous forest near streams does not begin to provide substantial LWD until the stand is 80 years old.

The most detailed data available on riparian vegetation within the watershed comes from the AHI surveys conducted within the watershed. For the riparian inventory portion of the AHI, survey crews record observations of riparian vegetation within a transect 5 m wide by 30 m long, perpendicular to the stream channel, on both sides of the stream. Data collected includes geomorphic surface (e.g., floodplain, hillslope, wetland, pool, road bed, etc.), slope, canopy closure, shrub cover, grass and forb cover, type of trees (conifer vs. hardwood), and a count of trees by size class. ODFW benchmarks were used to evaluate this data, although the AHI data contain more detail than the benchmarks address, and therefore merit more detailed study.

ODFW benchmarks assign riparian conifers to two size classes, medium (>20" dbh) and large (>35" dbh). Desirable levels are more than 300 medium conifers or more than 200 large conifers per 1000 ft stream length; undesirable levels are less than 150 medium conifers or 75 large conifers per 1000 ft of stream length. **All catchments in the watershed had undesirably low numbers of large conifer in the riparian zone.**

Since not all streams in the watershed have been surveyed by AHI teams, we also characterized vegetation (land cover) in riparian areas using a more extensive land cover layer, namely **CLAMS88** satellite data. This analysis is described in **Land cover: Large conifers in riparian areas** above. The results of the **CLAMS88** analysis agree with the AHI survey results (showing low levels of large conifer cover in the riparian zone).

5.7 Wetlands

Only one information source was available for wetlands in the watershed: National Wetland Inventory paper maps created by the U.S. Department of the Interior, Fish and Wildlife Service. The maps were created in the late 1970's (the exact date of publication is not shown), and are based on interpretation of aerial photographs dated 1975. They were created at a scale of 1:62,500 and are not yet available in digital form. These NWI maps are intended to be used as overlays for USGS 15 minute quadrangles, but the appropriate USGS quad maps are not readily available.

Nearly all the wetlands shown within the watershed on the NWI map are located in riparian areas (**Figure 3.16**). These wetlands are intermittently- or seasonally-flooded, with vegetation ranging from emergent (herbaceous grasses, sedges, rushes, and forbs), to shrub-scrub (such as willows) and forested (generally with an alder canopy). Several isolated ponds and emergent wetlands are located in the northeast portion of the watershed, in the ancient landslide formation at the base of the steep north-facing slope of Green Mountain. These ponds and depressional wetlands are not directly connected to streams, but they may function as important recharge areas for streams or serve to desynchronize hydrologic peaks by increasing the water storage capacity of the catchment.

Wetlands shown on the NWI map (**Figure 3.16**) are coded as follows: the first letter indicates the major wetland type (wetland system), and further coding describes characteristics of that system. Types and characteristics are shown in **Table 5.5**.

TABLE 5.5. NWI wetland codes.

Code	System	Subsystem	Class	Subclass	Water regime
R30WH	R=Riverine	3=Upper perennial	OW=open water	none	H=permanently flooded
R4SBE		4=Intermittent	SB=streambed		E=seasonally flooded
PEM5A	P=Palustrine	none	EM=emergent	none	A=temporarily flooded
PEM5Ad	P=Palustrine	none	EM=emergent	none	Ad=temporarily flooded, partially drained/ditched
PEM5E	P=Palustrine	none	EM=emergent	none	E=seasonally flooded
PEM5F	P=Palustrine	none	EM=emergent	none	F=semipermanently flooded
PFO1J	P=Palustrine	none	FO=forested	1=broad-leaved deciduous	J=intermittently flooded
PFO/SS1C	P=Palustrine	none	FO/SS=forested/ scrub-shrub	1=broad-leaved deciduous	C=seasonally flooded
PFO/SS1J	P=Palustrine	none	FO/SS=forested/ scrub-shrub	1=broad-leaved deciduous	J=intermittently flooded
PSSIB	P=Palustrine	none	SS=scrub-shrub	1=broad-leaved deciduous	B=saturated
PSSIJ	P=Palustrine	none	SS=scrub-shrub	1=broad-leaved deciduous	J=intermittently flooded
PSS/EM5J	P=Palustrine	none	SS/EM=scrub-shrub/emergent	none	J=intermittently flooded

Although the watershed's riparian wetlands are small in size, their location makes them strategically important to salmonids. Water floods these wetlands during high flow periods. The wetlands slow the water flow, cleaning sediments from floodwaters and filtering out sediment and other pollutants. Slower-flowing water in flooded backwater wetlands provides a resting area and refuge for juvenile salmon, helping them avoid being flushed downstream in high flow events. Backwater wetlands also provide aquatic habitats rich in invertebrate prey. Dense plant cover and shallow water in wetlands provides refuge from aquatic and terrestrial predators.

It is important to note that NWI maps are based on interpretation of aerial photography, and therefore do not have the accuracy of ground-based wetland inventory. Field inventory of wetlands generally results in discovery of many wetlands that are not shown on NWI maps.

5.8 Stream temperatures

[See ***Water temperature*** *below]*

5.9 Fish barriers

5.9.1 Culverts

Culvert, dams, and natural barriers (including debris jams) are important because they may adversely affect fish passage, both up and downstream. All have an affect on hydrologic patterns and improperly sized culverts and debris jams can lead to road failures.

In 1997, crews organized under the Hire-the-Fisher program surveyed culverts in the watershed. ODFW compiled that portion of the results that related to county road crossings. The 9 culverts which were surveyed and compiled, and which are in need of upgrades to improve fish passage, are shown in **Figure 5.11**. All are designated "medium" to "low" priority for upgrades, and all carry flow from streams designated by ODFW in the list as "fair" fish habitat. All 9 are located along Rock Creek Road, and carry flow under the road from tributaries into Rock Creek. All are 50 to 80 ft (15-24 m) in length and 2 to 4 ft (0.6-1.2 m) in diameter. These culverts restrict access to cutthroat habitat and possibly also to coho habitat. The contact for further information on upgrades needed and details of the ODFW culvert survey is John Cambellique at (503) 986-2652.

Obviously, there are many more than 9 culverts in the Rock Creek watershed. There are 153 mi (247 km) of roads shown in the watershed on the DLG GIS Coverage and USGS maps that form our roads layer for this study. However, we were unable to obtain further information on locations, specifications or condition of culverts in the watershed. All major state, federal and private industrial landowners in the watershed were contacted in writing or by phone during November 1998. Private industrial landowners had data on culverts, but due to corporate policy, they could not release the data to us. Neither the Oregon Department of Forestry nor the Bureau of Land Management could get culvert data to us in time for this report.

An example of the likely density of culverts is provided by maps of timber sales provided by ODF. On one of these maps, eleven culverts are shown along the length of Beaver Creek Road (a distance of about 5 or 6 mi, or 8-9.6 km). None of the other timber sale maps show culvert locations, so we could not determine whether this was a typical culvert density.

Although no comprehensive data are available for culvert locations and status in the watershed, locations of road/stream proximity may provide a useful stand-in for culvert locations. **Figure 5.11** shows the locations in the watershed where roads cross streams; there are 127 such locations. However, as discussed in **Development of base layers** above, a substantial proportion of the roads in the watershed are missing from the USGS data set that was our best source of roads data. Therefore, it is likely that many culvert locations were missed.

5.9.2 Dams

There are no water storage dams in the watershed at present. In the 1970's, the Oregon Water Resources Department mapped two dams in the watershed, one located about a mile (1.6 km) up Steer Creek, and one about 5 mi (8 km) up Big Rock Creek (above Lucas Creek but below Young Creek) (**Figure 5.12**).

In 1949, the Steer Creek dam (**Figure 5.12**) was operated as a millpond dam by the Smith Lumber Company of Nashville (Clutter and Jones 1949). Although it had a fish ladder at that time, the ladder was inadequate and the dam was considered a serious barrier to fish passage. This dam is no longer present.

Surveys of Big Rock Creek by the Oregon Department of Fish and Wildlife in 1949 and 1953 (Clutter and Jones 1949; Willis and Best 1953) did not describe any man-made dams on that stream. The 1953 survey stated that at that time, the Valsetz Lumber Company appeared to be logging a large area from Lucas Creek north to Valsetz. Valsetz Lumber Company records might be used to confirm the presence of the dam on Big Rock Creek and explain its purpose. In any case, the dam location shown in **Figure 5.12** and on the OWRD map was upstream of the Big Rock Creek falls, which are considered a barrier to anadromous fish.

The Siletz River Hatchery operated a water supply dam on Rock Creek during its active operations from 1937 to 1987; this dam washed out in the winter of 1986. The dam was a

4 ft (1.2 m) high wooden structure that diverted water from Rock Creek into the intake facility leading to hatchery ponds. A concrete fishway provided fish passage over the dam.

