TABLE OF CONTENTS

APPENDIX A. TILLAMOOK BAY RIVER SYSTEM CHARACTERIZATION

LIST OF FIGURES

Appendix A. Tillamook Bay River System Characterization

This appendix provides a series of assessments that define the current state of the river systems in the Tillamook Bay Basin. The assessments provide a compilation of basic data that will be used to develop an IRMS for the Tillamook Bay Basin. Conclusions from the assessments are presented in GIS maps, tables, charts, or diagrams. The goal was to make the conclusions as meaningful and understandable as possible within the constraints of available data and funding. Conclusions derived from GIS were mapped at either the basin extent (Figure A-1) or the lowland valley floodplain extent (Figure A-2). The lowland valley floodplain extent is a subset of the geomorphic lowland valley floodplain. Assessment mapping was focused on this smaller area because much of the available spatial data covered this area. The smaller area also allowed the development of a more detailed vegetation analysis (Appendix B).

The assessments are grouped in eight categories: Regional Precipitation and Climate, Basin Landform, River Hydrology, River Hydraulics, Tidal Processes, Vegetation, River System Morphology, Salmon Habitat and Distribution, and Human Land Use and Flood Risk. Each group of assessments builds upon those that precede it and illustrates the integrated relationship between natural and cultural systems. The natural system assessments begin by describing in spatial and temporal terms the interaction between land and water in the basin, moving on to vegetation and salmon distribution. The interaction between land and water is the foundation of the form and function of river systems. River and floodplain forms, combined with flood and tidal processes, create the conditions required to support a variety of native plant communities. These plant communities affect the way tides and floods alter landscape forms and are therefore essential to the geomorphic process. The complete system composed of water, land form, and vegetation in turn supports terrestrial and aquatic species such as salmon. The same conditions that support native plants and salmon have also encouraged human inhabitation in the Tillamook Bay Basin.

The assessments done for this report are intended to support the OWEB Oregon Watershed Assessment Manual, so many of the assessments correspond to activities described in the most recent version of this manual. However, the assessments done here are limited to those that help determine where and how flood risk reduction and salmon habitat enhancement can be achived in a coastal watershed. There are also a number of assessments of coastal and tidal processes that were added because they are not addressed in the OWEB manual. These processes are an integral part of the lowland river systems in the Tillamook Bay Basin and were considered important for assessing estuarine habitat in light of recent Endangered Species Act listings. They can be done relatively easily and may provide valuable information for Oregon watershed councils. With the exception of institutional characteristics, these assessments also support the categories for the analysis of river corridor conditions presented in Chapter 7 of the Federal Interagency Stream Restoration Working Group manual (Federal Interagency Stream Restoration Working Group, 1998).

These assessments were used to develop an understanding of natural processes and land use patterns with the Tillamook Bay Basin. This understanding was the basis of an IRMS. To demonstrate the IRMS, a concept plan for the lowland valley in the vicinity of the City of Tillamook was developed to locate, at a planning level, potential management actions within the lowland valley. GIS was used as an assessment tool because of its ability to describe the spatial coincidence between natural flood and tidal processes, post-flood permit activity, and salmon habitat. This spatial information was used to locate potential lowland valley actions. All of the assessments, including those using GIS, relied upon available data.

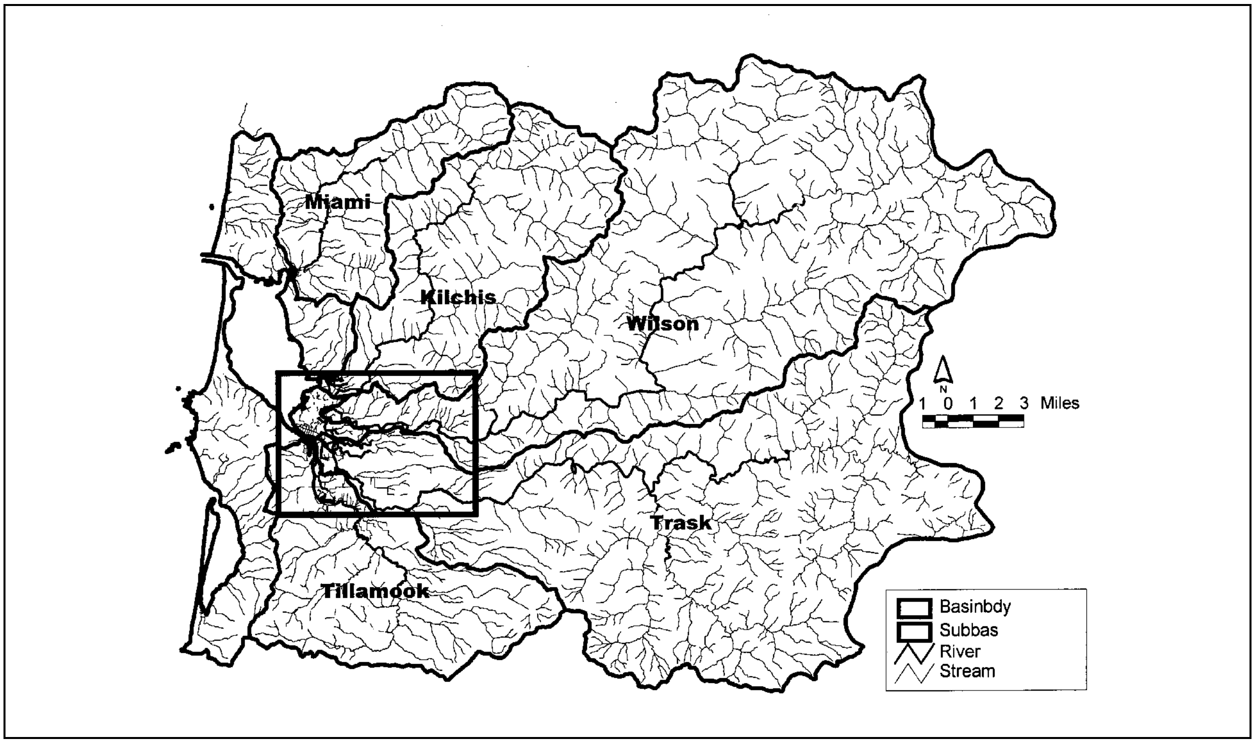


Figure A-1. Basin Scale Map Extent

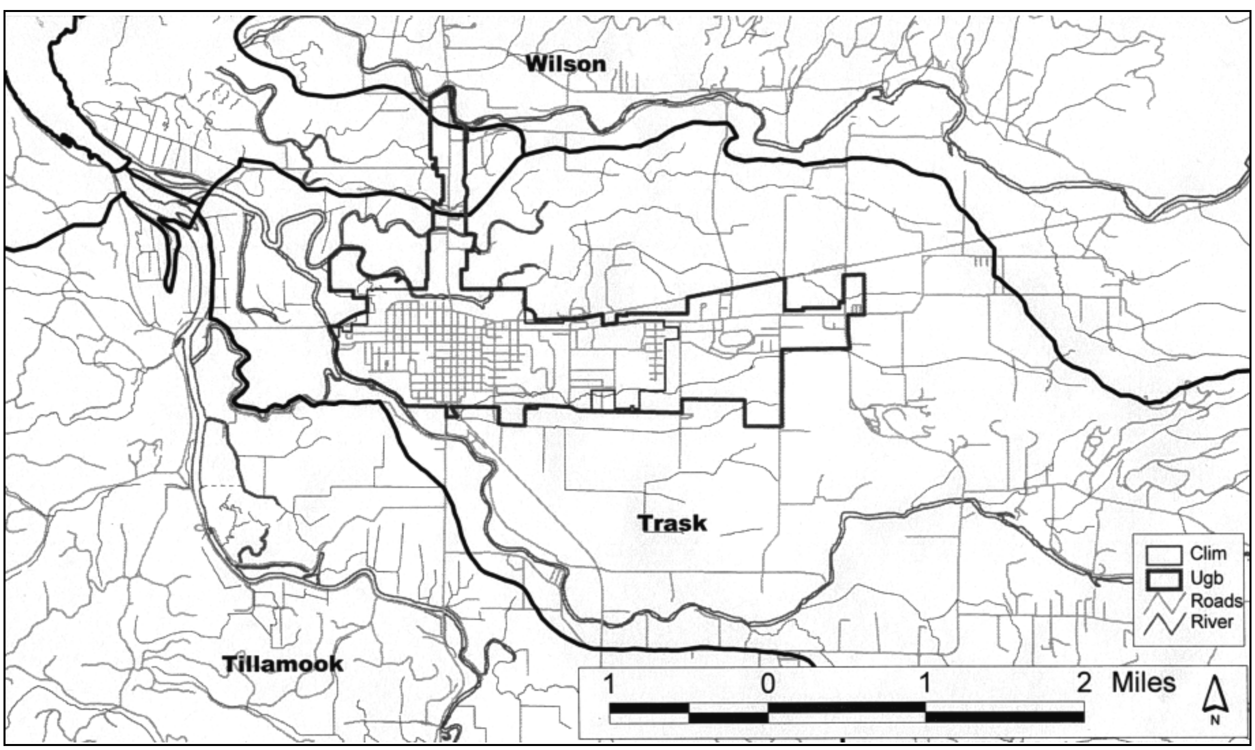


Figure A-2. Lowland Scale Map Extent

A.1 Regional Precipitation and Climate

Precipitation and climate control the amount, timing, and distribution of water in a river system. They are the principal components affecting both flood risk and salmon population viability. This section discusses precipitation history and trends in the Tillamook Bay watershed, as well as annual and monthly cycles of precipitation and evaporation, snow and snow melt, winds, and sun angles.

A.1.1 Precipitation History and Trends

■ Objectives

Precipitation, an important part of the hydrologic cycle, is the result of climatic and topographic factors, and is the predominant source of water into a fluvial system. The objective of the precipitation history assessment was to characterize past regional and local precipitation trends in the Tillamook area, and to predict future trends and their effect on fisheries and floods.

■ Methods

Historic regional precipitation trends for the Oregon Coast were obtained from the Oregon Climate Service (OCS) web site (http://www.ocs.orst.edu). Precipitation at all stations west of the crest of the Coast Range was averaged for each water year. Figure A-1-1 provides a summary of each year's departure from average water year precipitation from 1896 to 1995. The bars indicate individual water year departures and the line graph indicates a 5-year moving average. Figure A-1-2 provides a historic summary of water year precipitation for the Oregon Coast area from data also obtained from the OCS.

■ Discussion

Four climatic periods are identified in Figure A-1-1, alternating between wet and cool periods and dry and warm periods. These periods are generally 20 years in length. Because the last dry and warm period began in 1976, there is a possibility the Oregon Coast may currently be headed into a period of cooler and wetter weather.

These climatic cycles have a direct bearing on flood potential, and have recently been recognized as a possible indicator of salmon behavior, with cooler and wetter conditions being more favorable for the survival and resurgence of salmon. Wetter weather conditions also have direct implications for increased flooding potential, depending on the ability of the watershed system to absorb precipitation and attenuate runoff. Therefore, it may become increasingly important to manage the forested upland watershed areas of the Tillamook basin to slow the movement of water when it enters the river system as precipitation.

The fluctuation between annual and 5-year-average water year precipitation (Figure A-1-2) appears to be increasing in recent years, as compared to the moderate changes that occurred up to 1945. This variability may have implications on moisture stress and plant growth rates for vegetation basin-wide, including upland forests, lowland agricultural areas, and revegetation efforts associated with floodplain restoration.

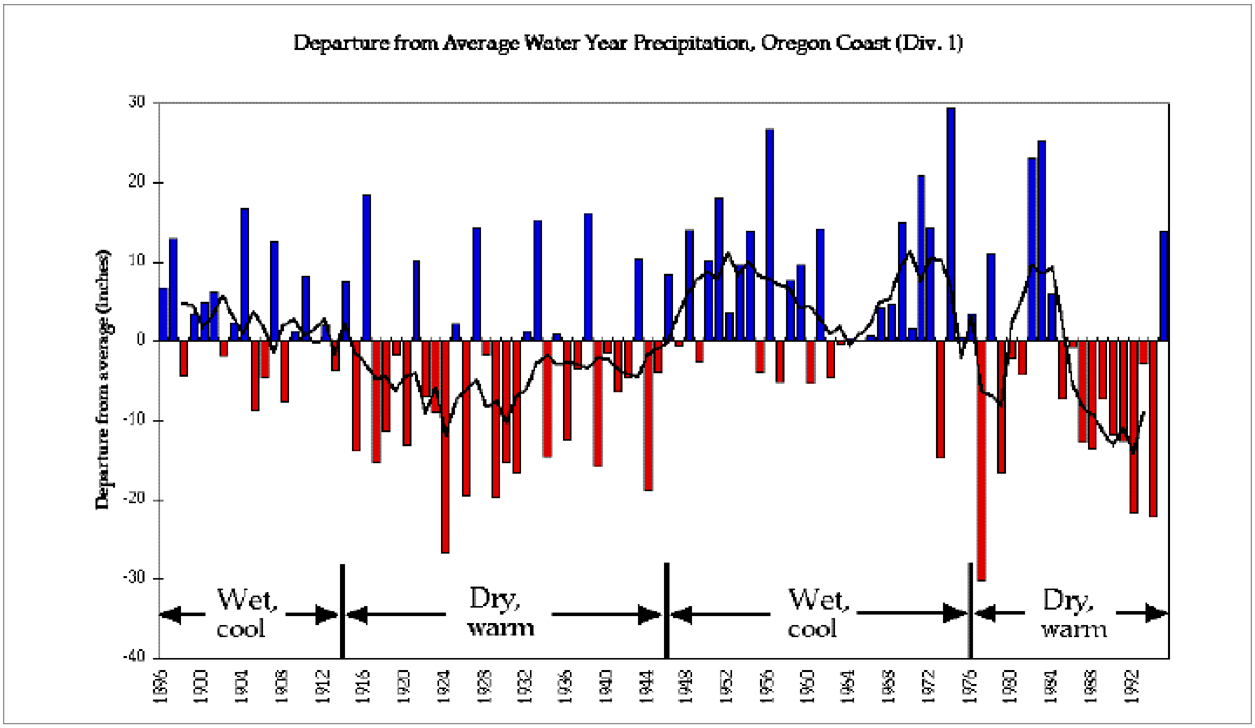


Figure A-1-1. Departure from Average Water Year Precipitation, Oregon Coast (Div. 1)

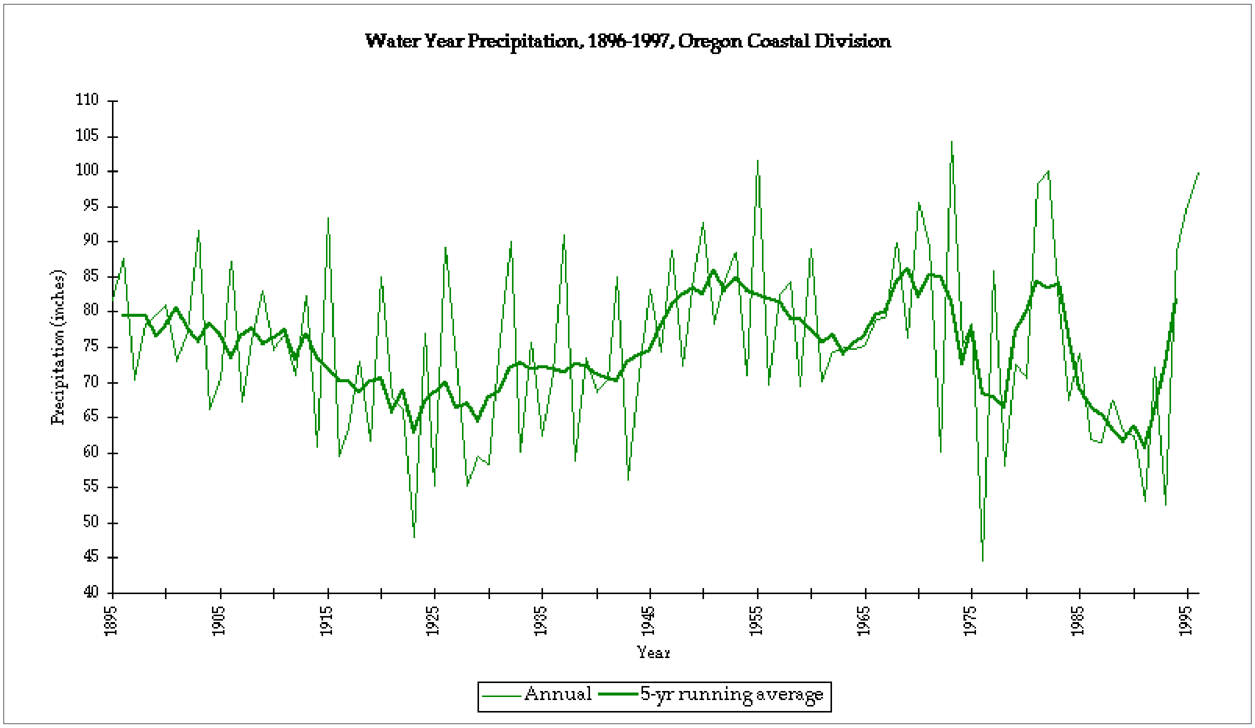


Figure A-1-2. Water Year Precipitation, Oregon Coast 1896-1997 (with 5-year Smoothing)

A.1.2 Precipitation Distribution

■ Objective

The objective of the precipitation distribution assessment was to evaluate the spatial and temporal distribution of mean annual precipitation within the Tillamook Bay basin and individual river subbasins, and the distribution of mean annual direct precipitation on lowland valley areas.

■ Methods

Average annual precipitation data (Figure A-1-3) and GIS data on mean annual precipitation distribution were obtained from the Oregon Climate Service (OCS). Isopleths—or contours—of mean annual precipitation for the Tillamook Bay basin are shown in Figure A-1-4. Cumulative mean annual precipitation by watershed area was estimated for the five major rivers draining to Tillamook Bay. Using the GIS, precipitation isopleths were overlaid on the river watershed boundaries. Land areas bounded by the different isopleths and watershed boundaries were calculated and summarized for each watershed (Figure A-1-5).