5.9.3 Natural barriers

A steep section of Big Rock Creek forms a natural barrier to anadromous fish passage where Big Rock Creek flows across an igneous intrusion (the same intrusion that forms Green Mountain to the east). Two barriers are shown on the ODFW fish habitat maps (ODFW 1997a), one where Fall Creek enters Big Rock Creek and one just downstream from the entrance of Lucas Creek. The geologic formations under these stream sections are described in **Geologic formations**. Other natural barriers may exist. For example, debris jams from landslides and bank slumps may block fish passage temporarily until water channels form that allow fish passage. Such blockages are natural and temporary, but their frequency may be increased by human land use activity in the watershed.

Upstream limits of fish use (**FISHLIM**) and ODF stream classification are shown on **Figure 5.13**. According to metadata, these fish presence data originate from the Oregon Department of Forestry. However, paper maps received from ODF and updated in 1998 show data that differ from the **FISHLIM** layer in many areas. The paper maps provided by ODF are considered the definitive source for this information (Mary Holbert, ODFW, personal communication).

5.10 Channel modifications

5.10.1 Introduction

The stream channel network in the Rock Creek basin, and therefore its biological productivity, has been altered by human actions. For Rock Creek as well as for other coastal streams, the use of the stream channel for transportation has led to removal of woody debris from stream channels (Coulton et al. 1996). Stream channels have been disconnected from the valley floor due to activities that increase water velocity, i.e., channelization, dikes and rip-rap. Channel modifications and removal of jam-forming debris simplifies the stream network by removing areas where organic material is transformed. Faster water velocities resulted in lowered streambeds, further separating the stream from the valley floor. Organic debris naturally enters and exits the stream channel during flooding when the stream overflows its banks. Due to the simplification of stream channels, material that would have been deposited on stream banks or tied up in debris jams is quickly flushed from the stream network (**Appendix 1**).

For Rock Creek, these types of stream channel modifications may have resulted in separation of the streams from their historic floodplains (see **Channel types** above);

another visible effect is the lack of large woody debris in the watershed's streams (see **Aquatic habitats: In-stream structure**) above.

5.10.2 Roads

Road building can dramatically alter watershed processes by changing the movement of water. Water can be routed down roads instead of across the forest floor. In a study in the western Cascades of Oregon, over half of the logging roads surveyed appeared to route water directly into stream channels and may function as “extended stream channels” during storm events by carrying appreciable volumes of runoff (Wemple 1994). In other words, overland water velocities can be higher along roads than in unroaded areas, and faster water can transport more sediment to the stream channel. Therefore, forest roads can be a significant source of sediments. In addition, large pulses of water can be delivered quickly to stream channels along forest roads, resulting in stream downcutting, which can disconnect streams from their floodplains. Finally, roads built in floodplains confine stream channels by preventing natural meandering of the stream and/or by limiting floodwater access to the floodplain. For this assessment, we used road-stream proximity to determine the degree of impact to stream channels from nearby roads. The results of this assessment are presented in **Roads** in **Sediment Sources: Surface Erosion** below.

5.10.3 Dams

No dams are currently located in the watershed. However, some dams existed in the past (see **Dams** in **Fish barriers** above). Some channel modifications are also present at the hatchery on Little Rock Creek, where diversion structures and fish ladders have been constructed for operation of the hatchery.

5.10.4 Channelization

No channelization has been described for the AHI-surveyed streams in the watershed. These surveyed streams are the most likely to have been channelized, since surrounding land use includes a high proportion of agricultural and rural residential land uses.

5.10.5 Splash damming

Splash damming probably did not occur to any appreciable extent in the Rock Creek watershed (Tom Downey, personal communication, 1998). However, stream channels may have been scoured and simplified by log skidding in valley bottoms.

5.10.6 Filling of wetlands, floodplains and small streams

The Oregon Division of State Lands reports that only one wetland fill/removal permit has been issued within the watershed. This was a General Authorization for Fish Enhancement in Steer Creek (DSL Project #GA-15204), issued to the ODFW in May 1998. The project consists of placing 4 pieces of large woody debris in the channel at about Mile 2.5 of Steer Creek, with the intent of creating pool habitat. This restoration project is described in **Existing watershed restoration projects** above.

FEMA mapping of floodplains in the watershed is very limited (only a very small area is shown, near the mouth of Rock Creek). AHI data show that lower reaches of streams in the watershed, which appear to have wide floodplains, are in fact terrace-constrained. Floodplain areas may therefore be limited even in low, flat areas near Rock Creek, Big Rock, Little Rock and Steer Creeks. The Lincoln County Planning Department has not issued any floodplain fill permits for the watershed (Steve Morris, Lincoln County Planning Department, personal communication), although unpermitted floodplain fills may have occurred.

6 Sediment sources

6.1 Landslides

Landslides affect fish habitat in several ways. They deliver large amounts of unsorted sediment to the stream system. This sediment input provides gravel that is needed for salmon spawning beds. Landslides also provide fine sediments that can cover gravel beds and make them unsuitable for spawning. Landslides that enter a stream channel can develop into debris torrents, which scour stream channels, obliterating fish habitat. Montgomery and Dietrich (1994) reported that common approaches to assessing landslide hazards include field inspection, projection of future patterns based on landslide inventories, multivariate analysis of factors that characterize areas of instability, stability ranking based on physical features, and failure probability analysis based on slope stability models.

We examined known and potential landslide areas in the Rock Creek watershed using the following information and approaches:

- We examined the GIS data layer for landslides provided by ODF;
- We modeled areas in the watershed that may be susceptible to landslides due to roads. These areas were defined as roads that pass through polygons that have slopes of 60% or more;
- We modeled open areas on slopes greater than 80%. These areas may have higher landslide risk than areas with forest cover.

Available GIS data (ODF GIS, **LANDSLIDE**) shows two recent landslides in the watershed (**Figure 3.5**). Both of the landslides originated at quarries located on the flanks of Steer Divide. A rapid, shallow landslide originated at the hatchery quarry in T10S R8W Sec. 7, and a landslide and debris torrent originated at the quarry at the headwaters of Beaver Creek (T10S R8W Sec. 4). These landslides were the only slides described as significant slides by local residents [SWG meeting, 12/15/98]. It is likely that other landslides have occurred recently in the watershed, but they may be in more remote locations or hidden under the tree canopy.

An understanding of topographic patterns is important in watershed analysis. The movement of water is greatly affected by the slope or gradient in a watershed. As the speed of water increases, so does its capacity to move sediments suspended in water. An understanding of topographical patterns is also important in understanding patterns in the movement of soil and debris into the stream network.

We derived slopes using ArcView from the 10 m DEM files. Slopes in the Rock Creek basin ranged from 0 to 64 degrees (0 to 205 % slopes). Although the 10 m DEM files are the best available topographic data for the Rock Creek watershed, these data are limited in that a single elevation value is reported for a 10 X 10 meter area. Many of the factors that make an area predisposed to landslides (e.g., topographical concavity) may not appear in DEM files. For this reason, ODF (1998) criticized the use of 1:24,000 topographic maps (this may well apply to 10 m DEM files) because of the lack of agreement between what the map shows and what is measured on the ground. Nevertheless, a watershed-wide view of slope may be helpful to identify potential problem areas.

We found that there was quite a bit of variability in the slopes derived for the entire Rock Creek Watershed. Interestingly, we found that 1,396.9 ha or 12.5 percent of the total Rock Creek watershed has a slope greater than 60% when summarized by this method (**Figure 6.1**).

Although landslides occur naturally in the Coast Range, most experts agree that the frequency of landslides has increased as a result of human activity, and that most landslides are now associated with road building and timber harvest [USFS 1996, 1997; BLM 1996]. In particular, road building has destabilized slopes and altered natural water flow patterns. Roads directly destabilize slopes when the soil profile is disturbed during road construction. In addition, soils located on steep slopes, particularly on concave slopes, are likely to intercept subsurface water flow, causing water buildup in the soils near the road. During high rainfall periods, these soils become saturated and are likely to fail and produce a landslide.

6.1.1 Road Densities in areas with slopes greater than 60%

The GWEB manual indicates that roads below or through areas with high slopes can lead to an increased risk of slope failures. We identified areas of the Rock Creek watershed that had slopes greater than 60% (**SLOPE_GR60.SHP**) with roads passing through them. We realize the limitations of this sort of analysis. For example, slopes derived from 10 m DEM files may not capture enough fine-scale topographic detail to adequately assess the risk of slope failure (e.g., concavity). In addition, the spatial error associated with the data layers is too great to determine precisely where the roads are located relative to high slopes (e.g., at the foot of the slope or at the top of the slope). Finally, our roads layer is incomplete (see **Roads** in **Sediment Sources: Surface Erosion** below). Nonetheless, we feel that this approach can be useful to identify sites where there is a high potential for slope failure due to roads.

Of roads mapped in the Rock Creek watershed, there are 7,110.8 m of roads that pass through areas with slopes greater than 60% (approximately 2.9% of all of the roads in GIS roads layer for the Rock Creek watershed) (**Figures 6.2A, 6.2B**).