■ Discussion

Mean annual precipitation within the Tillamook Bay basin ranges from 80 inches along the coast to 200 inches in the headwaters of the Wilson River subbasin. The highest precipitation values are located in the North Fork Wilson River subbasin (200 inches) and in the East Fork of the South Fork Trask River and Bark Shanty Creek areas (150 inches). Land cover changes in these locations may have the highest potential to alter seasonal runoff patterns and affect the characteristics of sediment erosion and flooding.

Direct precipitation on the lowland valley areas is highest in the Miami River valley (100 to 110 inches) and lower in the south bay area (85 inches). Depending on soils and near-surface geology conditions in the valley areas, this relative magnitude of precipitation may be an indicator of seasonal water table conditions and the potential response of vegetation planted as part of floodplain restoration measures.

Figure A-1-5 provides a plot of the of the precipitation distribution by percent of river subbasin area. The low relief of the Tillamook River subbasin, and consequent low orographic precipitation (precipitation affected by topographic features) is evident in the significantly lower curve for this subbasin. The Trask and Miami River subbasins have relatively similar distributions of precipitation, ranging up to nearly 160 inches per year. The Kilchis and Wilson experience the largest range in precipitation, with the Kilchis subbasin receiving up to 170 inches, and the Wilson subbasin receiving up to 200 inches of mean annual precipitation. Half the area of each of these last two subbasins receives about 140 inches of precipitation annually.

From a river management perspective, the relative distribution of precipitation among the river subbasins indicates that a priority should be placed on managing runoff from the Kilchis and Wilson River subbasins, because these subbasins receive the highest amounts of precipitation, and because higher values of precipitation are prevalent throughout a relatively larger percentage of the subbasin area than in other subbasins.

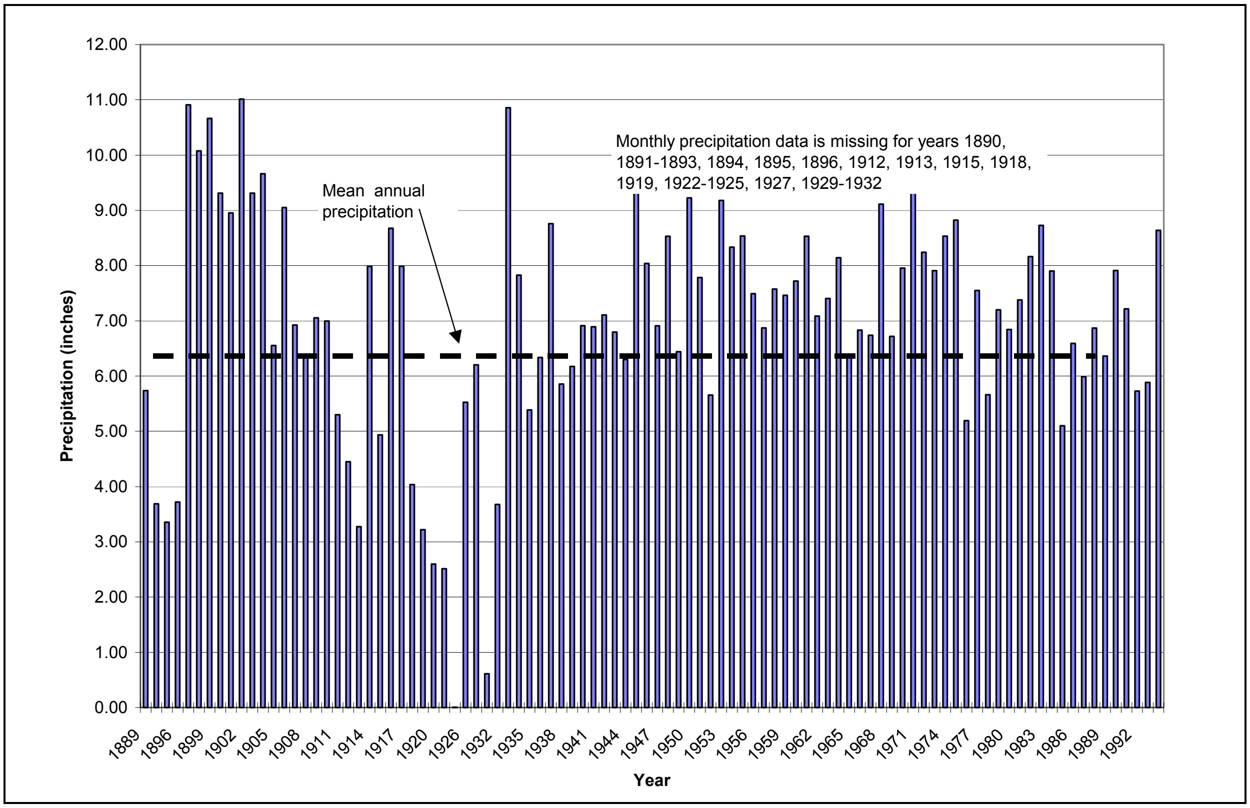


Figure A-1-3. Tillamook Average Annual Precipitation, 1889-1994

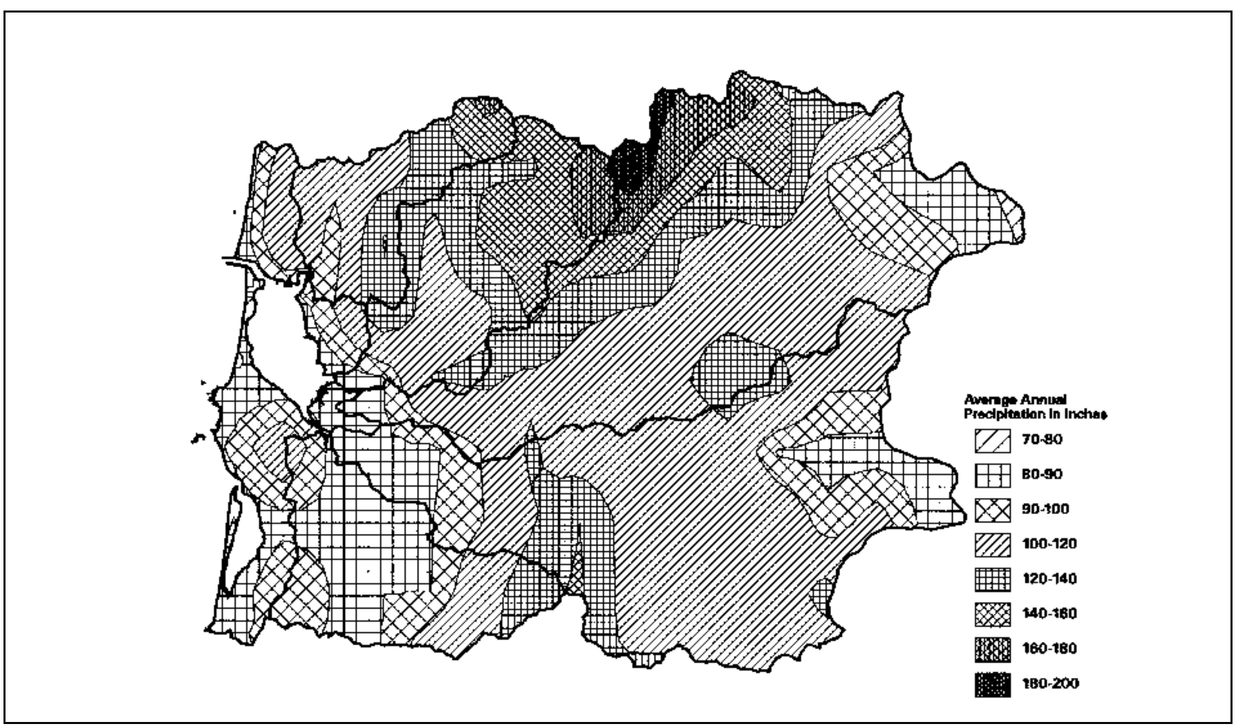


Figure A-1-4. Tillamook Bay Basin Mean Annual Precipitation Distribution in Inches by Subbasin

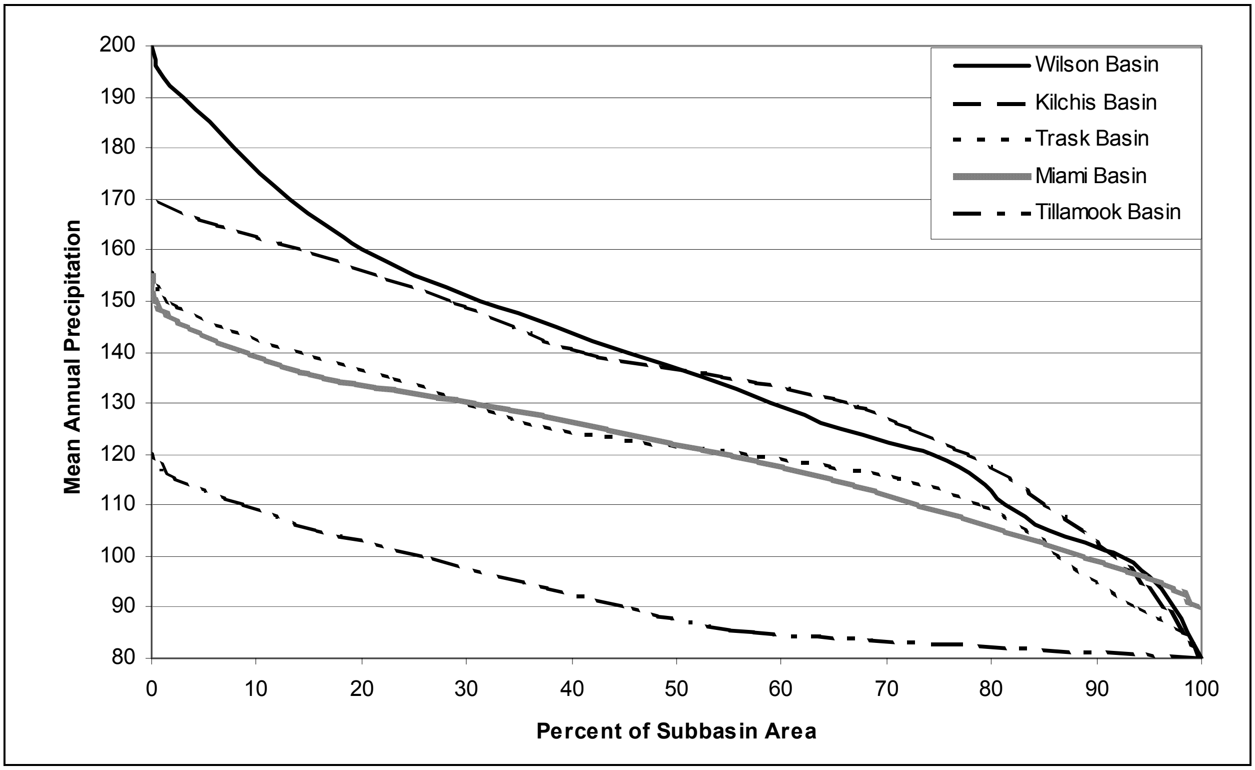


Figure A-1-5. Cumulative Mean Annual Precipitation by River Basin area for the Tillamook Bay Basin

A.1.3 Monthly Precipitation, Air Temperature and Evaporation

▪ Objectives

The objective of this assessment was to document monthly patterns of precipitation, air temperature and evaporation, and to determine the implications for fishery life cycle characteristics and habitat needs, and for potential floodplain re-vegetation/restoration efforts.

▪ Methods

Mean monthly temperature and precipitation data were obtained from the Oregon Climate Service web site, and pan evaporation data were obtained directly from the State Climatologist (Taylor, 2001). Estimates of evapotranspiration can be made using air temperature data or pan evaporation data (Dunne and Leopold, 1978). An estimated annual evapotranspiration rate for Pacific Coast Douglas fir/hemlock forests is 30 inches, where precipitation ranges from 20 to 100 inches (Chow, 1964).

▪ Discussion

Monthly precipitation is highest during the early winter months and lowest during July and August (Figure A-1-6). Air temperatures are highest from July through September, with mean maximum temperatures tending to occur later within this time period (Figure A-1-7). Evaporation rates are relatively high throughout the summer months and remain around one inch per month through the winter.

These climatic conditions are extremely significant for agriculture productivity in the lowland valley, and have led to agricultural water management practices to maintain productivity and extend the growing season, including: 1) drain tile to remove standing water and to lower high seasonal water tables caused by high precipitation; and 2) groundwater and surface water diversions to fulfill water rights for irrigation during the low precipitation/high temperature summer months.

These climatic conditions are also significant for river management efforts in the lowland valleys. For example, the relatively high precipitation during the winter months implies that plugging or removing drain tile could help raise seasonal water tables relatively quickly in order to encourage the growth of native wetland plants in restored portions of the floodplain.

In summer, monthly mean air temperatures of less than 60 degrees closely coincide with an upper water temperature limit of 50 to 57 degrees for properly functioning salmonid habitat (Bjorn and Reiser, 1991). This relatively narrow air/water temperature differential may be achieved through the strategic use of riparian vegetation to shade and cool the water surface, and through recharging floodplain water tables for increased seepage of cooler water to the rivers.

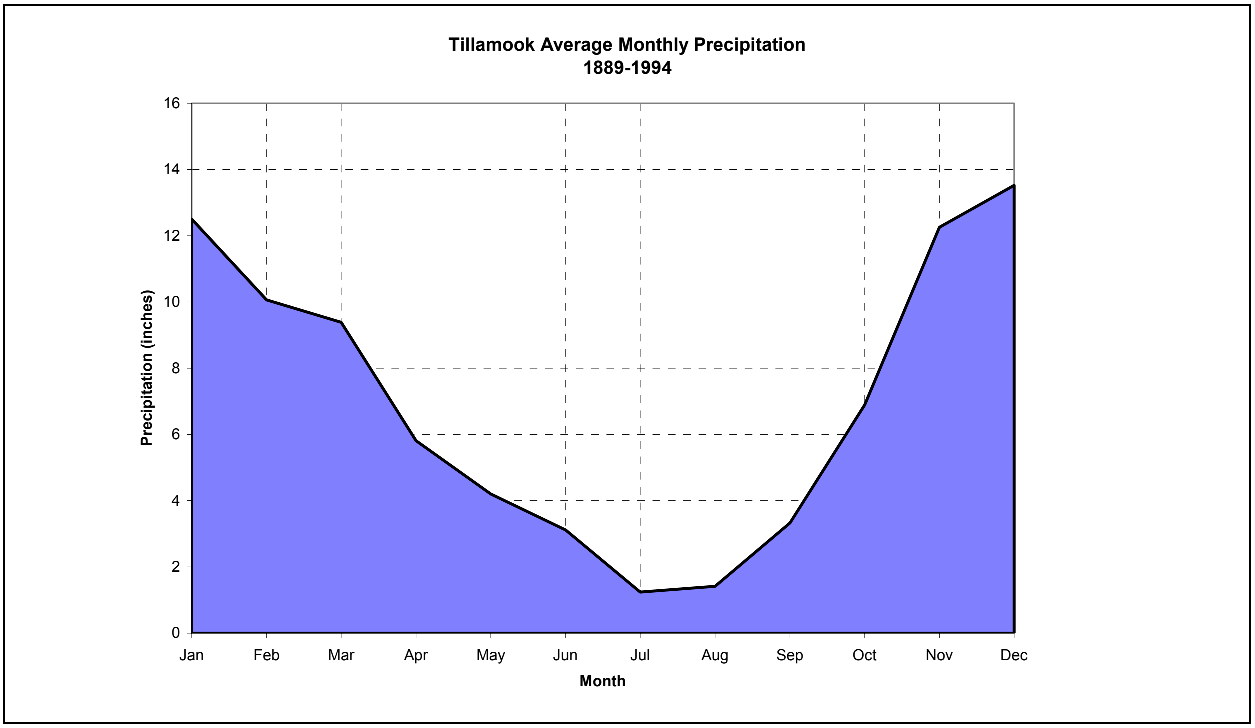


Figure A-1-6. Tillamook Average Monthly Precipitation

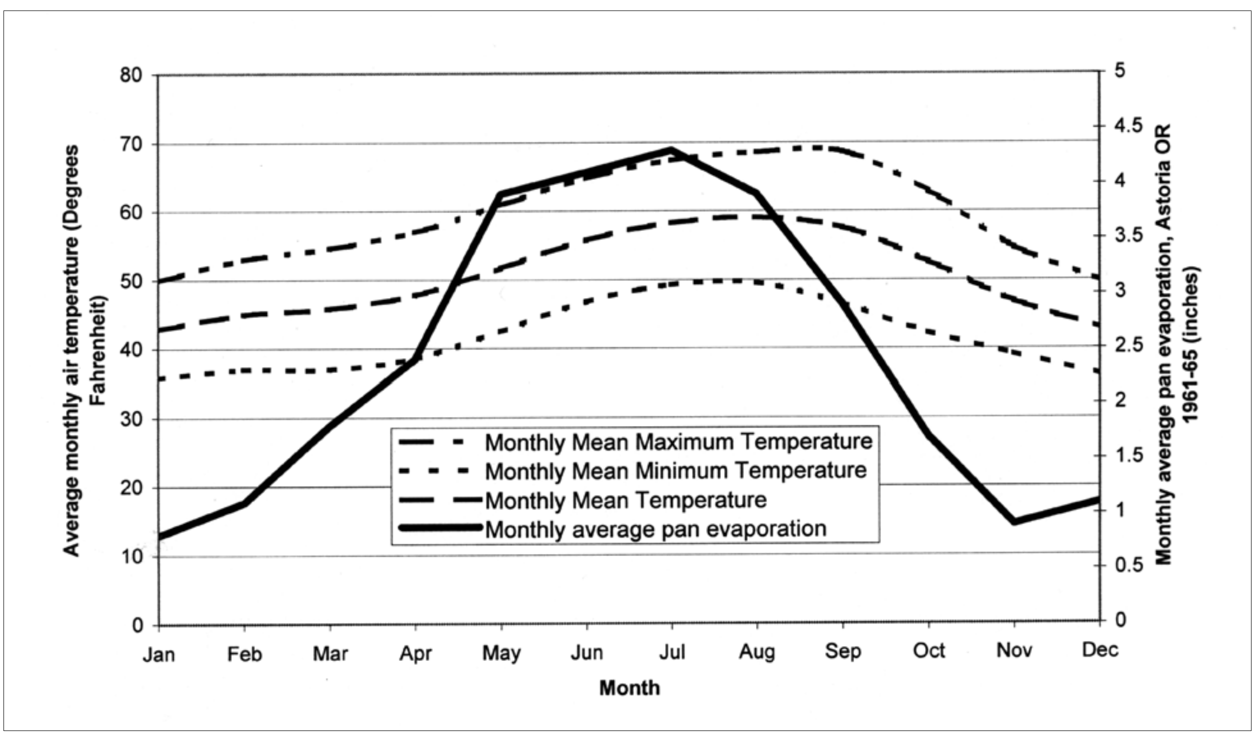


Figure A-1-7. Average Monthly Air Temperatures and Evaporation Rates

A.1.4 Snow and Snowmelt

▪ Objectives

Besides rainfall, snowfall is the other of the two forms of precipitation that provide water to the Tillamook Bay basin system. Snowmelt is not normally a significant factor in flood events on the Oregon Coast, because the coastal area is relatively temperate. Relatively little snow accumulates, and what snow does accumulate is limited to high elevation areas. Peak flows are typically produced by rainfall during the months of December and January and rain-on-snow events are rare. The objective of this assessment was to describe the general spatial distribution of snow conditions in the Tillamook Bay Basin and to explore trends in snowfall to guide upland management strategies for areas where rain-on-snow conditions may develop.