We also queried the GIS to determine where there were open areas within the Rock Creek watershed that occurred on slopes greater than 80%, because these areas are known to have relatively unstable slopes. We found that 266.2 ha or 2.4 percent of the Rock Creek watershed has a slope greater than 80%; however, only a few acres of this area (12.8 acres) were classified as open in CLAMS88.

6.2 Bank erosion

AHI crews record actively eroding streambanks in each habitat unit surveyed. If any portion of the streambank is actively eroding, that unit is marked as containing actively eroding banks. A high proportion of catchments in the Steer Creek and Little Rock Creek subbasins contained actively eroding banks (**Figure 6.3**). The proportion of AHI survey units containing actively eroding banks was over 80% in many of these catchments. Proportion of AHI survey units containing actively eroding streambanks in the rest of the watershed was generally under 40%.

Major differences between streams in recorded bank erosion, despite similar channel forms, may indicate discrepancies in methods used to determine bank erosion. It is notable that the two streams surveyed by Hire-the-Fisher crews show considerably high percent of units with bank erosion estimates (generally 60 to 100%) than the streams for which data was compiled by ODFW (generally less than 40%). A more thorough investigation of bank erosion in the watershed would be needed to evaluate the reasons for the patterns of bank erosion observed in the watershed.

6.3 Surface erosion

6.3.1 Costs of Erosion and Sedimentation

In the United States alone, the off-site costs associated with water erosion in the U.S. are approximately $17 billion per year and includes costs associated with damage to roadways, sewers, and pavements; drainage disruption, earth dam failures, eutrophication of waterways, siltation of harbors and channels, loss of reservoir storage, disruption of stream ecosystems and loss of wildlife habitat, damage to public health and increased water treatment costs. Approximately one third of the 75×10^9 tons of soil that erode each year come from non-agricultural land (adapted from Pimentel et al. 1995).

Erosion and deposition of fine sediments reduces the productivity of forest, crop and pasture lands; damages fisheries in streams and ultimately in the Siletz Bay and estuary; and reduces boating opportunities and other recreational opportunities. Sedimentation of streambeds and its effect on fish are discussed in **Aquatic habitats: Spawning bed conditions: Sedimentation** above.

Without additional study it would be difficult to estimate the cost of erosion for the Rock Creek watershed.

6.3.2 Roads

Sediments can enter streams where roads cross streams or where roads run adjacent to streams. We queried the GIS to determine where roads were close to streams and potential floodplains. We defined "floodplains" as areas of slope 0 - 8% near streams. We also generated a buffer around streams. The average stream width reported from the AHI data for Big Rock, Little Rock, Steer and William Creeks was 4.8 m. Therefore, we used 5.0 m as an average width for a stream in the Rock Creek basin. A 5 m (or one stream width) was created on either side of the stream for a total buffer size of 15 m. This combination of "floodplains" and 5 m stream buffer was called the "aquatic zone." We found that this aquatic zone covered approximately 10% of the watershed. We then looked for where roads cross this stream buffer aquatic zone. We found that about 8.9% of all roads in the watershed pass through or near streams (**Figure 6.4**).

6.3.3 Agriculture

Agricultural activity involving tillage presents a risk for surface erosion. There is little or no commercial-scale tilled land in the watershed. Surface erosion may also occur on grazed lands where the condition of vegetation is poor, and pastures in poor condition provide little filtering for overland flow, allowing more sediment to enter streams.

Grazed lands in the watershed include large areas of open range in the southern half of the watershed, and managed pastures along Rock Creek, Little Rock Creek, Steer Creek and Big Rock Creek. Grazed land in good condition generally is not prone to surface erosion. The general condition of grazed land in the watershed is unknown; however, livestock with direct access to streams have caused streambank erosion (see **Bank erosion**). This erosion has prompted riparian fencing and off-stream watering projects (see **Existing watershed restoration projects**).

6.3.4 Mining

USGS 7.5 minute quadrangle maps show 4 quarries and 2 borrow pits in the watershed. All 6 of these rock removal areas are located on the igneous intrusive rock formations that run through the watershed. Locations and impacts of these quarries are discussed in **Geology**. Both of the recent, significant landslides recorded in the watershed originated at quarries (see **Geology**).

6.3.5 Building sites

6.3.6 Introduction

Development activity in the floodplain affects fish habitat in several ways. Riparian vegetation is often disturbed, resulting in less shading and reduced water-filtering capability. Soils are often compacted, surfaced with impermeable materials, or raised with fill material, decreasing water infiltration rates, increasing surface runoff, and increasing delivery of sediment and other pollutants to the stream.

Building sites can contribute sediment to streams, particularly during construction if heavy machinery is used to move soil during winter rainy periods. Heavy machinery compacts soils, resulting in low infiltration and high surface runoff during rainy periods. Such surface runoff carries eroded sediment into streams. Proper construction techniques such as silt fencing, sediment detention ponds, and sediment trapping materials placed in ditches can greatly reduce sedimentation of streams.

Building placement in floodplains reduces functioning of riparian corridors. Buildings and associated structures like driveways and parking lots are impermeable surfaces that prevent infiltration of water into the soil. If culverted to the streambank, water flowing over these surfaces can carry its load of sediment and pollutants directly to the stream. Retention of a vegetated riparian area between a building site and the streambank is therefore vital to healthy functioning streams. The larger the vegetation buffer, the better: groomed lawns function poorly as sediment and pollutant filters, but natural shrub or forest corridors are much more effective at protecting water quality.

When buildings are placed near streams, riparian vegetation may be removed. Shade provided by trees and shrubs is important throughout the watershed, but that shade is particularly important in developed areas where natural forest cover is no longer a possibility. Building sites should be designed to retain as much streamside vegetation as possible.

Buildings located in floodplains are often raised above the original ground level to reduce flood risk. Sometimes large amounts of fill material are used to raise the structures. This fill material acts to channelize the stream during flood flows, and reduces the flood control functions of the riparian corridor. Poorly stabilized fill material may also be subject to erosion during flood events, contributing sediment to the stream and exposing the building to structural damage.

Buildings located in floodplains may also impinge on backwater wetlands and other wetlands that are important to healthy watershed function. Placement of fill material in wetlands is regulated by the Oregon Division of State Lands and the U.S. Army Corps of Engineers; permits are required for such fill activity. Whether permitted or unpermitted, filling of wetlands impairs watershed functions (see **Wetlands**).

6.3.7 Current conditions

Rural residential development in the Rock Creek watershed is very limited at this time. Building sites are located mainly in the broad valleys of the lower watershed. Vegetated yards and nearby structures generally present minor risks of erosion and sedimentation. However, with increasing population in the area, the impact of residences will grow. The watershed group can serve a valuable function by educating rural residents on the best ways to reduce human impact to riparian areas (see **Watershed Enhancement Recommendations**).

7 Water resources

7.1 Water quality

7.1.1 Introduction

Predominant water uses in the Rock Creek watershed are sensitive to water quality. These uses include private domestic water supply, salmonid spawning and rearing, and shellfish production (freshwater mussels).

None of the streams in the watershed are listed as water-quality limited by the Oregon Department of Environmental Quality (**OR303STR**). There are no permitted wastewater discharge sites (NPDES sites) within the watershed (**NPDES**). Despite these positive indicators, the Siletz Watershed Group has expressed concern for water quality in the watershed. This concern is justified, since the primary water uses in the watershed are water-quality sensitive. Several land uses in the watershed could impact water quality in the watershed in ways that affect all of these uses. Livestock operations, pesticide use and rural residential development can contribute contaminants to streams. Timber harvest, agriculture, and land development for housing and roads can also contribute sediment to streams and influence water temperatures through removal or alteration of vegetation on or near the streambank.

Few water quality measurements have been recorded for the Rock Creek watershed. A cooperative project between the Confederated Tribes of Siletz Indians and the Hire-the-Fisher program gathered monthly water quality data at 10 locations during 1996, 1997 and 1998. Results are presented in **Water chemistry** below.

STORET is a national database operated by U.S. EPA that contains water quality measurements made by state and federal agencies. STORET sample locations in the MidCoast region were extracted from the database and used to create a GIS layer which is present on the MCWC-CD (**STOR_PTS**). Locations, dates, and description of data collected are given in **Table 7.1**. The STORET data could not be compared to the more recent data collected in the watershed because they are generally not replicated and were taken at a number of different locations.

TABLE 7.1. STORET data for the Rock Creek watershed

STORET Water Quality Station ID	Station Location	Type of Data	Dates
402930	ROCK CREEK 2 MI U/S LOGSDEN	5 Temperatures	01 May 1972- 15 Oct 1973
SIL103	BIG ROCK CR AT ROAD XING NR GAGE	4 Temperatures 4 Total Suspended Solids	11 Dec 1978 – 26 Mar 1980
405057	STEER CREEK - LOWER	1 Temperature 1 Total Suspended Solids	18 Aug 1994
405056	STEER CREEK - UPPER	1 Temperature 1 Total Suspended Solids	17 Aug 1994
405059	BRUSH CREEK	2 Temperatures 2 Total Suspended Solids	19 Aug 1994

The Siletz Watershed Group is also concerned about potential pollution from direct livestock access to streams (see **Non-point pollution sources** below).