▪ Methods

The primary physical conditions governing snow accumulation and snowmelt are elevation, aspect and vegetation. These conditions were evaluated for the basin using a GIS. The southern aspects of landforms within the basin were considered as areas where snowmelt would be most predominant, since South-facing areas experience the highest intensity and duration of sunlight. Southern aspects of the basin landforms were delineated on a 10-meter DEM and shaded gray (Figure A-1-8). Data from snow monitoring stations were used to develop regression equations relating snow water equivalent to ground elevation for the Northwest Oregon region. These relationships indicate that there is typically little snow available below 2000 feet during the winter months when peak flood flows often occur. Consequently, only land areas above 2000 feet in elevation have significant potential to contribute to rain-on-snow flood events. This 'snow zone' was derived from the 10-meter DEM for the basin and is represented by a narrow black line (Figure A-1-8).

Trends in snow water content for the basin were also evaluated by obtaining data from NRCS for the Saddle Mountain SNOTEL station, located near the crest of the Coast Range at elevation 3250 feet. This station was assumed to be representative of the high-elevation uplands in the basin. Figure A-1-9 shows monthly snow water content for this station from 1979 into 2000.

▪ Discussion

Land having a southern aspect and lying within the snow zone (Figure A-1-8) can potentially contribute to rain-on-snow flood events. These land areas should receive a higher priority for management with an objective to maintain and improve natural processes to attenuate runoff and erosion. The water equivalent of the snowfall in the basin typically ranges from 5 to 20 inches annually (Figure A-1-9). For comparison, the average annual discharge of the Wilson River at the USGS gauge is 100 inches. Therefore the annual snowpack probably accounts for about 5 to 20 % of the annual discharge for the Wilson. For basins where high daily rainfall rates occur, the addition of even a small snowmelt can increase the magnitude of peak flood flows significantly (Harr, 1986).

Forest cutting and terrain disturbances may have impacts on snow accumulation, snow melt and water yield. Figure A-1-10 shows the results of snowpack monitoring in both open and forested areas in the Sierra Nevada mountains. Higher amounts of water were measured in large open areas and cut strip areas than in forested areas at the time of maximum snow accumulation (April 1). Furthermore, as snowmelt progressed, the large open areas melted faster than the cut strip and forested areas. This example indicates that for a given pattern of snowfall, forested areas probably release less meltwater overall, and release it more slowly, compared to open areas such as clearcuts.

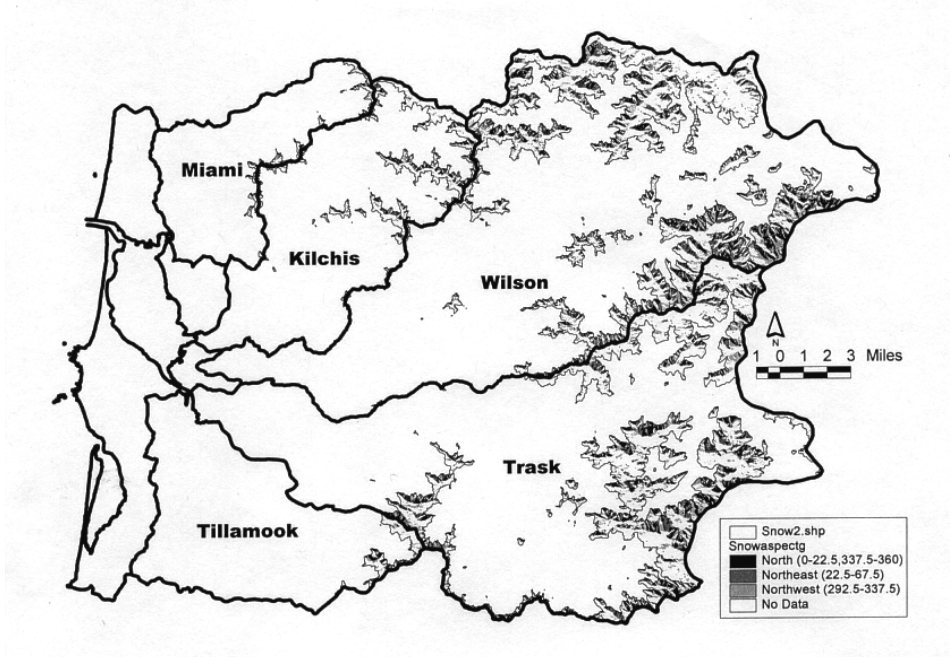


Figure A-1-8. Southern Aspect within Snow Zone

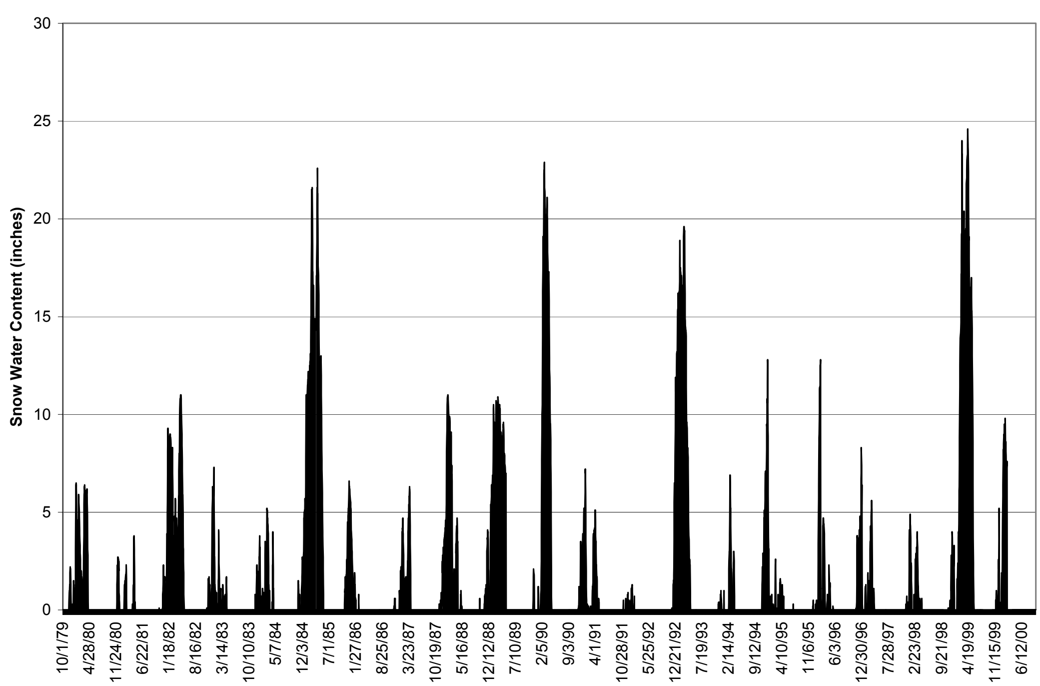


Figure A-1-9. Snow Water Content Trends for the Oregon Cost Range (Saddle Mountain SNOTEL Station Record 1979-1999)

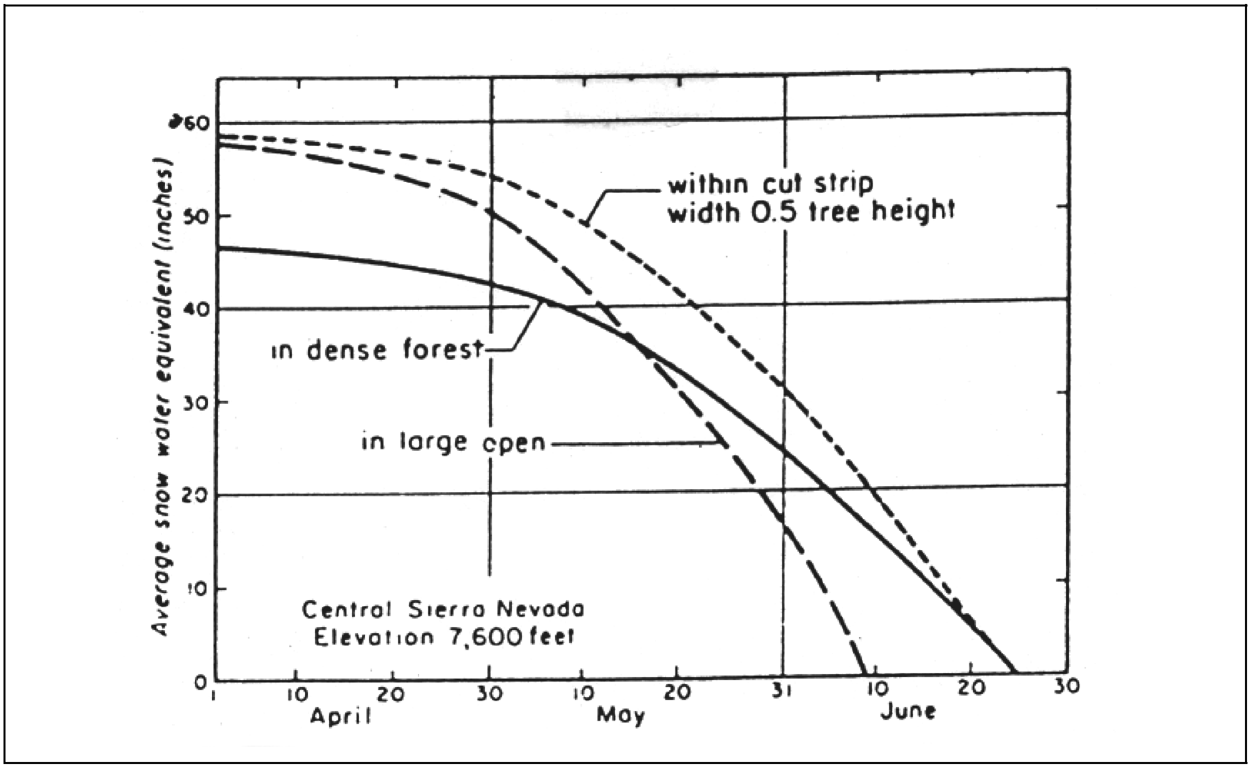


Figure A-1-10. Snow Water Equivalents for Forested and Open Areas in the Sierra Nevada

A.1.5 Wind Direction and Sun Angle

▪ Objectives

The objective of this assessment was to understand the characteristics of seasonal wind directions and sun positions, in order to guide the conceptual layout of shelterbelts as a land management measure with multiple benefits for agriculture, flood management and fish and wildlife habitat interests.

▪ Methods

Monthly and annual wind data for Tillamook (wind speed class, direction and frequency) were obtained from the Climatological Handbook for the Columbia Basin States. These data were published in 1968, but are the most recent available for the Tillamook area, and likely remain representative of seasonal wind characteristics.

Figure A-1-11 shows an annual summary of wind percentage frequency by direction for Tillamook. Predominant wind directions are from the South and the Northwest. Figure A-1-12 shows representative summer and winter wind percentage frequency by direction using the months of July and January, respectively. Southerly winds generally occur during the late fall and winter, and northwesterly winds occur during the summer months through the growing season.

The annual variation of the angle of the sun was assessed by documenting the altitude of the sun, the angle in degrees from the horizontal (Figure A-1-13). The sun altitude was estimated at weekly intervals throughout a representative year (Figure A-1-14) using software available over the Internet [www.susdesign.com/sunposition].

▪ Discussion

Given this generalization of the wind directions for Tillamook, several shelterbelt concepts can be formulated. Shelterbelts may be most beneficial for fish when planted along the northwest edges of streams, such that leaves, twigs and other organic matter are blown into the water and contribute to the food source for benthic invertebrates and, in turn, for fish. Meanwhile, shelterbelts placed along the southern edges of streams can shade surface waters to moderate water temperatures and improve water quality for fish and other aquatic organisms. The sun's position throughout the year (Figure A-1-14) can be used to guide the placement and height of riparian plantings in relation to water bodies, so that the beneficial effects of shading are optimized during key fishery life cycle stages.

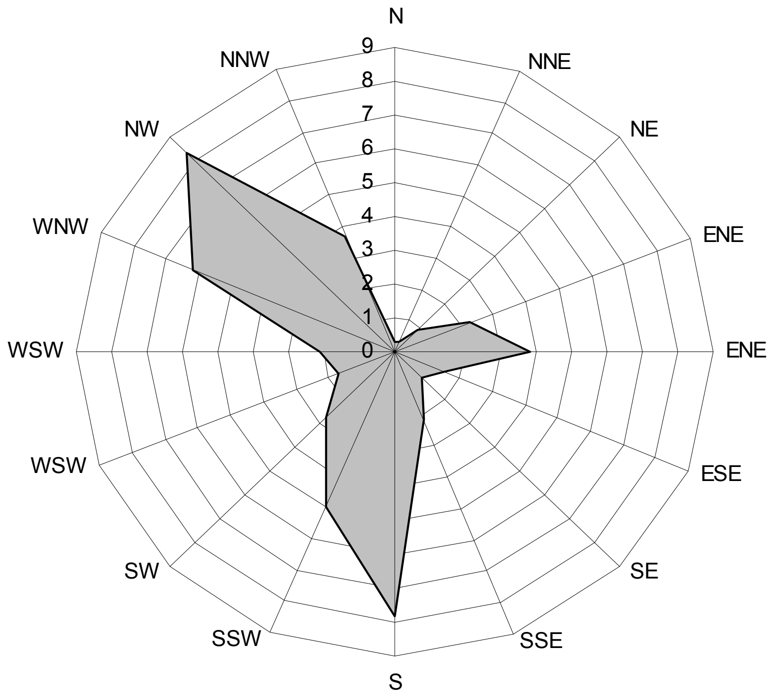


Figure A-1-11. Annual Percentage Frequency of Wind by Direction for Tillamook County

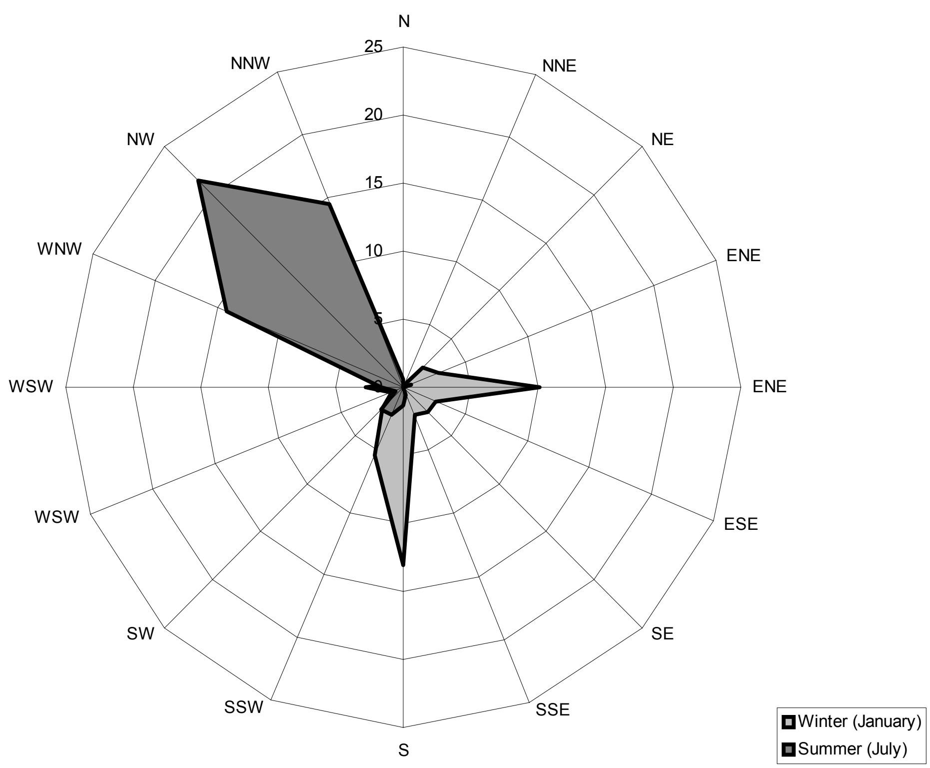


Figure A-1-12. Representative Percentage Frequency of Summer and Winter Winds by Direction for Tillamook County