7.1.2 Water temperature

Salmon have specific ecological requirements for stream temperatures. During August and September 1997, water temperature was recorded at three locations in the watershed with continuous water temperature monitoring devices (locations shown in **Figure 5.12**). Average daily maximum temperatures were above 64° F less than half the time during the recording period (**Table 7.2**). The 7-day moving average of the daily maximum temperature was under 62 ° F at the Little Rock Creek locations and under 63 °F at the Rock Creek location. These temperatures are considered moderately impaired according to the GWEB Watershed Assessment Manual (Watershed Professionals Network 1999), with water temperatures exceeding the assessment criteria between 15 and 50% of the time.

TABLE 7.2. Daily maximum temperatures from continuous recording units, Aug.-Sept. 1997

Location	Average daily max Temp. (°F)	No. days	7-day average daily max Temp. (°F)	No. Days over 64° F	% of days over 64 ° F
Little Rock	61.5	56	61.5	12	21
Rock Creek	62.8	56	62.7	25	45
Upper Little Rock	61.7	56	61.6	16	29

Comparison of historical water temperatures to the 1997 data is difficult, because only sporadic water temperature measurements were taken in the watershed prior to the mid-1990's. ODFW staff measured water temperatures in Rock Creek, Big Rock Creek and Little Rock Creek during stream surveys in 1949 and 1953 (Willis and Best 1953), but these temperature data could be very misleading since there were so few measurements. Twelve temperature readings were taken in Big Rock Creek on the day of the survey (7/9/1953); the average of the 12 readings was 55.2° F (12.9° C). Only two temperatures were taken in lower Rock Creek; these were 59° F (15.0° C) and 54° F (12.2° C) in July 1949. Four temperature readings were taken in Rock Creek above the mouth of Big Rock Creek (7/22/1949: all around 60° F or 15.6° C), and four in Big Rock Creek (7/24/1949: all around 54° F or 12.2° C). These sporadic readings are considerably lower than the recent measurements, but they are not daily maxima and they weren't taken during the hottest part of the summer, so they can't be compared to the current data.

Springs and seeps can contribute cold water to streams, lowering the temperature in or downstream from areas with little shade. Although other springs are no doubt present in the watershed, available digital data shows only two springs. USGS 7.5 minute quads show three springs:

- a spring flowing to an unnamed tributary to Steer Creek between Rudder and Long Canyon Creek
- a spring flowing to Steer Creek just downstream of the entrance of the above unnamed tributary
- a spring flowing to Rock Creek, located on the right (north) bank of Rock Creek between Big Rock Creek and William Creek.

Locations of these springs are shown on **Figure 4.1**.

7.2 Water chemistry

The most detailed information on water quality parameters in the watershed (other than temperature) was collected during a joint effort of the Siletz Watershed Group and the Confederated Tribes of the Siletz Indians during 1996, 1997 and 1998. Locations of stations are shown in **Figure 5.12**. Water samples were analyzed for dissolved oxygen concentration, pH, and turbidity. Values averaged across the period of sampling are shown for each station below. Values were evaluated using benchmarks and methods described in the GWEB watershed assessment manual (Watershed Professionals Network 1999).

TABLE 7.3. Water quality measurements, CTSI/SWG sampling, 1997-98. See Figure 5.12 for sampling locations.

Site	**Average Dissolved Oxygen Concentration** (mg/L)	**Average pH***	**Average Turbidity** (NTUs)
1	8.26	6.71	1.32
2	7.72	6.63	2.72
3	7.68	6.60	3.40
4	7.74	6.63	3.68
5	7.74	6.67	0.95
6	7.93	6.64	1.68
7	8.02	6.67	2.37
8	7.96	6.59	2.56
9	8.14	6.62	2.21
10	7.84	6.62	1.55
Average	**7.90**	**6.64**	**2.29**

*Average of pH is an average of log10-transformed pH values; this average was then transformed back to correspond to original units.

Average dissolved oxygen concentration met the GWEB Manual benchmark of >=8mg/L only at two sites. However, grab sample data are of limited value in assessing water quality, since dissolved oxygen concentration can vary considerably over daily cycles.

Average pH values were within the expected range for the Coast Range. Turbidity was not in exceedance of the GWEB Manual criterion (50 NTU; Non-point Source Solutions 1997) at any sample date.

7.2.1 Non-point pollution sources

Non-point pollution sources in the watershed include nutrient and bacterial loading from pasture areas; land application of sewage sludge near the mouth of Rock Creek; herbicides applied on land or near water; and possible leakage of toxic materials from a closed gas station in Logsden.

During the Aquatic Habitat Inventory, field crews noted the presence of cattle in the stream at a number of sample points, so there is the potential for pathogens (disease-causing bacteria and viruses) to enter the stream. Pathogens are not directly measured in routine water quality testing. Instead, fecal coliform bacteria, which are easier to measure, are used to indicate possible human health risk due to pathogens. Like surface water, groundwater is normally monitored for fecal coliform during development of domestic water supplies; the watershed group could obtain the results of this work. However, groundwater testing would not necessarily provide indicators of pollutants in streams, since surface runoff may carry pollutants directly to streams without those pollutants entering groundwater.

Nutrient and bacterial pollutants enter streams from pasture areas along streams in the watershed, particularly at lower elevations. Riparian fencing and off-stream water sources can keep livestock off the streambank and provide a highly effective solution to this problem. Riparian fencing and off-stream watering accomplish several goals at once:

- allow re-growth of riparian vegetation that provides shade, bank stability, and habitat complexity to the stream environment
- prevent compaction and direct erosion of streambanks caused by livestock traffic
- prevent direct deposit of manure into the stream and greatly reduce washing of manure into the stream during rain events

Riparian fencing and off-stream water sources have been installed on several locations in the watershed (see **Existing watershed enhancement projects** above, and **Figure 3.17**).

An area of concern for the Siletz Watershed Group is land application of biosolids (sewage sludge) on the Howard Farm at the confluence of Rock Creek and the Siletz

River (**Figure 5.12**). Biosolids may contain high concentrations of fecal coliform bacteria (and pathogens) and nutrients such as nitrogen and phosphorus (which are pollutants when they enter streams). Biosolids may also contain toxic heavy metals. Local residents report that application of biosolids has occurred during heavy rain periods in winter (Siletz Watershed Group, January 19, 1999), suggesting that surface runoff could be carrying contamination directly to Rock Creek and the Siletz River.

Application of biosolids requires permits from a number of state and federal agencies; not all the restrictions on application at this site are known. However, a letter from the Oregon Department of Environmental Quality to the City of Toledo authorizing the land application stated a number of requirements, including pathogen reduction and setbacks (50 feet from roads and property lines, 200 feet from wells and water sources). The letter also stated that biosolids must be applied "evenly and thinly in a manner that will prevent ponding and runoff." This requirement suggests that application during periods of heavy rainfall could be a problem. For further discussion, see **Watershed enhancement recommendations** and **Monitoring recommendations** below.

The Siletz Watershed Group has expressed interest in evaluating possible non-point source water pollution originating from the application of herbicides. Herbicides could be transported in surface or subsurface flow into streams and could impact aquatic organisms. No data on herbicide applications were available for this watershed. However, if specific locations and materials applied are known, water flow models may be used with this assessment's GIS to determine appropriate monitoring locations for assessment of impacts from such applications.

7.3 Hydrology

7.3.1 Introduction

Basic information needed for assessment of current hydrologic conditions in the watershed includes stream flow data, terrain and stream channel type data, precipitation data, and determination of land cover. The general **Introduction to the Rock Creek Watershed** above contains a discussion of land cover, precipitation, terrain and stream channel types.

Existing streamflow data for the Rock Creek watershed is very limited. Only one water level data set has been collected within the watershed: this was for water flow between 1972 and 1989 at a gaged station located on Big Rock Creek (OWRD gage number 14304850). Data from this station show peak flows of 500 to 1000 (presumably cfs; generally in December and January) and low flows under 1 cfs in summer months (*http://www.wrd.state.or.us/cgi-bin/choose_gage.pl?huc=17100204*). Since this gage is located quite far upstream on Big Rock Creek (which does not have any permitted water users), the gage data are not very useful for this analysis.

Although there is a flow gage on the Siletz River at Siletz, the flow characteristics of the Siletz River are very different from those of Rock Creek and its tributaries, and therefore we did not consider Siletz River gage data useful in this analysis.

7.3.2 Rain on snow

Rain falling on snow is a significant hydrologic event in the watershed. Areas covered with snow prevent rainwater from soaking into the ground, increasing surface runoff as rainwater moves laterally across the snow's surface. In addition, rainfall can increase the rate of snowmelt, further adding water to the land surface. Because these increases in surface runoff result in higher than normal peak flows, flooding in the lower portions of the watershed may occur when rain falls on snow at higher elevations.