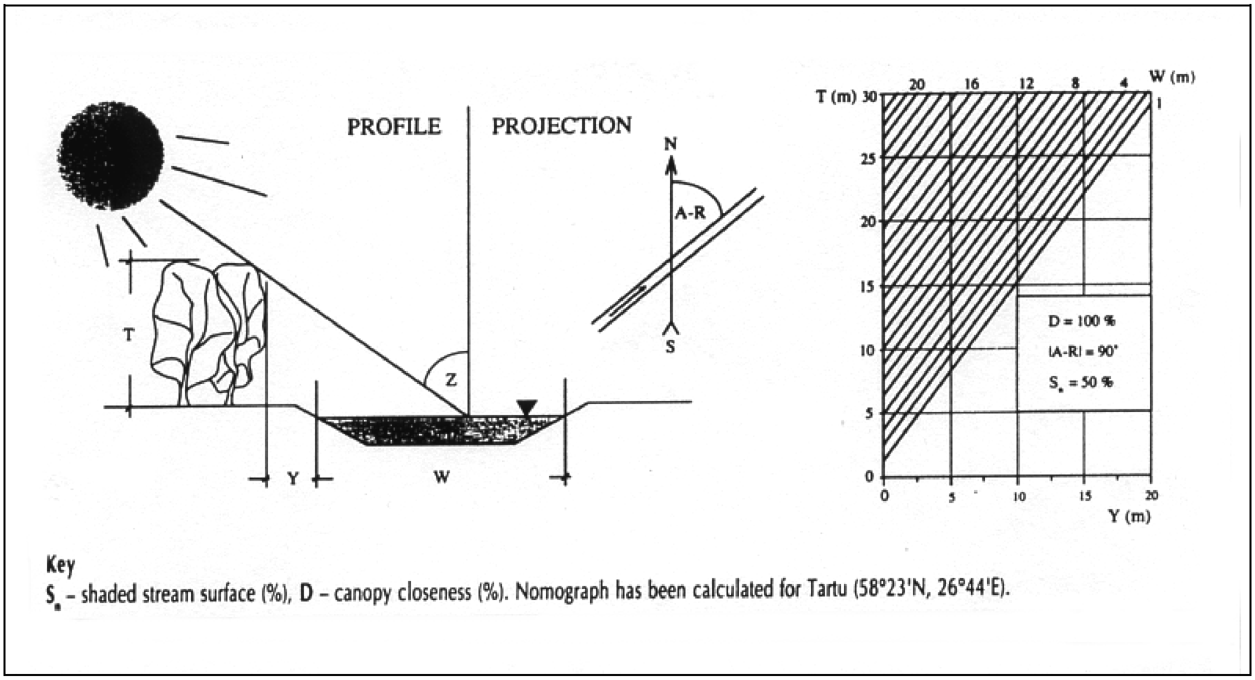


Figure A-1-13. Scheme and Nomograph for Estimation of the Optimal Parameters of Streamside Vegetation to Stream Surface Shade Source: Eiseltova and Briggs, 1995

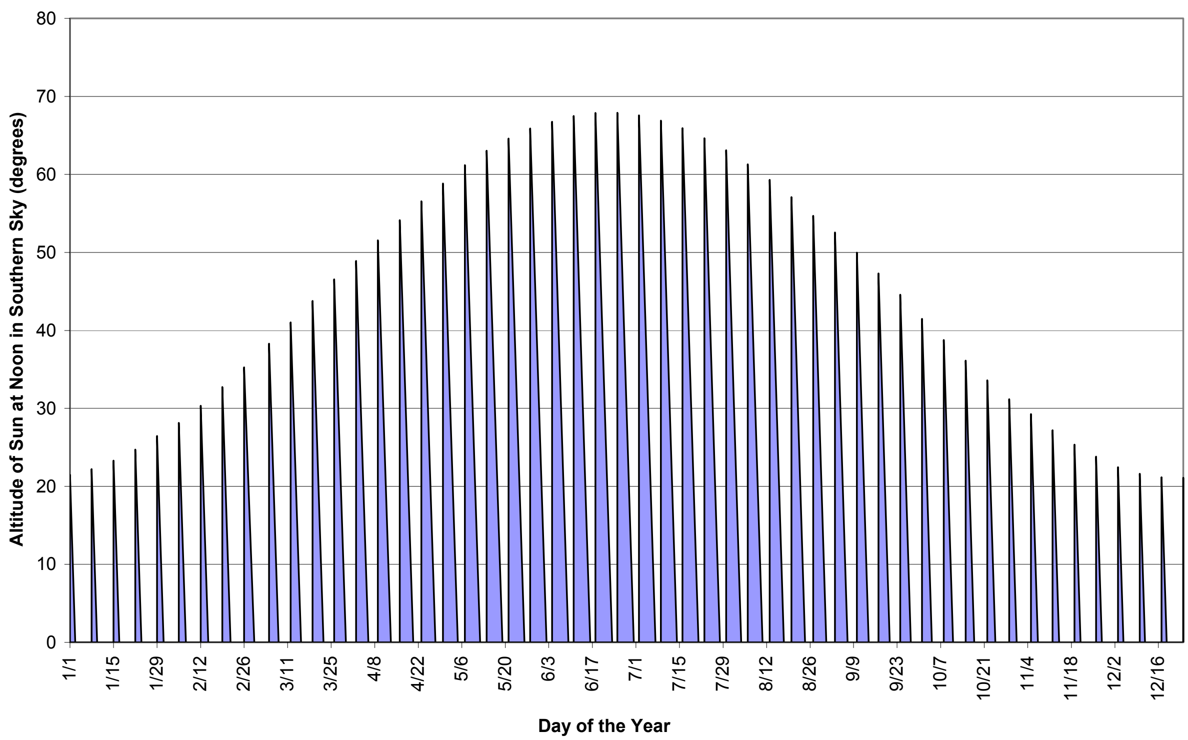


Figure A-1-14. Annual Variation of Sun Position in Tillamook County [Latitude 45.5 degrees north]

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A.2 Basin Landform

Landform includes elements that describe the topography and geology that make up a landscape. Landform composition affects weathering and vegetation growth, which in turn determine the rate at which runoff enters a river system and the amount and type of sediment that the system is likely to transport. This section covers watershed delineation, topography, geology, stream channel gradients, and longitudinal profile.

A.2.1 Watershed Delineation and Topography

■ Objectives

The objective of this assessment was to delineate the primary watersheds within the Tillamook Bay Basin and to show the relationship of those watersheds to the topography and geology of the basin's five major rivers, the Miami, Kilchis, Wilson, Trask, and Tillamook.

The topography of the Tillamook basin is described to help characterize its effect on hydrology and to provide a general template for understanding the spatial extent of flooding. In addition, topography can be used to evaluate the potential for processes such as soil erosion and slope failures.

■ Methods

The watershed boundaries shown (Figure A-2-1) were generated digitally from digital elevation models (DEM), but they can also be created manually by tracing high-quality topographic maps.

USGS 7.5-minute topographic maps and historical aerial photographs were used to describe the broad-scale topography of the five watersheds in the Tillamook basin. In addition, 10-meter resolution DEM coverages were used to produce GIS maps describing the elevation (Figure A-2-2), slope, and aspect (Figure A-2-3) of the watershed at the basin scale.

■ Discussion

The Tillamook Bay covers up to 12 square miles at high tide. Five major rivers flow into the bay. Four of these, the Tillamook, Wilson, Trask, and Kilchis, flow from the Southeast and are part of the major floodplain of the basin. A fifth river, the Miami, flows into the bay from the Northeast. The bay receives water from 550 square miles of steep forested hillsides and flat lowlands.

The Tillamook basin is characterized by steep, forested slopes along the eastern, northern, and southern extents of the watershed. Elevations reach a maximum of 3,690 feet. In the upper basin, river channels are generally moderately confined by adjacent hillslopes. Below an elevation of 100 feet, the basin grades into the valley floor. Here, unconfined channels traverse the valley, ultimately reaching Tillamook Bay.

Precipitation on the steep relief of the uppermost portions of the watershed is likely routed rapidly downhill. As streams converge and gradient decreases rapidly, large volumes of water accumulate in the lowermost alluvial valleys, resulting in valley flooding.

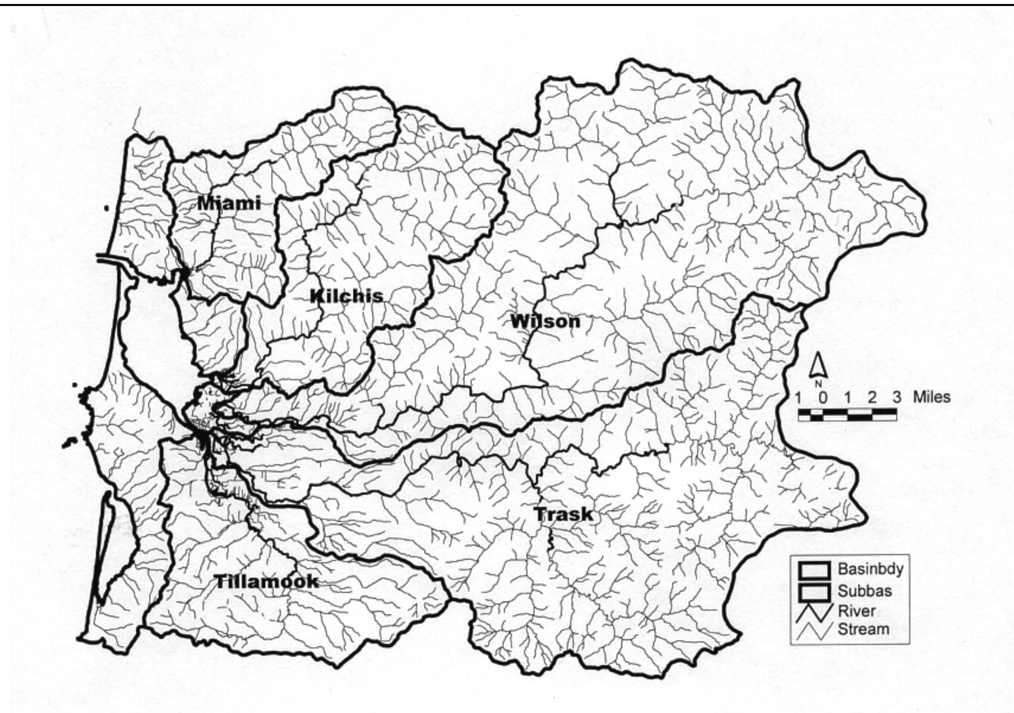


Figure A-2-1. Tillamook Bay Basin Watersheds

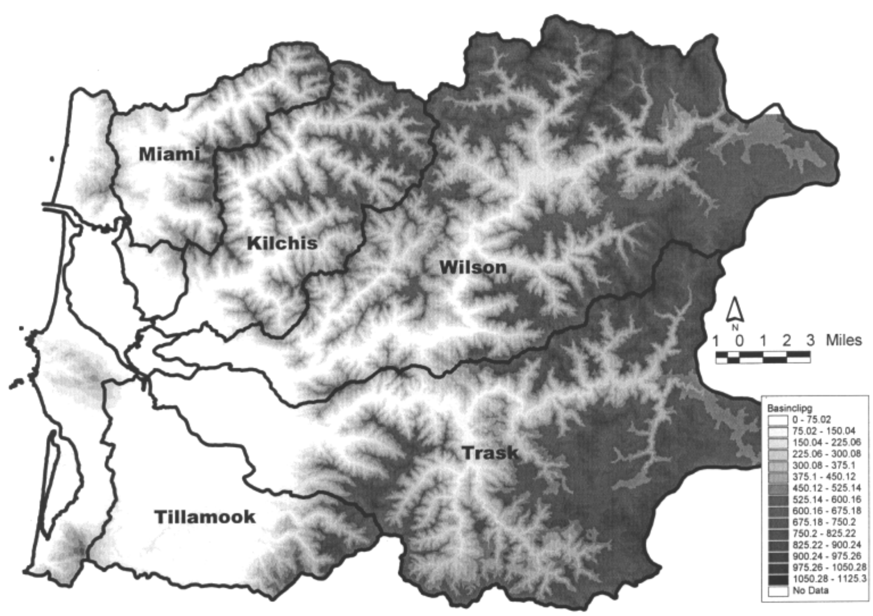


Figure A-2-2. Tillamook Bay Basin Elevation in Meters

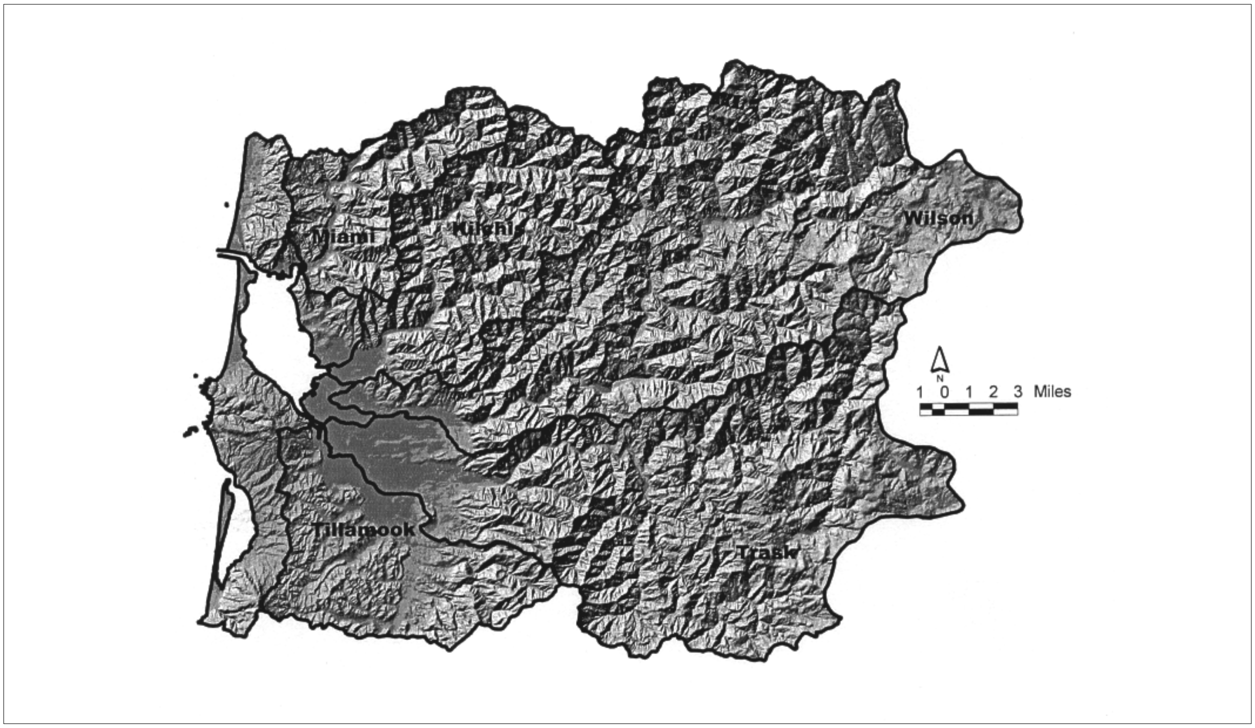


Figure A-2-3. Tillamook Bay Basin Hillshade (a Graphic Representation of Aspect)

A.2.2 Basin Geology

■ Objectives

The broad-scale interaction of substrate (geology and soils), topography, and climate determines the overall pattern of runoff in a basin (Grant, 1997). An understanding of regional geology is, therefore, useful in understanding the nature of a river's hydrologic regime. Geology strongly influences the topography of a landscape, the permeability of the substrate, and the resulting density of the drainage network. The interaction of geology with climate also influences the development of soils and the colonization of the landscape by vegetation, which further influences the magnitude and duration of flood events. Differences in the geology of the five main Tillamook basins provide a basis for understanding hydrologic responses. In addition, geologic information can be used to identify areas prone to mass failures, rapid weathering, high sediment yields, and high groundwater surface elevations.

■ Methods

Available materials describing the geology of the Tillamook Bay basin were collected. The most comprehensive and recent geologic map and report of the local geology is the Geologic Map of the Tillamook Highlands, Northwest Oregon Coast Range (Wells et al., 1994), published by the USGS and mapped on 24 standard 7.5-minute quadrangles. Originally compiled at the scale of 1:48,000, the geologic maps were scanned by the USGS into ArcInfo to produce a GIS geology data layer. Within each basin, the spatial data were used in conjunction with other available GIS layers to identify interactions between geomorphic properties (such as channel gradient and drainage density) and underlying geology.