In the Rock Creek watershed, elevation and land cover determine where rain on snow events are likely to have hydrologic impacts. The lower elevation threshold for rain on snow events in the Oregon Coast Range may be as low as 1000 ft (NonPoint Source Solution 1997). This threshold elevation was therefore used in determining possible rain-on-snow areas in the Rock Creek watershed.

We addressed rain on snow events in two ways. First, we used the 10m DEM data set to identify areas with an elevation between 1,000 and 2,500 ft (304 - 762 m) and created a GIS coverage of these areas (**RC1000)**. The GWEB Manual (Non-point Source Solutions 1997) indicates that these are areas likely to experience rain on snow events. We found that elevations in the Rock Creek watershed ranged from 158 to 2,828 ft (48 to 862 m), with an average elevation of 1,492 ft (455 m). 3,983 ha (35.6%) of the Rock Creek watershed had an elevation of more than 1,000 ft.

Next, we mapped the areas that are classified as "open" in the **CLAMS88** data set from the MCWC CD-ROM (**RCOPEN)**. We found that 621 ha were classified as being open (5.5% of the total Rock Creek watershed).

Finally, we combined the **RC1000** and **RCOPEN** coverages to create a polygon GIS coverage of open areas above 1,000 feet (**RCOPEN&1000-2.SHP**). We found that 211.8 ha (about 2% of the total watershed area) in the Rock Creek watershed met these criteria (**Figure 7.1**). We ranked each catchment by the proportion of that catchment that consisted of open areas above 1000 feet ("ROS impact areas"). The greater the proportion of the catchment's area covered with ROS impact areas, the higher the score. We found that 79 of the 347 catchments contain ROS impact areas. Proportion of these catchments occupied by ROS impact areas ranged from 0 to 50%, with most catchments having between 10-20 % of their area occupied by ROS impact areas.

It is important to note that all areas (not just open areas) where rain falls on snow will experience high peak flows due to the combination of current rainfall and snowmelt caused by that rainfall. Forested areas also experience increased peak flows due to rain on snow events. However, open areas are likely to accumulate snow and may therefore have a more extreme hydrologic response to rain on snow events (Non-point Source Solutions 1997).

7.3.3 Flooding

See **Filling of wetlands, floodplains and small streams** above.

7.3.4 Wetlands

As discussed in Section 4.6, the watershed appears to contain mainly riparian wetlands. Wetlands shown on National Wetland Inventory maps for the watershed are shown in **Figure 3.16**. These riparian wetlands provide important habitat for salmonids and their prey. They also provide floodwater storage, which can reduce downstream flooding. Riparian backwater wetlands receive water that overtops the streambanks during high flow events. The wetlands retain this water, reducing and delaying peak flows in the stream. During spring and summer, wetlands retain water that would otherwise flow out of the system, releasing it slowly to maintain more even water flow through the dry season.

7.3.5 Peak flows

Peak flows occur as water quickly moves from the landscape to the stream network. Peak flows can be characterized by the amplitude of the peak and duration, both are represented on a hydrograph. All streams have peak flows; in many high gradient streams, peak flows are responsible for organizing stream channel complexity. Many streams are naturally "flashy" and experienced high peak flows long before modern land use changes. In the Pacific Northwest, aquatic organisms have adapted to these high flow events or were able to find refuge in backwater areas within the watershed. However, many modern land use practices have dramatically altered patterns in peak flows.

Timber harvest and associated road construction have been shown to increase wintertime peak flows in Coast Range watersheds (Harr 1980 and 1983; Hicks 1990). Increased peak flows can cause major alterations in aquatic habitats. For example, higher flood peaks can cause streambank erosion and channel scouring, obliterating salmon spawning redds (ODFW 1997a). Streams affected by repeated, abnormally high flood peaks may undergo downcutting, which separates them from their natural floodplains. When streams become disconnected from their floodplains, peak flows are further exaggerated, since floodwaters are no longer delayed or retained in backwater wetlands and side channels. All stream channels in the Rock Creek watershed are classified as confined channel types (see **Channel types** above, and **Figure 3.15**), despite the presence of broad, flat areas (possibly former floodplains) adjacent to the lower reaches of major streams. This combination of features may indicate downcutting of the watershed's streams, possibly related to recent changes in peak flow characteristics.

Road construction in forest lands can increase peak flows (see **Channel modifications: Roads** above). Subwatersheds with under 4% of surface land area occupied by roads are considered to have low potential for peak flow increases; subwatersheds with 4 to 8% road coverage have moderate risk; and areas with over 8% have high risk (Watershed Professionals Network 1999). Digital data available for this study show that there are 153 mi (247 km) of roads in the Rock Creek watershed: 115 mi (184 km) are paved and 38 mi (62 km) are unpaved.

Road densities can be used to guide more intensive inventory of roads in the watershed. We calculated road densities for all catchments and found that road densities (m road / ha) ranged from 0 to 105 m of road / ha. The average catchment road density was 27.5 m of road / ha, and 235 catchments had densities exceeding 10 m of road / ha (**Figure 7.2**).

7.3.6 Low flows and salmonid use

Coho salmon spawn in upper watersheds high in the Coast Range. These fish evolved under conditions of low flow in summer. However, human activities have further reduced summer low flows, and these reduced flows may have had strong impacts on fish reproduction in general, and particularly for salmonids. Coho juveniles, for example, spend their first summer in pools of upper stream reaches, where reduced flows can result in increased water temperatures and reduced water quality. ODFW designates all of the Rock Creek watershed as low priority for spring, summer, fall, and winter streamflow restoration (ODFW website, *www.dfw.state.or.us*), but impacts from low flow reductions could still exist within the watershed despite this designation.

In a recent paper, Dunne (1998) reports that forest hydrology has a "sad history of controversy … Forest hydrologists could be recruited to defend almost any side of a debate." He specifically mentions that our understanding of forest hydrology came chiefly from "small-scale problems in carefully selected, relatively simple environments…". It is not surprising that a number of studies can be found that demonstrate that timber harvest can increase in summer base flows, while other studies demonstrate that logging reduces summer low flows, particularly in inland watersheds underlain by sandstone formations, and in areas subject to fog drip (Harr 1980; Hicks 1990). Summer low flow reductions could impact fish habitat by reducing coho access to spawning grounds. Coho begin migrating upstream to spawn in October, when fall rains may not yet have been abundant and stream flows may still be low. Juvenile coho migrate downstream from their freshwater rearing habitat in spring and summer, and reductions in summer low flows may reduce rearing habitat and prevent juvenile outmigration. When many natural flow constrictions and small obstructions exist, even small reductions in stream flow could block coho access to large parts of the watershed.

7.3.7 Low flows & human water uses

The Oregon Water Resources Department issues permits for water use in the watershed. Human consumption and livestock use are exempt from permit requirements. Water rights dated prior to 3/26/74 are prioritized in the Rock Creek watershed; a summer minimum flow of 10 cfs is maintained (ODFW 1997a).

Eighteen water users in the Rock Creek watershed have applied for and received water use permits from the Oregon Water Resources Department (**Figure 7.3**). Five of these users are located in the Steer Creek watershed, two low in the subbasin and three on upper Steer Creek, above the entrance of Little Steer Creek. One user is located on lower Rudder Creek, and one is near the mouth of Steer Creek. Two are located at the mouth of the unnamed tributary that enters Rock Creek just upstream of the hatchery. The hatchery has a water use permit. Two users fall between the hatchery and Big Rock Creek; another just downstream from Big Rock Creek. Three users are located on unnamed tributaries and four in the lower portion of Rock Creek. Total permitted withdrawals are 1.57 cfs (data from OWRD website, *http://www.wrd.state.or.us*). Since there are no stream level gage data for the streams on which water use permits have been issued, the effect of the permitted withdrawals on stream flows cannot be calculated.

Due to the region's Mediterranean climate, summer flows have always been low in the Siletz River basin. In past decades, people foresaw increasing demands for water in the mid-coast region and a proposal was developed for a water supply dam on Big Rock Creek. This proposal was supported in a U.S. Department of the Interior Appraisal Report dated 1981 (USDI 1981). The maximum development proposal would have included a second dam on Sunshine Creek northwest of the Rock Creek watershed, with a connecting spillway from Big Rock Reservoir into the Sunshine Creek reservoir.

Proposed uses for water stored in the reservoir included municipal and industrial uses, freshwater recreation (boating and fishing in the proposed reservoir), augmentation of summer low flows for salmonid production, additional water supply for the Siletz River Hatchery on Rock Creek, and agricultural use. The Appraisal Report did not consider any possible negative impact to salmonid populations from the proposed dam. Possible negative impacts would include water quality changes and hydrologic alterations to the Rock Creek watershed caused by creation of a large artificial lake; road construction impacts; and recreational use impacts.

8 Data recommendations

8.1 General

- Select a base map. We developed a series of base map layers at a scale of 1:24,000. We recommend that you continue to use this scale map (or larger, i.e., 1:12,000) as a base map. For use in the field, USGS 7.5 minute quadrangles are an appropriate map on which to record locations. For GIS development, we are providing the MCWC with the USGS DLG layers we acquired for roads and streams in the watershed.
- Georeference your data at the level of detail required for a 1:24,000 scale base map. When data are collected, record the location by drawing the sampling point or area on a USGS 7.5 minute topographic maps, or use a GPS unit and record latitude-longitude data for each location. If you're not sure exactly where you are, record distances to landmarks that can be readily located on a USGS quad map, on the digital orthoquads, or on an air photo.
- Get expert advice on data collection, data analysis and data archiving. Consult with the MidCoast Watershed Council Technical Team to develop appropriate data collection, data analysis, and data archival methods and strategies. Store data in a centralized location (preferably the MidCoast Watershed Council office) to ensure accessibility. The GIS is an appropriate archival location for data: use the MCWC Tech Team's expertise to update your watershed GIS periodically.
- Use strategic sampling to maximize the return on your effort. Develop data collection strategies that will answer specific questions about the watershed. Develop a scientific hypothesis before collecting data, and design your sampling to test that hypothesis. Work together with groups that are already conducting sampling in the watershed to develop data collection and analysis strategies. Coordinating efforts will reduce redundancy and greatly increase return on effort.
- Ensure that all data collected is processed. Process your data (enter it into a computer spreadsheet, calibrate the results, analyze the results, and archive the information) in a timely fashion. This will help ensure that questions that arise during data processing can be answered while the individuals who collected the data remember important details. Before collecting new data process and evaluate the old data to see if the data can be used to answer the question of interest. If not, re-evaluate your data collection needs.
- Collect data in strategic locations. For example, study areas could be sited in and near known/likely salmon habitat, in a series of comparable areas (to determine variability), downstream of existing restoration projects, etc. Collect data at the same locations across a period of time to determine seasonal and longer cycles of change. Discuss these issues with MCWC Technical Team.

8.2 Land cover

- Visit areas shown in this assessment to have high densities of large conifers. Verify the presence of large conifers both in catchments and in riparian areas.
- Update land cover information to reflect the current condition of the watershed.
- Survey riparian plant communities, especially in areas known to have spawning coho.
- Locate areas (catchments) of comparable land cover for monitoring activities (see also Water Quality below). Consider establishing monitoring points downstream of rare species management areas, for comparison to more intensively managed areas.
- Verify areas shown as "open" in CLAMS88 data. Differentiate between grazed open areas and non-grazed open areas.
- Locate, map and monitor areas of exotic species of concern -- for example, Japanese knotweed.
- Determine the condition of pasture areas and track herd densities.
- Determine the condition of fences along streams.

8.3 Roads

- Acquire a more complete roads layer. Maintain contact with groups that are preparing more complete roads layers, such as timber companies and the Oregon Department of Forestry, and request data sharing to maximize the accuracy of the road layer.
- Map road failures.
- Map culvert locations and collect information on culvert features. Use a standardized data sheet to collect this information. Contact ODFW for current data collection methods and data sheets. Determine which culverts present a barrier to fish passage.
- Map areas where roads are confining streams (streams flow directly along roadsides) to verify and refine the information in this assessment.
- During or after heavy rainfall events, record locations where surface flow runs directly along roads and into streams. These roads can be major sources of sediment delivery to streams.
- Where road information is available, perform road restoration activities such as road decommissioning and obliteration, removal of culverts to re-establish natural drainage patterns, and perform erosion control measures to minimize sediment delivery to streams.

8.4 Streams

- Map active floodplains and wetland areas. Collect data from landowners on flood frequency and locations of flood zones, alternate stream channels, backwater wetlands, and other areas that flood during high flows. This information will help you determine whether streams are connected to their floodplains. The NWI map would be a good starting point for mapping wetlands and might point you to some areas where stream channels are unconfined.

- Map areas of dynamic (frequently changing) stream channels.
- Map the locations of riprap, debris jams, beaver ponds, water diversions, springs and seeps, and stream channelization. These features are recorded as comment codes in the AHI datasheets; their locations may be estimated using the landmarks (bridge crossings, tributary junctions, structures, property boundaries, etc.) recorded in the comment codes.

8.5 Biological data

- Work with ODFW to develop reliable estimates of populations and distribution of species of concern, such as salmon, lamprey, and mussels. Volunteers can assist and expand agency surveys. The lack of data in this area is a major impediment to development of successful watershed enhancement strategies.
- Design data collection strategies that include biological sampling. For example, water quality monitoring should include sampling for benthic macroinvertebrates, which are good indicators of water quality.
- Work with ODFW to update the Aquatic Habitat inventory periodically. To improve mapping, measure habitat unit lengths and locations with hip chains or GPS if possible, and record landmarks as often as possible. Calibrate observers to maximize accuracy. Ensure that data are completely processed by ODFW and tied to an appropriate scale GIS base layer.
- Analyze Aquatic Habitat Inventory data for locations of beaver dams and beaver activity (observations of beaver activity and dams are recorded as comment codes in the Unit 2 form). Compare results to those described in beaver habitat models (e.g., Suzuki and McComb 1998). Use results to predict other beaver habitat in the watershed; consider this factor when deciding where to plant riparian conifers (see **Watershed enhancement recommendations**, below).
- Compare the current digital layer for fish limits (**Figure 5.13**) to the paper maps of fish limits from ODF. Work with MCWC to update the digital data layer for fish limits, using ODF fish limits maps as the data source.
- Document locations of rare species in the watershed, including rare plants such as *Filipendula occidentalis*.
- Record areas of algal blooms that could indicate nutrient pollution and low dissolved oxygen concentrations.

8.6 Water resources and water quality

- Set up a systematic water quality monitoring program, with strategically located sample points -- for instance, in areas known to have spawning salmon, downstream of rare species management areas, and downstream of more intensively managed forests. Set up monitoring program to answer specific questions and to develop baseline information.
- Continue and expand continuous stream temperature monitoring (HOBO temperature units).
- Document dates and weather conditions during times of biosolids application. Look for and record surface runoff during application periods.
- Establish stream gaging stations, weather stations and rainfall gages to improve knowledge of water availability.
- Map water diversions (pipes in streams).
- Map well locations and known springs.
- Obtain well records (water quality, level) and document water shortages and water quality problems.
- Consider water temperature modeling (methods available at NRCS).
- Locate and map potential water contamination sources, for example underground storage tanks and agricultural chemical storage.
- Collect information on and coordinate restoration projects to make sure efforts are not working at cross-purposes.

8.7 Land use

- The Confederated Tribes of the Siletz Indians have developed a GIS layer containing names of non-industrial private landowners whose property fronts on Rock Creek, lower Little Rock Creek, and lower Steer Creek. This information should be added into the MCWC GIS. If this is done, differences between the CTSI ownership layer and the MCWC GIS ownership layer should be resolved (there are a few places where the information differs, so it is important to determine which coverage is correct).
- Map houses and other buildings in the watershed. Incorporate tax assessment information (parcels, assessed structures) into the GIS when this information becomes available from Lincoln County.
- Update and map changing land use information, e.g., timber harvest plans, pesticide application areas, construction projects. All of these factors can have an effect on salmonid populations and water quality.

9 Watershed enhancement recommendations

9.1 Recommendations for Aquatic Habitat Improvement:

We summarized the condition of the Rock Creek watershed using aquatic habitat information in **Figures 5.2 – 5.10**. We combined information from each of the AHI variables to generate an integrated summary of the aquatic habitat (defined by ODFW benchmarks) for each catchment. Because some AHI variables were missing data from a substantial number of catchments, only the following variables were used: percent silt-sand-organic sediments, percent gravel, shade, percent of stream that is pools, width to depth ratio, countable pieces of large wood per 100 m, and volume of countable wood per 100 m. We found only 12 catchments that were considered to be “desirable” (according to ODFW benchmarks) for at least half (4 out of 8) AHI variables (**Figure 9.1**). The “best” catchments only received a desirable rank for 5 out of 8 AHI variables suggesting that there is room for improvement (**Table 9.1**). Most of the "best" catchments were locatd in upper Big Rock Creek, above the falls that form a barrier to anadromous fish.

TABLE 9.1. Summary of the catchments with the greatest number of "Desirable" AHI scores. Shown are areas that could be improved to increase the overall desirability of each catchment.

Catchment No.	%silt+sand+organic	%gravel	Amount of shade	Percent of stream area that is pools	Stream widths between pools	Stream width/ depth ratio	Number of countable pieces of wood /100m	Volume of countable wood per 100m
1	X						X	X
2				X	X		X	
3	X						X	X
4	X						X	X
5	X						X	X
6	X						X	X
7	X				X		X	X
8	X				X		X	X
9	X	X	X	X		X		
10	X					X	X	X
11	X				X		X	X
12	X		X				X	X

Considering that many of these catchments are potential fish habitat (**Figure 5.13**) there are actions that can be performed to increase the "Aquatic Habitat" value of these stream segments (as evaluated by AHI crews).