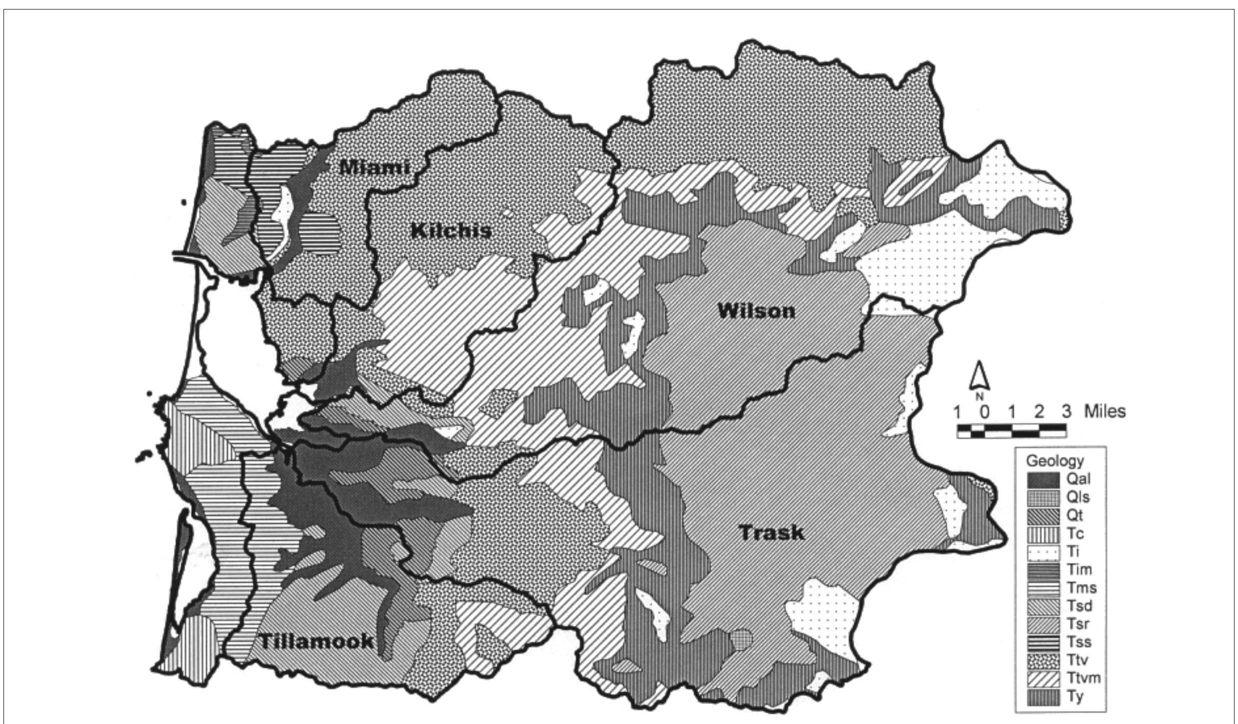


Figure A-2-4. Tillamook Bay Basin Geology

■ Discussion

Each of the five watersheds in the Tillamook basin covers a unique combination of geologic units (Figure A-2-4 and Table A-2-1). These units can be generalized into categories of erosiveness or permeability. As shown in Figure A-2-5, the Miami River flows primarily through sedimentary rocks, the Tillamook River flows through sedimentary and volcanic rocks, and the Kilchis, Wilson, and Trask basins are dominated by volcanic rocks. Volcanic or igneous rocks are generally solidified from a molten or partially molten material, and are therefore less permeable than sedimentary rocks, which are composed of accumulated sediment. Basins dominated by the sedimentary substrate are more likely to have a strong groundwater component, relatively even year-round flows, and lower flood peaks. The influence of geology on these flow properties is explored in later sections on surface hydrology.

Table A-2-1. Tillamook Basin Geologic Units

Formation	Major Lithology	Type
Qal, Qt,	Alluvium	Sedimentary
Qls	Landslide	Unconsolidated
Tss	Shale and Mudstone	Sedimentary
Tms, Tsd, Ty	Siltstone	Sedimentary
Ttvm	Mafic Pyroclastics	Unconsolidated
Tc, Ttv	Mafic Volcanic Flows	Igneous
Ti, Tim	Mafic Intrusive Rocks	Igneous

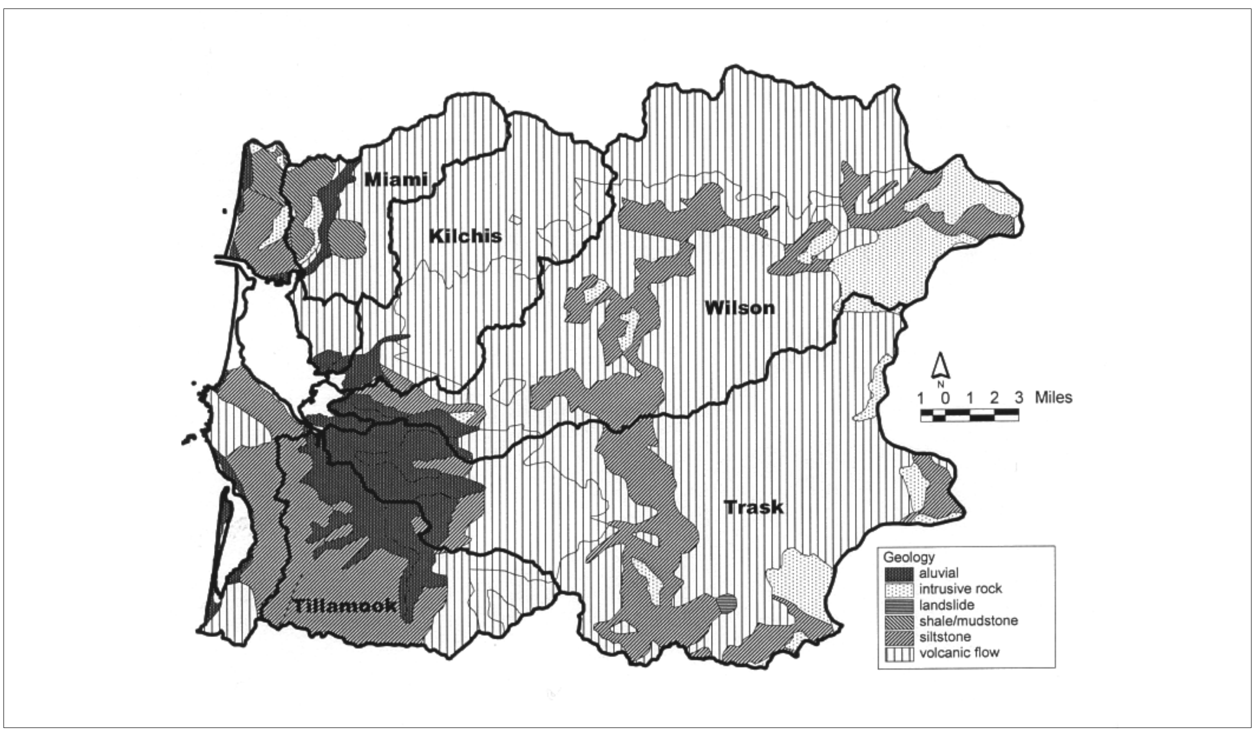


Figure A-2-5. Tillamook Bay Basin Generalized Geology

A.2.3 Estuary Size

■ Objectives

In its historic natural state, the 582-square mile Tillamook Bay basin provided a highly diverse physical habitat for plants, animals, and aquatic species such as salmon. The diversity of these habitats was largely a reflection of the geomorphic characteristics and interrelationships of the basin's uplands, lowlands, and estuary. To gain a better understanding of its historically diverse and productive aquatic ecosystems we compared the size of the Tillamook Bay estuary to its surrounding drainage basin and to the estuaries elsewhere in coastal Oregon.

■ Methods

The assessment of estuary size was based on summaries of Oregon's coastal estuaries by Percy *et al.* (1974), along with planimetric measurements of additional estuary and watershed areas taken from 7.5-minute USGS topographic maps.

■ Discussion

Although small when compared to estuaries globally, Tillamook Bay is large in proportion to its drainage basin when compared to other estuaries along the Oregon Coast (Figure A-2-6). This is of significance because estuaries and tidal wetlands are the most productive natural systems. Tiner (1984) has demonstrated that salt marshes are the most productive ecosystem type in terms of biomass generated per unit area, greater than even tropical rainforests.

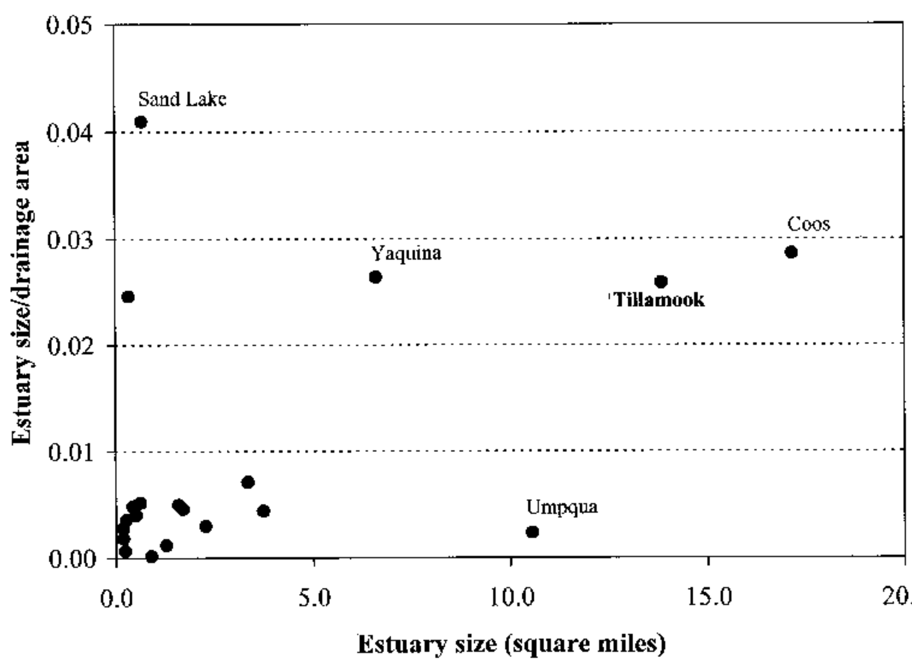


Figure A-2-6. Estuary Size and Drainage Area for Oregon Coastal Basins

A.2.4 Stream Channel Gradients

■ Objectives

Channels in the Tillamook Bay Basin were described using GIS to compare channel slope and floodplain characteristics across the five major subbasins, and to analyze the spatial distribution of low-gradient stream channels within the basins.

■ Methods

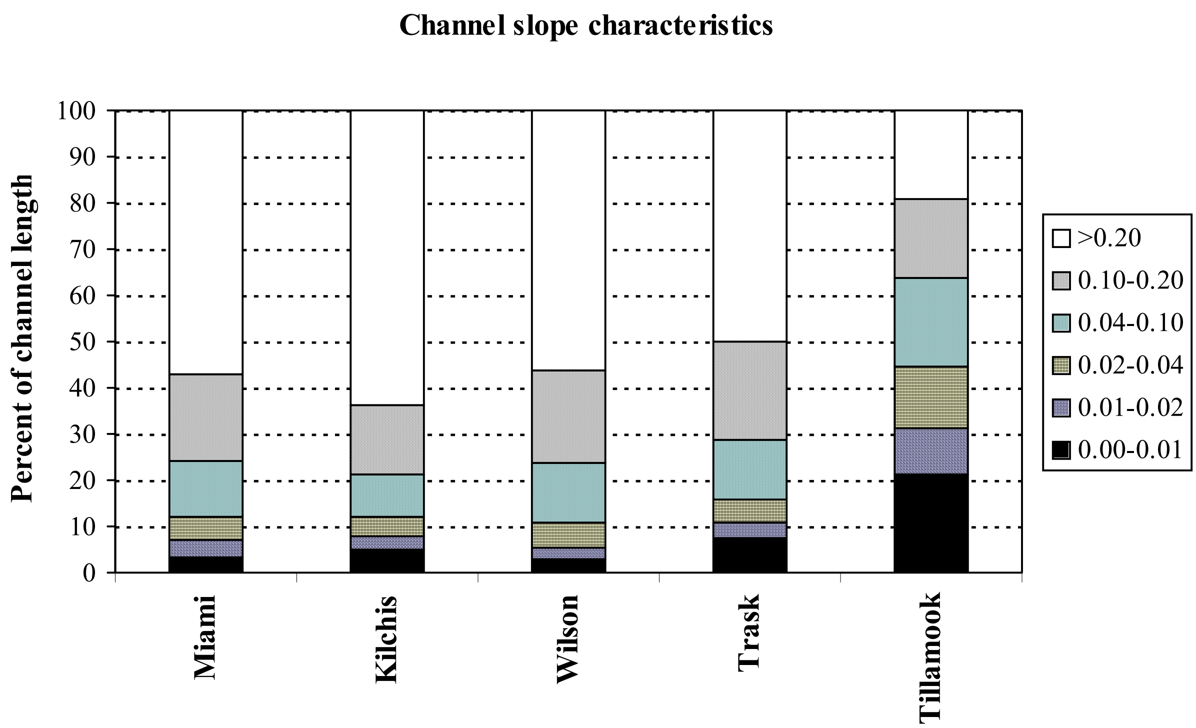
Channel slopes and distributions of low-gradient (<2%) channels were examined using a 10-meter DEM for the entire Tillamook Bay watershed to map the locations, slopes, and lengths of stream channels throughout the drainage network. Relationships between the areal extent of lowland floodplains and the drainage area of each major subbasin were evaluated using GIS databases acquired from the Tillamook Bay National Estuary Project.

■ Discussion

All of the major rivers that drain into Tillamook Bay, except the Tillamook River, have drainage networks dominated by steep stream channels that are capable of generating or transporting substantial volumes of sediment (Figure A-2-7). Seventy percent or more of the total channel length in the Miami, Kilchis, Wilson, and Trask subbasins has slopes exceeding 10 percent, and over half of the channels in each of these subbasins have slopes exceeding 20 percent. The opposite pattern holds true for low-gradient channels, that account for over 30 percent of the drainage network in the Tillamook subbasin, but only 6 to 11 percent in the other four subbasins.

Floodplains are extensive in the lowlands surrounding Tillamook Bay, and are a particularly dominant feature of the Tillamook subbasin and the lower portions of the Wilson and Trask subbasins (Figure A-2-8). About two-thirds of all low-gradient stream channels in the Tillamook basin, and a considerably higher proportion of those that are naturally unconfined, are found in lowland areas. This is important because such channels tend to be those most responsive to inputs of wood and sediment, and are generally recognized as being capable of providing the most complex and productive aquatic habitats when properly functioning. An example of the distribution of stream gradients is shown for the Miami River watershed, where gradients from zero to greater than 16 percent are mapped (Figures A-2-9 to A-2-13).

Within the basin's uplands, stream channels tend to be moderately steep to very steep and most low-gradient channels in these areas are strongly confined by adjacent landforms. However, several locations in the uplands are moderately-confined stream channels that can be quite responsive and dynamic. These include multiple areas within the Wilson and Trask subbasins. A recent analysis of channel characteristics in upland areas of the Kilchis subbasin found 4.5 percent of total stream length was in confined low-gradient channels, 22.6 percent in moderate gradient channels with moderate to strong confinement, and 72.9 percent in tightly confined steep to very steep channels (TBNEP 1998b).



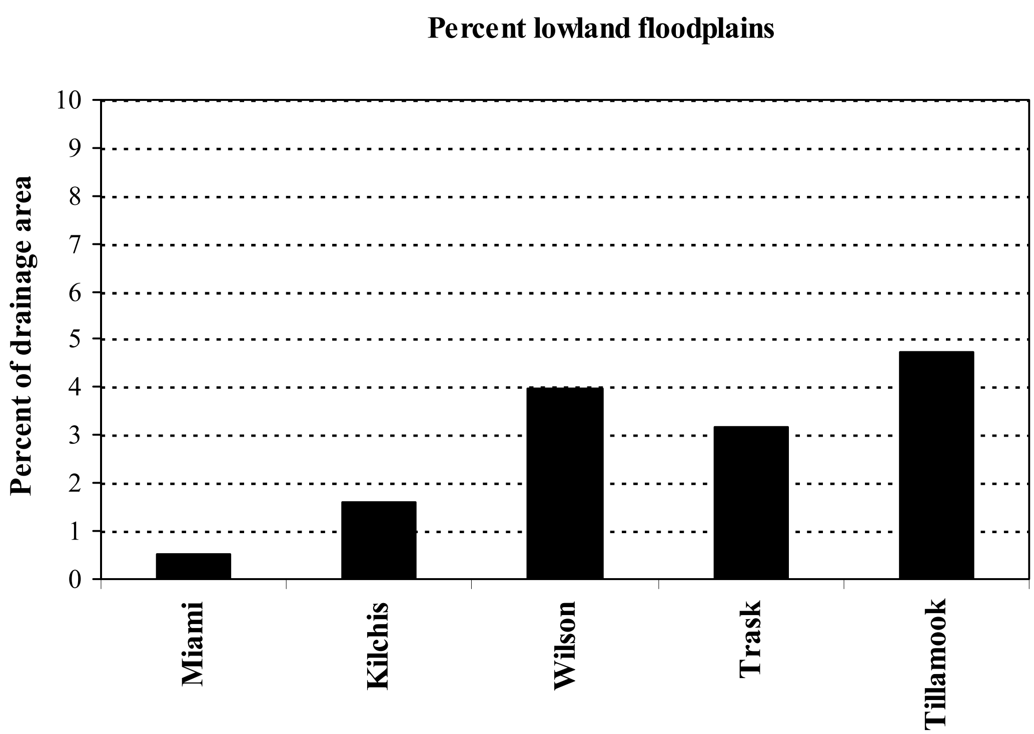


Figure A-2-7. Channel Slopes (top) and Percent Lowland Floodplain Area (bottom) for Five Tillamook Bay Subbasins

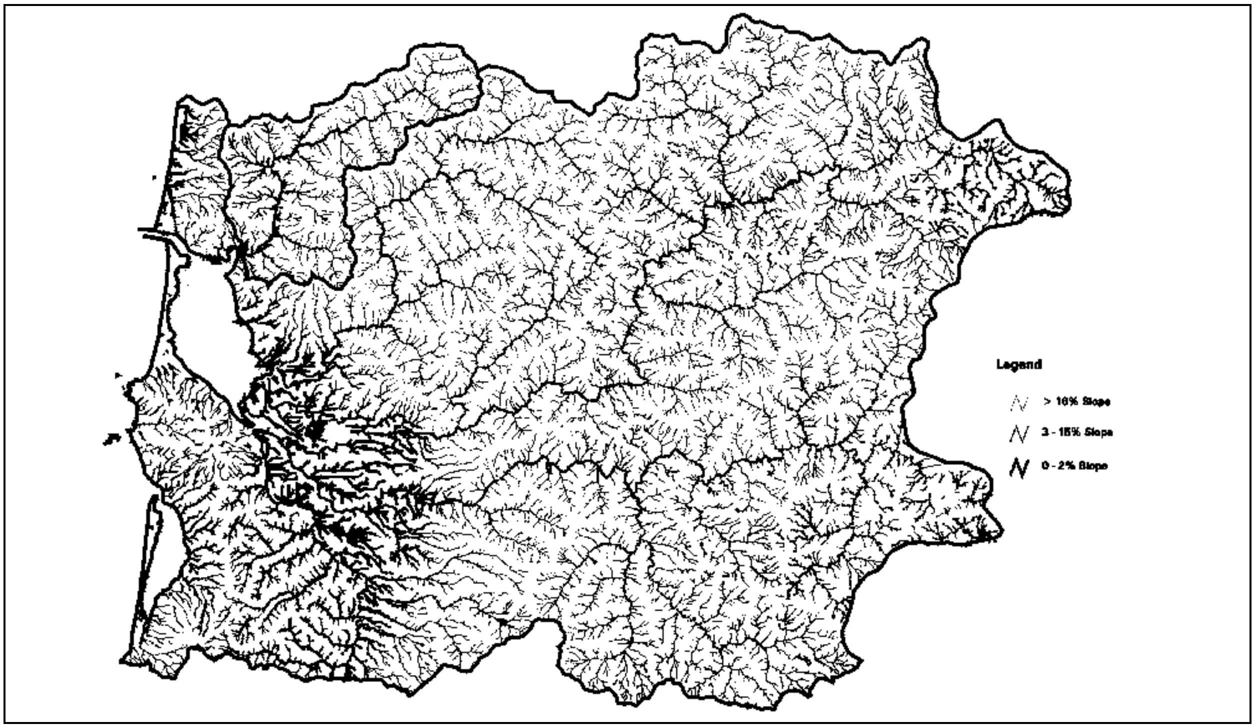


Figure 6-2-8. Stream Channels in Three Gradient Classes 0-2%, 3-15%, and >15% slope