Most common riparian management actions directly affect the amount of shade and the amount of wood in streams (pieces and volume). While it is difficult to alter the stream substrate and the frequency and depth of pools and riffles, we recognize that placement of large woody debris can “improve” streams at specific locations by promoting stream scour and sediment deposition.

Stream-side vegetation provides shade and areas of potential wood recruitment. None of the catchments identified had high proportions of large wood in riparian areas (**Figures 3.9 and 3.10**). This suggests that riparian plantings may be an appropriate restoration strategy. Enhancement of riparian shade would improve the overall rank of catchments number 9 and 12.

In addition to riparian areas, large trees can also be recruited from other areas in the catchment during debris flows or landslides. Catchments 1, 4, 5, 7, 9, and 12 all have areas of steep slopes (**Figure 6.1**) and could potentially supply large wood to streams. We identified catchments 1 and 7 as having a moderately high index of Large Conifers (**Figure 3.11**). We recommend that the current vegetation of these 12 catchments be ground-truthed. In particular, catchment No. 7 should be visited because it is a relatively high elevation (**Figure 7.1**) headwater catchment that has the potential for large wood recruitment.

9.2 General recommendations

- Prioritize management activities based on information in this assessment. Focus watershed enhancement efforts in areas known to have or likely to have salmonid spawning and rearing habitat -- areas upstream and downstream of juvenile coho "hot spots", areas with good in-stream characteristics, and catchments with relatively high levels of large conifers.
- Prepare a strategy to improve large woody debris in streams. Consider existing locations of large conifers in riparian areas, fish hot spots, natural areas of stream confinement, and timber harvest rotation lengths. Use methods that enhance long-term woody debris recruitment, including conifer plantings (see next item) or other actions that will increase vegetation cover and the number of large trees in riparian areas. Consider the importance of beaver in the ecosystem (see next item), and consider this statement from a recent paper by Oregon State University Professor Robert Beschta (1998):

  > "While structural diversity may be an important need for Pacific Northwest streams, there is a lack of research that demonstrates significant and long-term improvement in fisheries production following instream habitat alterations … The

> mere addition of structure to a channel for specific habitat components may not satisfy the needs of stressed fisheries populations. Particularly in unconfined reaches, some structural approaches may actually be counterproductive to restoring ecological functions . . ."

Beschta concludes by recommending that managers should focus on minimizing and eliminating activities that degrade riparian ecosystems, rather than relying on "structural approaches."

- Plant riparian conifers in areas that are suitable, or facilitate conifer growth through less expensive management actions, i.e., removing alders or shrubby thickets. Lack of large woody debris recruitment potential is one of the major problems in the watershed.

  Although beaver can be destructive to conifer plantings, beaver also create winter habitat for juvenile salmon, and they create that habitat within a short time frame compared to the time required for maturation of conifer plantings. Therefore, trapping or otherwise removing beaver in order to improve survival of conifer plantings may be counterproductive for salmon. Instead, locate conifer plantings outside areas that are prime beaver habitat. Stream characteristics such as gradient, width, and valley floor width are closely related to the frequency of beaver dams (Duzuki and McComb 1998), so it may be possible to predict which areas are prime beaver habitat. Use expert advice to determine likely beaver habitat, and locate conifer plantings elsewhere. In addition, locate conifer planting areas strategically to enhance the areas with known salmon spawning and rearing, and areas where conditions are conducive to salmon spawning and rearing.

- Develop a strategy for creating backwater wetlands, off-channel habitat and other rearing areas. Locate created habitat in areas known or likely to have salmon spawning or rearing activity. Consider areas of active floodplain (after determining these areas; see **Data recommendations: Streams** above).

- Replace culverts to improve fish passage (after completing a field survey of culverts).

- Maintain vegetated buffer strips along streams. Continue and expand the riparian fencing program in the watershed. Develop a strategy for riparian plantings in pastures and other areas which lack good riparian plant communities. Prioritize areas of known salmon spawning and rearing. Plant only native species. Base planting plans on surveys of riparian plant communities in comparable, relatively undisturbed settings.

- Maintain contacts with Oregon Department of Forestry, Bureau of Land Management, and the Confederated Tribes of the Siletz Indians. Request that they inform you of planned timber harvest areas in the watershed a year or two in advance; set up monitoring activities accordingly.

- Develop a public education strategy. Talk with local homeowners about watershed resources and the importance of maintaining native riparian vegetation on their property.
- Check for and/or establish sediment detention structures on roadsides.
- Develop familiarity with the Oregon Department of Forestry Forest Practices Act. Discuss timber harvest practices with landowners in the watershed. Particularly in areas upstream of known salmon habitat, encourage riparian setbacks, avoidance of clearcuts on steep slopes and near-vertical headwalls, and timing of clearcuts to avoid harvesting an entire subwatershed at once.

10 References

Aviolio, G. W. 1973. Granulometric analysis of recent sediments of Tillamook Bay, OR. Thesis, Portland State University, Portland, OR.

Beschta, R. L. 1998. Forest hydrology in the Pacific Northwest: additional research needs. J. of the American Water Resources Assoc. 34:729-741.

Botkin, D. B. et al. 1994. Status and future of anadromous fish of western Oregon and northern California: available data on fish populations. Research Reports 931001-931003. The Center for the Study of the Environment: Portland, OR.

Bottom, D. L., J. A. Lichatowich, and C. A. Frissell. 1998. Variability of Pacific Northwest Marine Ecosystems and Relation to Salmon Production. In McMurray, G. R. and R. J. Bailey [eds]. Change in Pacific Northwest Coastal Ecosystems. NOAA Coastal Ocean Program, Decision Analysis Series No. 11. , Silver Spring, MD. Pages 181-252.

Borgerson, L.A., and R.K. Bowden. 1991 through 1997. Scale Analysis. ODFW Fish Research Report F-144-R-7. Annual Progress Report, Portland, OR.

Bryant, M. D. 1983. The role and management of woody debris in west coast salmonid nursery streams. North American J. of Fisheries Management, 3: 322-330.

Bureau of Land Management. 1991. Forest Stand Age Classes, Oregon Coast Range, 1850, 1890, 1920, and 1940. Maps prepared by Salem District and Oregon State Office, Bureau of Land Management, Sept. 1991.

Bureau of Land Management. 1995. Salem District Record of Decision and Resource Management Plan. U.S. Department of the Interior, Bureau of Land Management, Salem District Office, Salem, Oregon. 76 p.

Bureau of Land Management. 1996. Upper Siletz Watershed Analysis. Marys Peak Resource Area, Salem District, Bureau of Land Management, U.S. Department of the Interior.

Center for Research in Water Resources. 1998. GIS Hydro '98: Introduction to GIS Hydrology. CD-ROM, Environmental Systems Research Institute, Inc.

Clutter, R. and A. Jones. 1949. Survey: Rock Creek, Siletz River, July 22-24, 1949. Unpublished report to Oregon Fish Commission, 14 pp. including figures.

Coulton, K., P. B. Williams, and P. A. Benner. 1996. An Environmental History of the Tillamook Bay Estuary and Watershed. Research Report CE 990292-1, Tillamook Bay National Estuary Project, Garibaldi, OR .

Creager, J. S., C. R. Sherwood, E. H. Roy, G. Gelfenbaum and T. Dempsey. 1984. Final report on the sedimentation and shoaling work unit of the Columbia River Estuary Data Development Program. Seattle, WA, CREST.

Dangermond, J. 1990. A classification of software components commonly used in geographical information systems. 1990. In Peuquet, D. J. and D. F. Marble (eds.) Introductory readings in Geographic Information Systems. Taylor & Francis, NY.

Dicken, S. N., C. L. Johannessen and B. Hanneson. 1961. Some recent physical changes of the Oregon coast. Eugene, OR, Dept. of Geography, University of Oregon & U.S. Dept of Navy.

Downey, T., D. Rilatos, A. Sondenaa, and B. Zybach. 1993. The Siletz Eels: Oral history interviews with Siletz Tribal Elders and neighboring residents regarding the decline in Siletz River lamprey populations. Preliminary report to the Council of the Confederated Tribes of the Siletz, August 21, 1993. Native Americans in Marine Science Program, Oregon State University, Corvallis, Oregon.

Dunne, T. 1998. Critical data requirements for prediction of erosion and sedimentation in mountain drainage basins. J. of the American Water Resources Association. 34: 795-806.

Franklin, J. F. and C. T. Dyrness. 1988. Natural Vegetation of Oregon and Washington. Oregon State University Press, Corvallis, OR 452 p.

Garono, R. J. 1999. A Review of the MCWC CD-ROM Version 4.0: use recommendations. Technical Report, MCWC, Newport, OR 341 p.

Guthrie, D. and J. Sidell. 1998. Beavers -- A keystone species. Beaver quests on the Oregon Coast. In Coast Range Association. Strategically approaching salmon protection in coastal watersheds: A guidance manual for local watershed residents. pages IV-10-15

Harmon, M. E., J. F. Franklin, F. J. Swanson, P. Sollins, S. V. Gregory, J. D. Lattin, N. H. Anderson, S. P. Cline, N. G. Aumen, J. R. Sedell, G. W. Lienkaemper, K. Cromack, Jr., and K. W. Cummins. 1986. Ecology of coarse wood debris in temperate ecosystems. In. Advances in ecological research, Vol. 15..Orlando Florida, Academic Press. 133-302.

Harr, R.D. 1980. Streamflow after patch logging in small drainages within the Bull Run Municipal Watershed, Oregon. USDA For. Serv. Res. Pap. PNW-268, 16 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, OR.

Harr, R.D. 1983. Potential for augmenting water yield through forest practices in western Washington and western Oregon.Water Resources Bulletin 19:383-393.

Hicks, B. J. 1989. The influence of geology and timber harvest on channel morphology and salmonid populations in Oregon Coast Range streams. Ph.D. Thesis, Oregon State University, 1989.

Jacobs, Steve. 1999. Oregon Department of Fish and Wildlife Internal documents on coho spawner surveys, 1990-1998.

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, 32: 959-974.

Keller, E. A. and F. J. Swanson. 1979. Effects of large organic material on channel form and fluvial processes. Earth Surface Processes, 4: 361-380.

Knezevich, C.A. 1982. Soil Survey of Polk County, Oregon. USDA Soil Conservation Service, in cooperation with the Oregon Agricultural Experiment Station.

Maleki, S. 1998. The Oregon Plan for Salmon and Watersheds Annual Progress Report: Watershed Restoration Inventory. Governor's Watershed Enhancement Board, August 1998.

McManus, J. P.D. Komar, G. Bostrom, D. Colbert, and J. Marra. 1998. Sediment sources and the history of accumulation in Tillamook Bay, OR. Technical Report, Tillamook Bay National Estuary Project, Garibaldi, OR. 58 p.

McMurray, G. R. and R. J. Bailey [eds]. Change in Pacific Northwest Coastal Ecosystems. NOAA Coastal Ocean Program, Decision Analysis Series No. 11. , Silver Spring, MD.

Montgomery, D. R. and W. E. Dietrich. 1994. A physically based model for the topographic control of shallow landsliding. Water Resources Res. 30: 1153-1171.

Moore, K., K. Jones, and J. Dambacher. 1997. Methods for stream habitat surveys. Aquatic Inventory Project. Oregon Department of Fish and Wildlife, Natural Production Program, Corvallis, OR. 45 p.

Morgan, A R. 1964. Oregon coastal salmon and steelhead tagging programs. Part II. Siletz River, 1954. Fish Commission of Oregon,Contribution No. 28: 43-62.

Muehrcke, P. C. 1986. *Map use: reading, analysis and interpretation*. JP Publications, Madison, WI.

Nehlsen, W. and T. C. Dewberry. 1995. Tillamook Bay watershed analysis framework. Technical Report, 05-95, Tillamook Bay National Estuary Project, Garibaldi, OR. 32 p.

Nickelson, T. E., J. D. Rodgers, S. L. Johnson, and M. F. Solazzi. 1992. Seasonal changes in habitat use by juvenile coho salmon (*Onchorhynchus kisutch*) in Oregon coastal streams. Can. J. Fish. Aquat. Sci. 49: 783-789.

Nicholas, J. W. and D. G. Hankin. 1988. Chinook salmon populations in Oregon coastal river basins: Description of life histories an assessment of recent trends in run strengths. Information Report No. 88-1. Oregon Department of Fish and Wildlife, Research and Development Setion. 359 pp.

Non-Point Source Solutions. 1997. *Draft: Oregon Watershed Assessment Manual*. Governor's Watershed Enhancement Board, Salem, OR.

Odum, E. P. 1975. Ecology: the link between the natural and social sciences. New York, Holt, Rinehart, and Winston.

Omernik, J. M., 1987. Ecoregions of the Conterminous United States. Annals of the Association of American Geographers, v. 77, no. 1, p.118-125.

Oregon Department of Fish and Wildlife, 1988. ODFW Sport Catch Statistics, 1975-1987. ODFW internal documents, 1988.

Oregon Department of Fish and Wildlife, 1997. Siletz River Basin Fish Management Plan. 191 p.

Oregon Department of Fish and Wildlife, 1997. ODFW Sport Catch Statistics, 1984-1996. ODFW internal documents, 1997.

Oregon Natural Heritage Program. 1998. Rare, Threatened and Endangered Plants and Animals of Oregon. Oregon Natural Heritage Program, Portland, OR. 84 pp.

Pimentel, D., C. Harvey, P. Resosudarmo, K. Sinclair, D. Kurz, M. McNair, S. Crist, L. Shpritz, L. Fitton, R. Saffouri, R. Blair. 1995. Environmental and economical costs of soil erosion and conservation benefits. Science. 267: 1117-1123

Proctor, C. M., J. C. Garcia, et al. 1980. An Ecological Characterization of the Pacific Northwest coastal region. Portland, OR, U.S. Fish and Wildlife Service, Biological Services Program.

Rousseau, R.F. 1987. Letter to Mary Jane Robb regarding ODFW water rights at hatchery on Rock Creek (Lincoln County). ODFW Policy and Program Division, Portland Oregon, October 1987. 1 pg.

Shipman, J. A. 1997. Soil Survey of Lincoln County Area, Oregon. USDA Natural Resources Conservation Service and Forest Service, in cooperation with the Oregon Agricultural Experiment Station.

Smith, H.S. 1956. Fish Commission of Oregon, Contribution #22.

Stewart, G. 1963. Special Report -- Siletz River Hatchery. Unpublished report submitted to ODFW in 1963.

Stickell, T. W. 1979. Special Report -- Siletz Hatchery. Unpublished report submitted to ODFW in April 1979.

Siletz Watershed Group. 1997. Draft Rock Creek Watershed Assessment / Action Plan. Siletz Watershed Group, MidCoast Watersheds Council, February 1997. 15 pp.

Thom, R. M. and A. B. Borde. 1998. Human intervention in Pacific Northwest coastal ecosystems. In McMurray, G. R. and R. J. Bailey [eds]. Change in Pacific Northwest Coastal Ecosystems. NOAA Coastal Ocean Program, Decision Analysis Series No. 11. , Silver Spring, MD. Pages 5-37.

Trask, S. 1998. Rapid Bio-assessment 1998. Report to Mid-Coast Watersheds Council, 1998, 17 pp.

Tuchmann, E., K. P. Connaughton, L. E. Freedman, C. B. Moriwaki. 1996. The Northwest Forest Plan: A report to the President and Congress. U. S. Department of Agriculture, Forest Service, Pacific Northwest Research Station. 253 p.

Turner, B. L., R. H. Moss, and D. L. Skole, eds. 1993. *Relating land use and global land-cover change: A proposal for an IGBP-HDP core project.* Report from the IGBP-HDP Working Group on Land-Use/Land-Cover Change. Joint publication of the International Geosphere-Biosphere Programme (Report No. 24) and the Human Dimensions of Global Environmental Change Programme (Report No. 5). Stockholm: Royal Swedish Academy of Sciences.

United States Department of the Interior. 1981. Siletz River Basin, Oregon: Appraisal Report. USDI.

United States Forest Service. 1996. Drift (Siletz) Watershed Analysis. Prepared by staff of the Hebo Ranger District, Siuslaw National Forest, Hebo, Oregon.

United States Forest Service. 1997. Drift Creek (Alsea) Watershed Analysis. Siuslaw National Forest, Corvallis, Oregon.

Walker, G. W., and R. A. Duncan. 1989. Geologic Map of the Salem 1 by 2 degree Quadrangle, Western OR. United States Geological Survey, Misc. Investigations Series Map I-1893

Watershed Professionals Network. 1999. Draft Oregon Watershed Assessment of Aquatic Resources Manual. Governor's Watershed Enhancement Board, .

Wemple, B. C. 1994. Hydrologic integration of forest roads with stream networks in two basins, Western Cascades, Oregon. M. S. Thesis, Oregon State University.

Willis, R. A., and E. Best. 1953. Survey: North Fork of Rock Creek, Siletz River, July 9 and September 11, 1953. Supplement to Survey: Rock Creek, Siletz, River, July 22-24, 1949. Unpublished report to Oregon Fish Commission, 10 pp. including figures.

Wissmar, R. C. and C. A. Simenstad. 1998. Variability of riverine and estuarine ecosystem productivity for supporting Pacific salmon. In McMurray, G. R. and R. J. Bailey [eds]. Change in Pacific Northwest Coastal Ecosystems. NOAA Coastal Ocean Program, Decision Analysis Series No. 11, Silver Spring, MD. Pages 253-301.

Zar, J. H. 1984. Biostatistical Analysis. Prentice Hall, New Jersey. 718 pp.