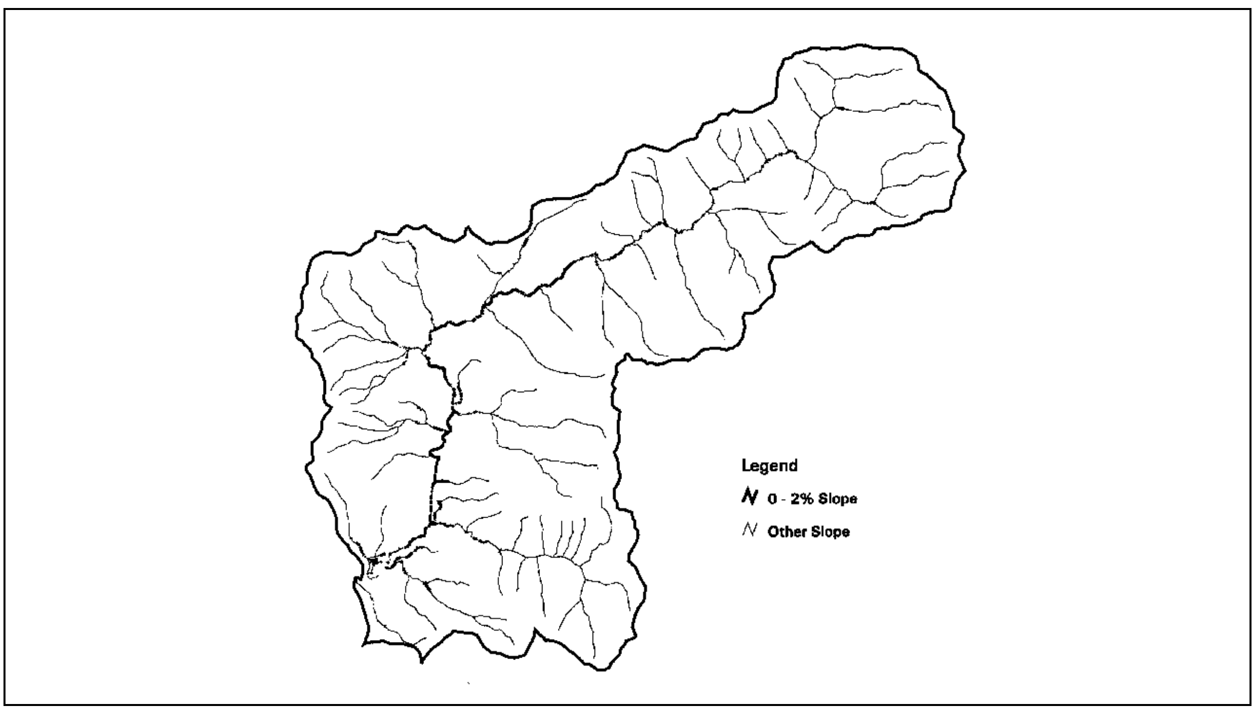


Figure 6-2-9. Stream Channels of the Miami Watershed Subbasin in Channel Gradient Class < 0% to 2% Slope

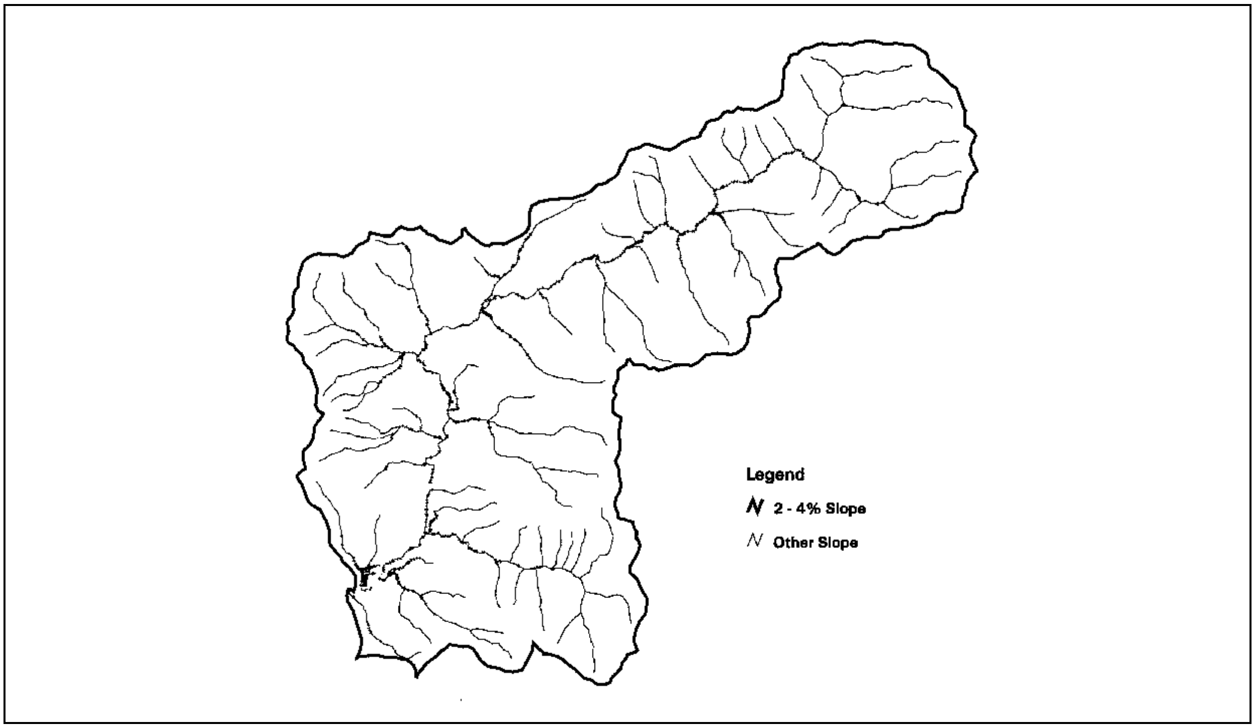


Figure 6-2-10. Stream Channels of the Miami Watershed Subbasin in Channel Gradient Class 2% to 4% Slope

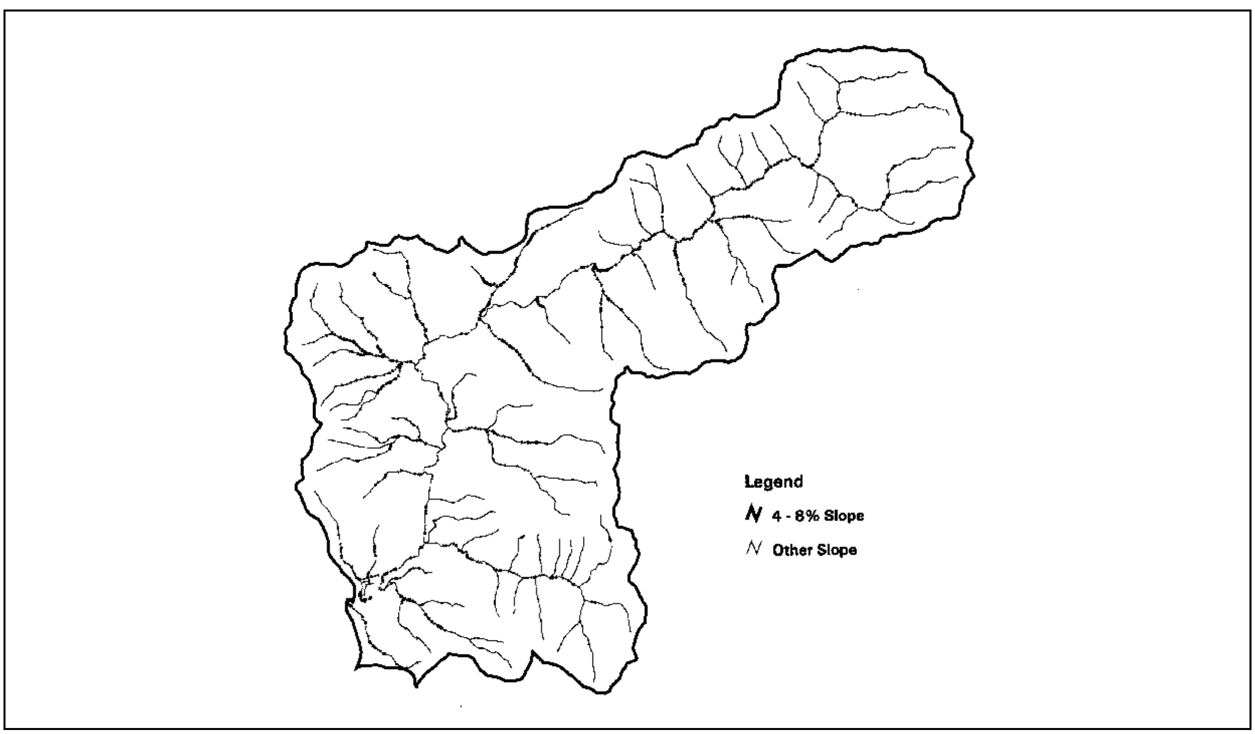


Figure 6-2-11. Stream Channels in Channel Gradient Class 4% to 8% Slope

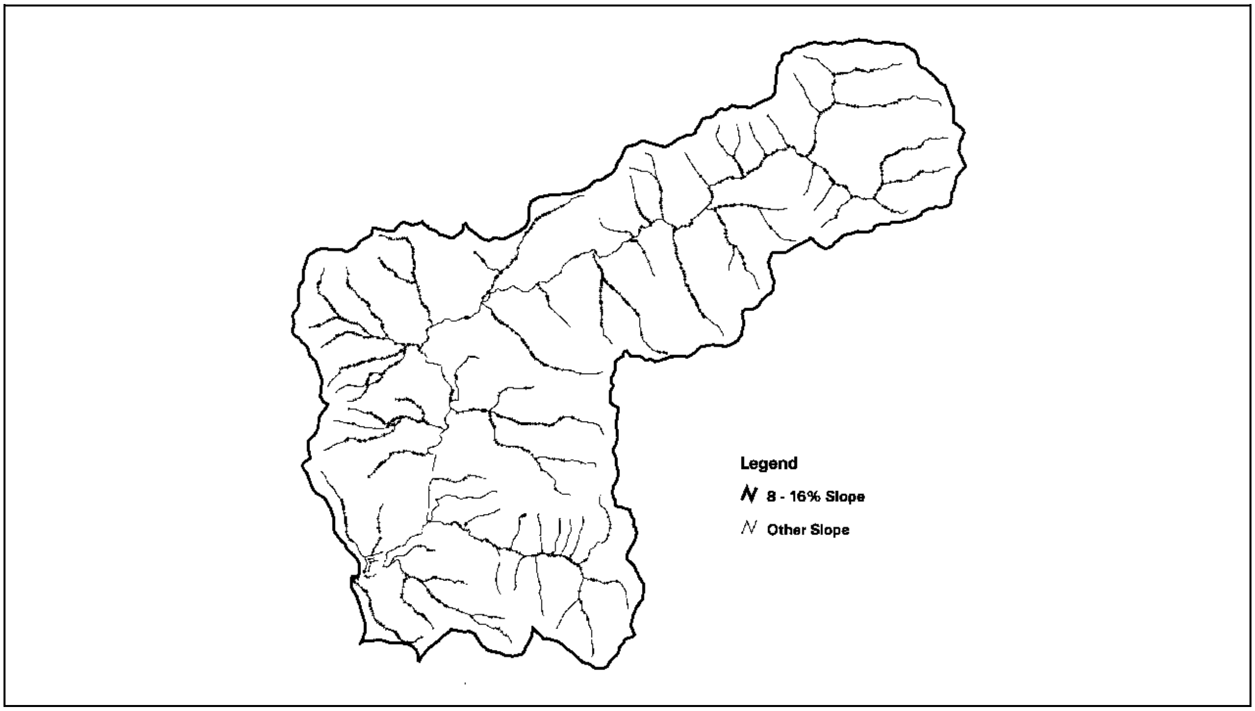


Figure 6-2-12. Stream Channels of the Miami Watershed Subbasin in Channel Gradient Class 8% to 16% Slope

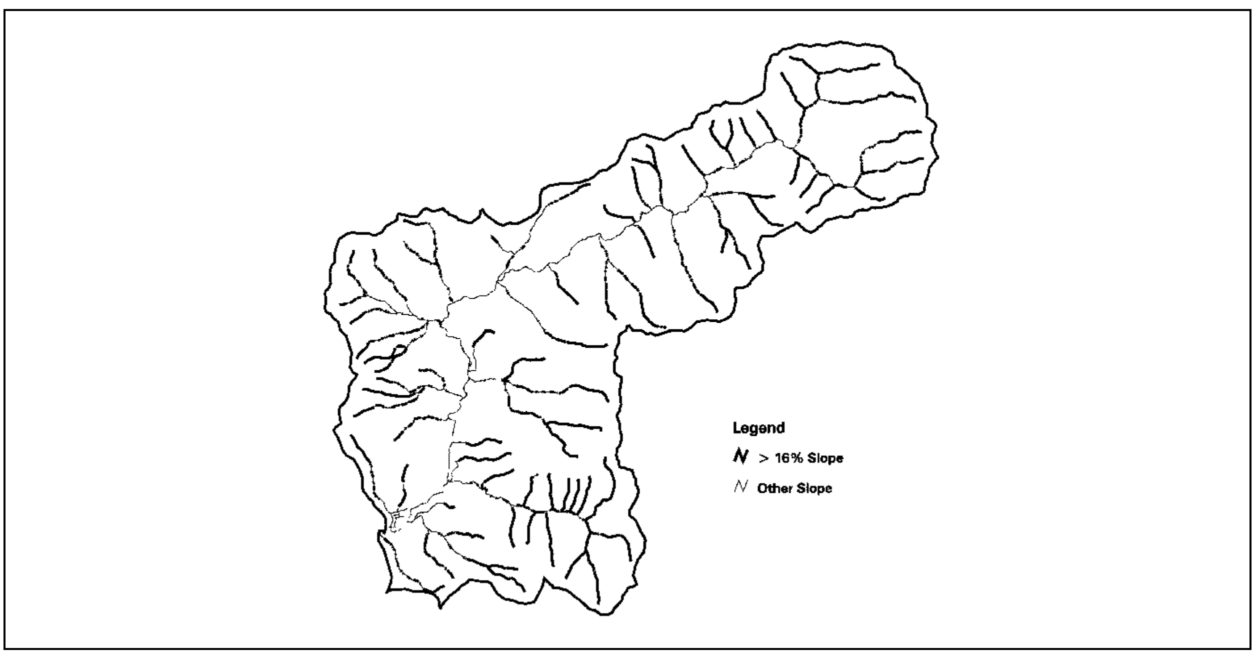


Figure 6-2-13. Stream Channels of the Miami Watershed Subbasin in Channel Gradient Class > 16% Slope

A.2.5 Mainstem River Longitudinal Profiles and Gradients

■ Objective

The longitudinal profile of a river describes the change in vertical elevation of the river channel over its length and provides an indication of the climatic and physiographic environments in which the river has evolved. The objective of this assessment was to document the physical characteristics of the mainstem river channels tributary to Tillamook Bay, and to relate these characteristics to river hydraulics and fisheries habitat.

■ Methods

Current edition 1:24,000 scale USGS quadrangle maps (derived from 1980 aerial photographs) were used to estimate the longitudinal profiles and gradients of the mainstems of the Tillamook Bay rivers (Figure A-2-14). These maps provide elevations in 40-foot contour intervals with 20-foot supplementary contour intervals in the lowland valley areas. Tick marks were made where contours crossed river channels. Locations of tick marks along the rivers were referenced to river miles identified on the maps by using a map wheel. River profiles were extended up to a common 600-foot elevation (Figure A-2-15). Distances between river mile markers were spot-checked, and it was noted that in some cases the distance between the river mile markers was not one mile. The assumed cause of this is river channel changes that may have occurred since the mile markers were first established by the USGS. Reference to the mile markers was maintained nonetheless, to facilitate reference to the published quadrangle maps. However, the combination of 40-foot contour intervals and potential inaccuracies in the river mile marker locations impart inaccuracies to the river profiles and the gradients derived from the profile information. Therefore, these data should not be considered highly accurate, but should be used to generally assess geomorphic conditions and make relative comparisons between rivers.

■ Discussion

Longitudinal profiles of rivers tend to be concave upwards (Morisawa, 1968). Discontinuities to the concave profile may be indications of geologic controls on the river channel or areas of sediment deposition. The Miami, Kilchis and Wilson Rivers all exhibit a discontinuity in their profiles in the 350 to 400 foot elevation range, possibly indicating a regional geologic control. The Kilchis River exhibits the most representative concave profile for most of its length, indicating an ability to transport sediment loads downstream effectively. The Wilson and Trask River profiles exhibit a noticeable convex shape in the 50 to 250 foot elevation range, possibly indicating sediment deposition -- either from tributaries or from the main channel itself -- of a volume and/or particle size that is in excess of the ability of the rivers to transport at this location in the system.

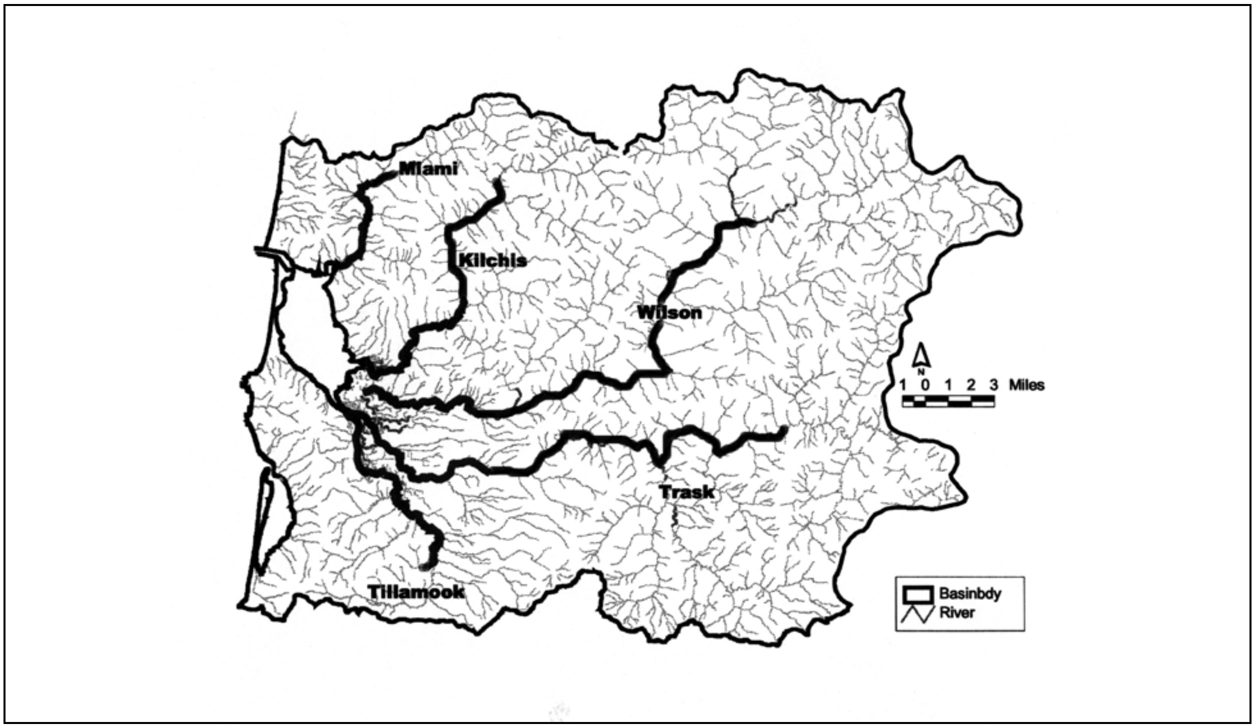


Figure A-2-14. Tillamook Bay Basin Mainstem River Profiles

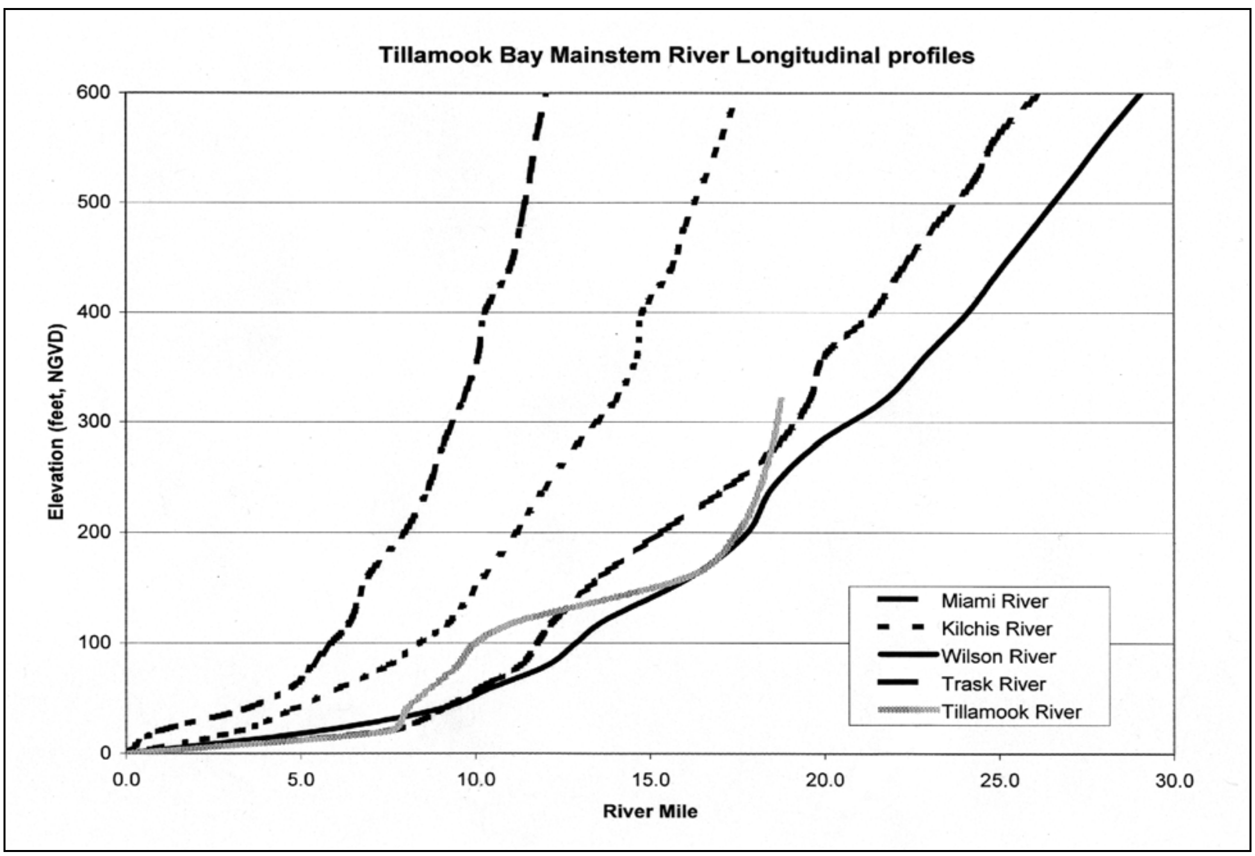


Figure A-2-15. Tillamook Bay Mainstem River Longitudinal Profiles

A.2.6 River System Classification

■ Objectives

Watershed morphology is controlled by slope, water discharge and sediment supply (Montgomery and Buffington, 1993). The landscape within a watershed can be generally divided into three spatial scales: watershed, valley and channel reach (Figure A-2-16). The spatial arrangement of source, transport and response reaches within these watershed divisions can be an indication of the degree of potential impacts and recovery times from disturbances to the river system. The objective of this assessment was to perform a reconnaissance-level classification of the basin watershed and river system, including source, transport and response landforms and river areas, in order to develop a conceptual model of watershed processes.

■ Methods

Reconnaissance-level channel classification methods developed by Montgomery and Buffington (1993) (Figures A-2-17) were used together with the 10-meter DEM of the basin to define the spatial extent of source, transport and response areas within the basin and along the river channel network based on land slope. The entire land surface of the basin was categorized according to the slope classes of 30% and greater for source areas, 30% to 3% for transport areas, and less than 3% for response areas (Figures A-2-18 to A-2-20). This mapping extends beyond the linear river channel network to include hillslopes and terrain features, and provides a general indication of the spatial variation of watershed processes within and beyond the river channel network.

■ Discussion

A majority of the basin land surfaces exceed 30 % slope and serve as source areas for sediment. The Kilchis subbasin appears to have the greatest density of source areas (black shading), with high concentrations also located along ridge lines and generally throughout the lower third of the forested uplands that ring the lowland valley of the south bay. Attention should be focused on these areas for source control management efforts, to limit disturbances that may increase runoff and erosion. This is especially true where source reaches are directly tributary to lowland valley response reaches, where increased sediment loads from disturbances could not be stored and gradually released to the lowland valley rivers, as could be done in connecting transport reaches.

Transport reaches may be higher priority areas for the installation of engineered wood jams to increase sediment trapping. Transitions between transport and response reaches (black and grey shading interfaces) can be significantly impacted by increased sediment supply (Montgomery and Buffington, 1993), and these locations along river channels should be monitored to assess channel morphology responses. Since anadromous salmon tend to spawn in pool-riffle reaches of the river system where slope is between 0.1 and 2 percent (Figure A-2-17), these response reaches (Figure A-2-20 light shaded areas) should receive prioritized attention for management and protection.

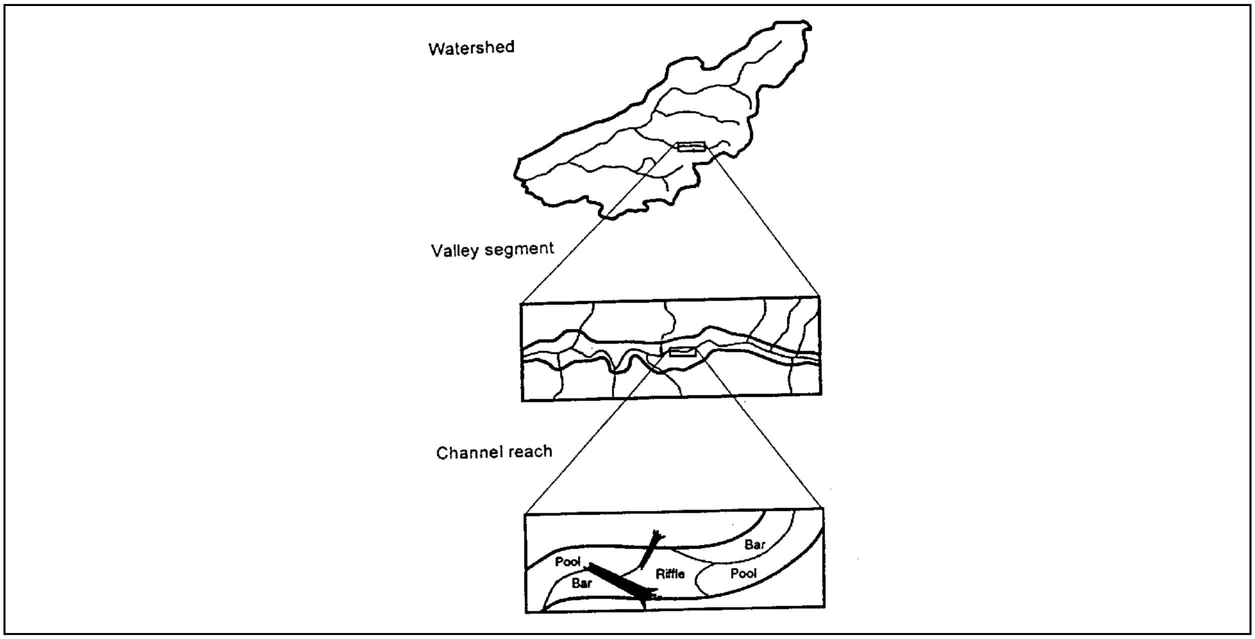


Figure A-2-16. Landscape Classifications Illustrating Process Divisions at the Watershed, Valley Sediment and Channel Reach Levels (After Montgomery and Buffington, 1998)

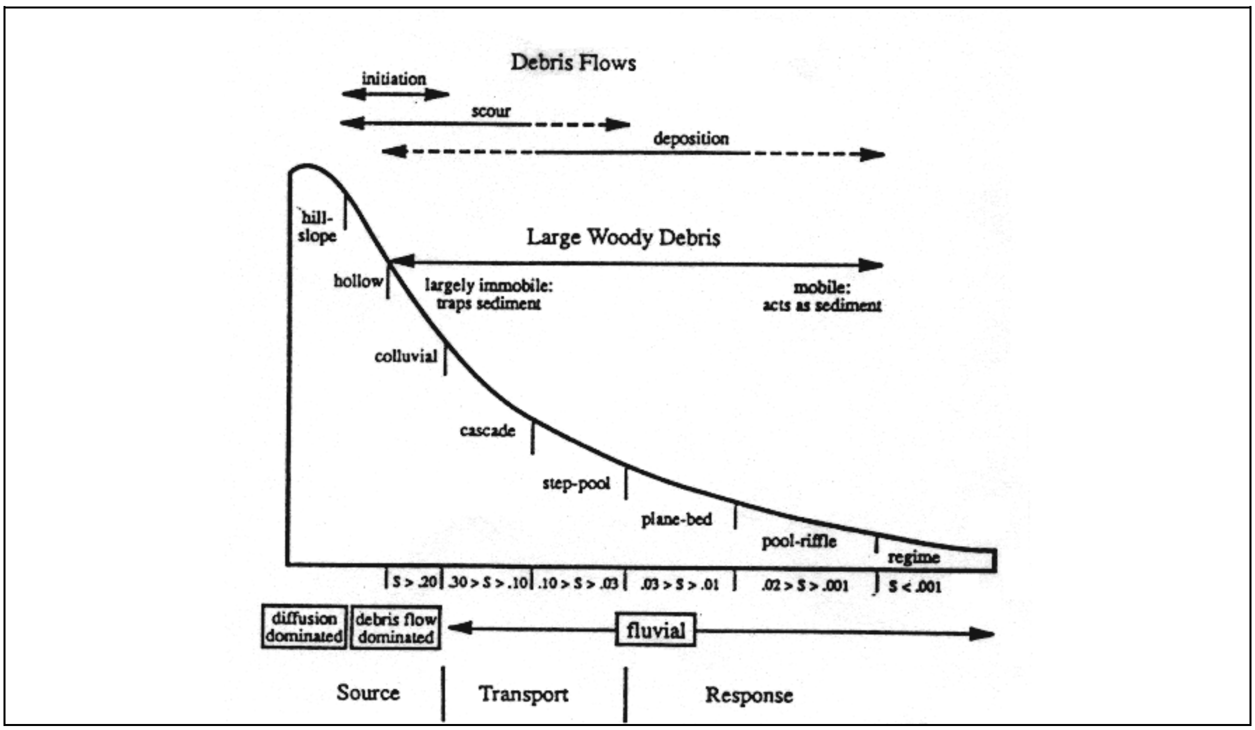


Figure A-2-17. Debris Flow Source: Montgomery and Buffington, 1997

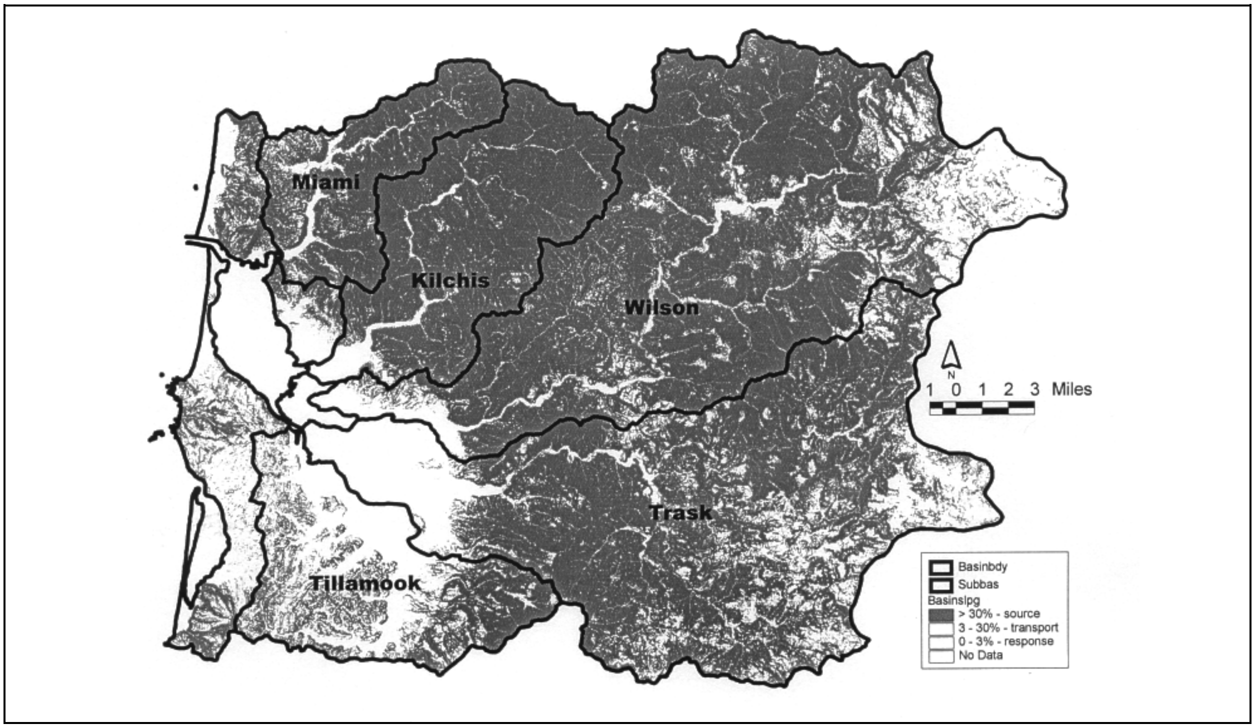


Figure A-2-18. Basin Slope > 30% - Source Zone

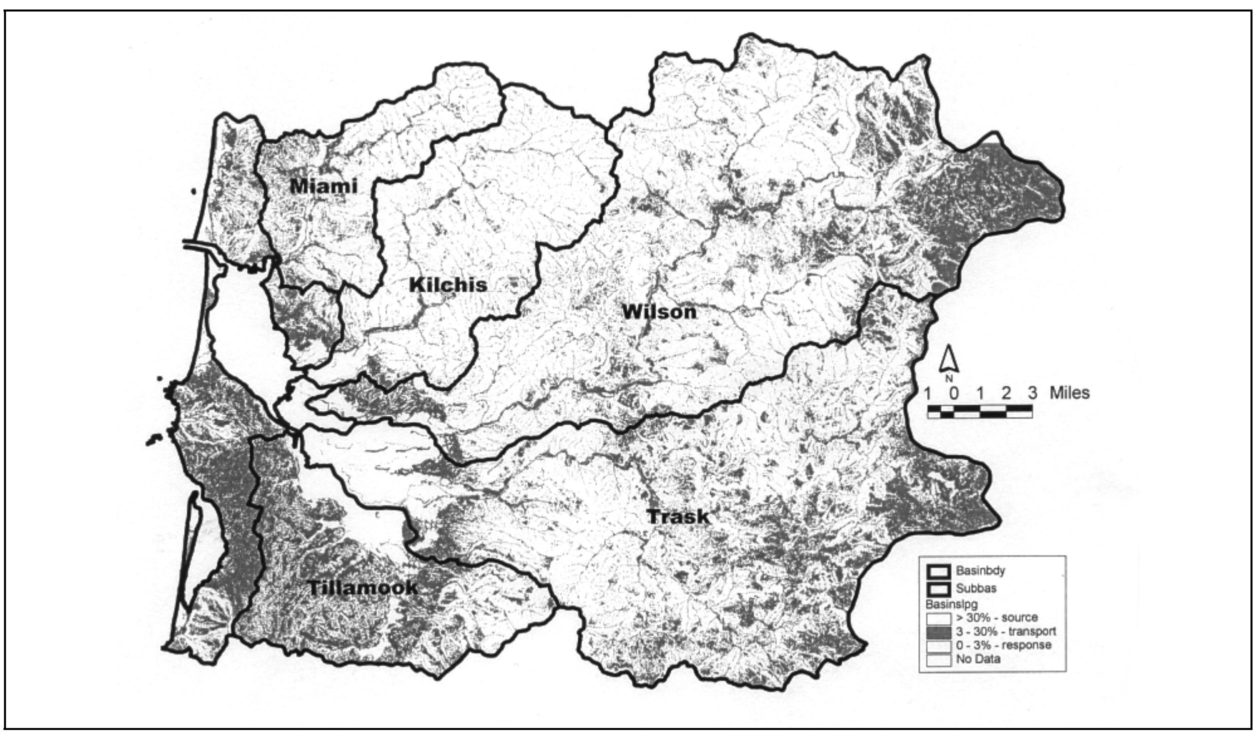


Figure A-2-19. Basin Slope 3 to 30% - Transport Zone

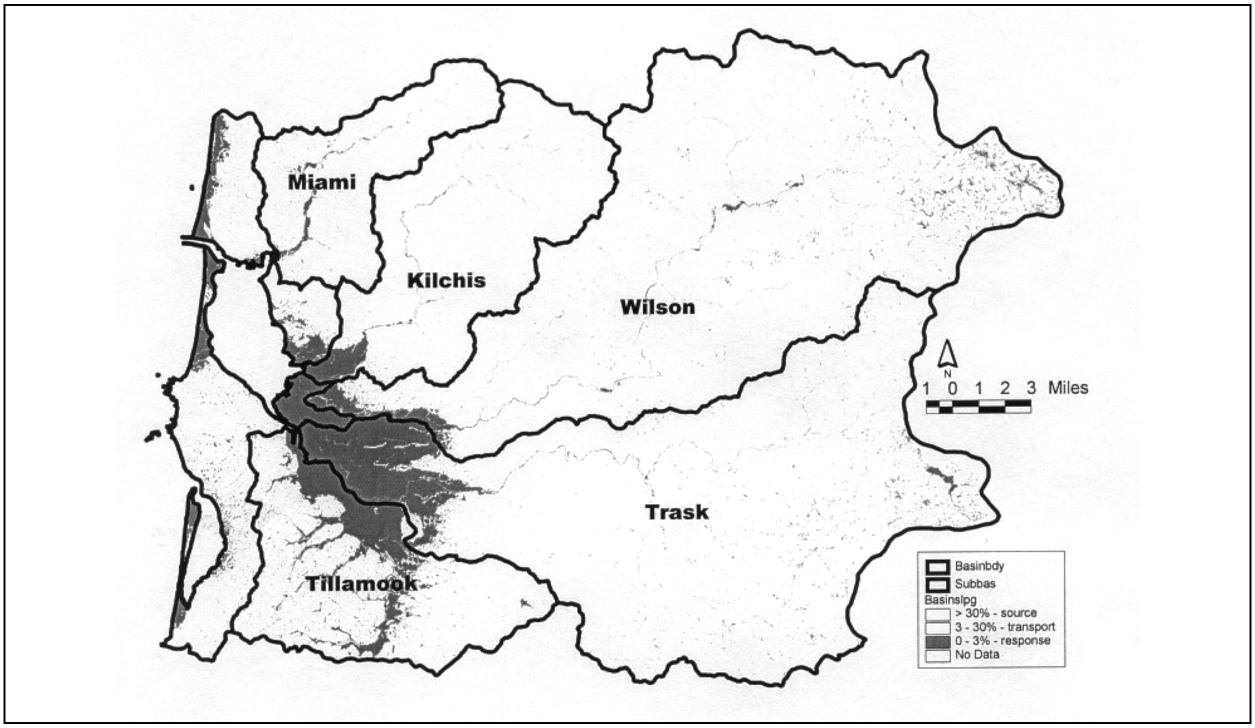


Figure A-2-20. . Basin Slope < 3% - Response Zone

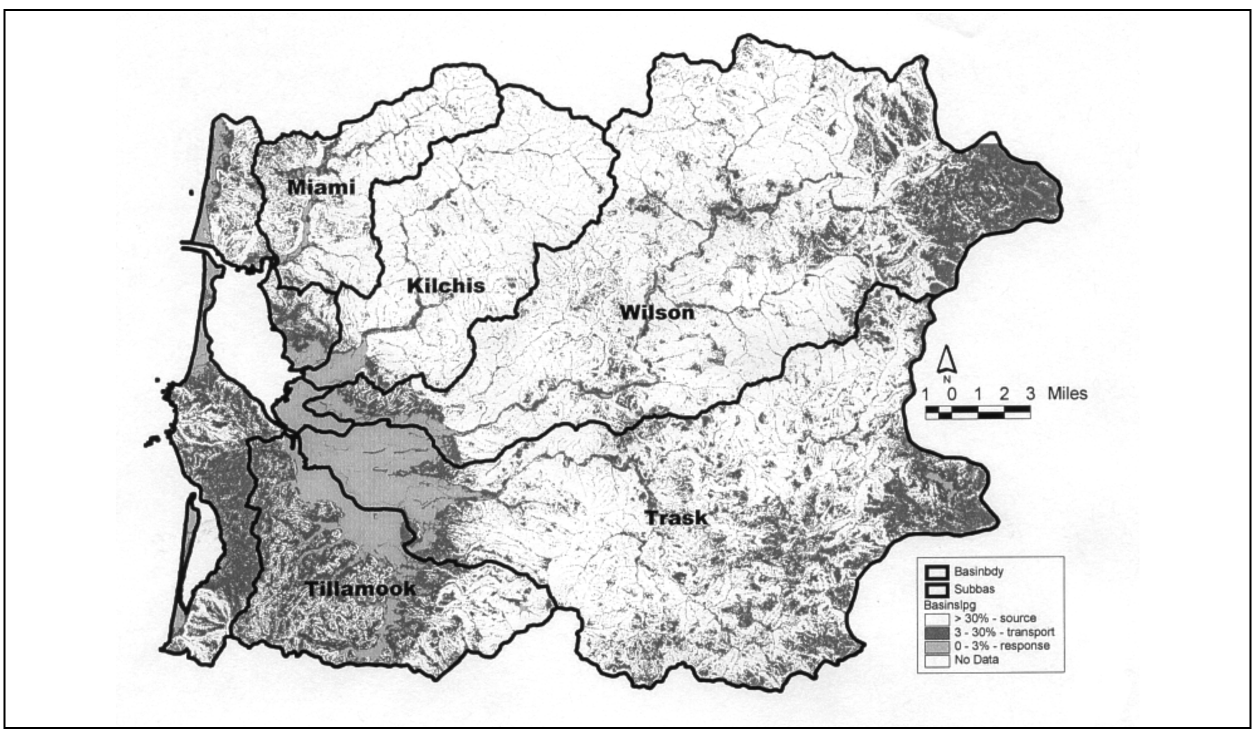


Figure A-2-21. Combined Transport and Response Zones Mapped Together

TABLE OF CONTENTS

LIST OF FIGURES

A.3 River Hydrology

River hydrology describes the timing, amount, and duration of water moving through a river system. These values can be measured at specific landscape locations through the use of stream gauges. Gauge data provide a historical record and a body of statistical value observations, which can be very useful in understanding seasonal patterns of stream flow and flooding, and in turn, their effects on salmon habitat and flood risk. This section covers streamflow gauging and streamflows in the Tillamook Basin, flow duration, flood frequency, and flood wave and flood pulse concepts.

A.3.1 Streamflow Gauging

■ Objectives

The goal of this assessment was to document the location and period of record of available stream gauge data for the major rivers in the Tillamook Bay Basin.

■ Method

The hydrologic analyses in this study made use of available streamflow information from the TBNEP and USGS. Each sub-watershed within the Tillamook basin currently has one gage located in the upper watershed outside of the zone of tidal influence. The location, upstream drainage area, and elevation vary for each gage. The two longer term gauges on the Wilson and Trask Rivers, and their gauged sub-watersheds, are shown in Figure A-3-1.

■ Discussion

Because the gauges are located relatively far upstream, not all of the runoff that enters the lowland river system is recorded by the gauges. The period of record of each gage varies as shown in Figure A-3-2. Since the period of record of stream gages on the Wilson and Trask rivers is substantially more extensive than for the Miami, Kilchis, and Tillamook Rivers, results from the latter gages are less representative of the actual longer term hydrology.

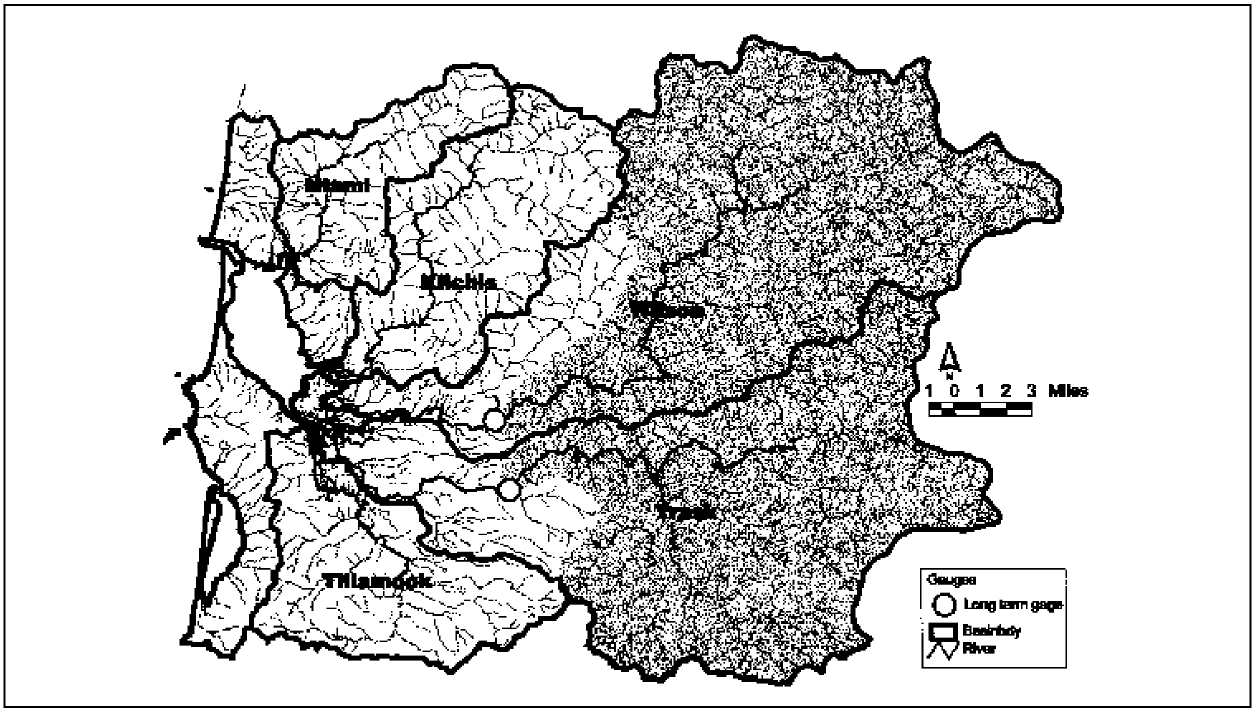


Figure A-3-1. Tillamook Bay Basin Gage Locations and Gauged Drainage Areas

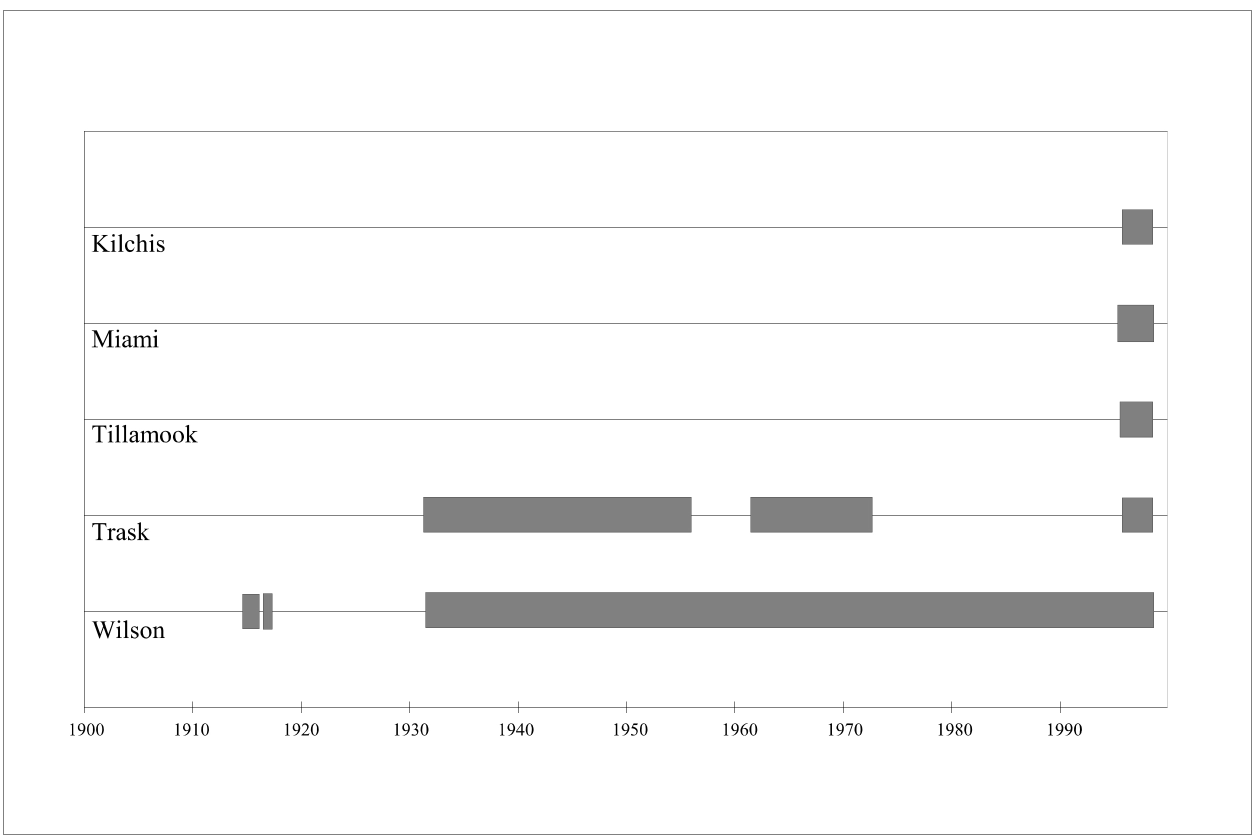


Figure A-3-2. Stream Gage Periods of Record in the Tillamook Basin

A.3.2 Mean Daily Streamflows

■ Objectives

The objective of this assessment was to develop an understanding of the daily variability and magnitude of streamflow to guide flood management and floodplain restoration planning.

■ Methods

Mean maximum and minimum daily discharge values for the Wilson River were obtained directly from the USGS because these data are not available over the Internet.

■ Discussion

These seasonal flow data can be translated into river stage elevations in upland and lowland reaches of the river system, once the relationship between stage and discharge is known from field observations and/or floodplain computer modeling. The resulting stage discharge relationships can be used together with floodplain topography to estimate the depth, lateral extent and duration of flooding at various locations along the river system.

Maximum mean daily discharges exceed the flood stage of the Wilson River (13,200 cfs) during the months of December through February (Figure A-3-3). Knowledge of the river stage elevations associated with these high discharges can be used in the restoration design of seasonal wetlands and floodplains.

Viewing the data on a semi-log plot (Figure A-3-4) helps to show the variability in the minimum mean daily discharges through the water year. The lowest values of mean daily discharge (August through September) tend to be indicative of baseflow conditions, when a majority of the river flow is derived from groundwater sources.

The average mean daily discharge, and the discharges between the maximum and minimum mean daily discharge values represent the range of daily discharges that can be expected throughout the water year. Since these flows are daily values, and not longer-term monthly average values or short duration peak values, they represent the daily flow conditions occurring during plant growing seasons. The translation of these flows to river stage elevations can be used to guide restoration re-vegetation efforts by defining the elevation and extent of aquatic and riparian plant communities for given floodplain topography. For example, aquatic vegetation would be expected to grow at elevations below the stage of minimum mean daily discharges because land below this elevation would remain consistently wet; similarly riparian vegetation would be expected to grow above the minimum mean daily discharge stage and up to the mean or maximum mean daily discharge stage because these land areas would be periodically wet.

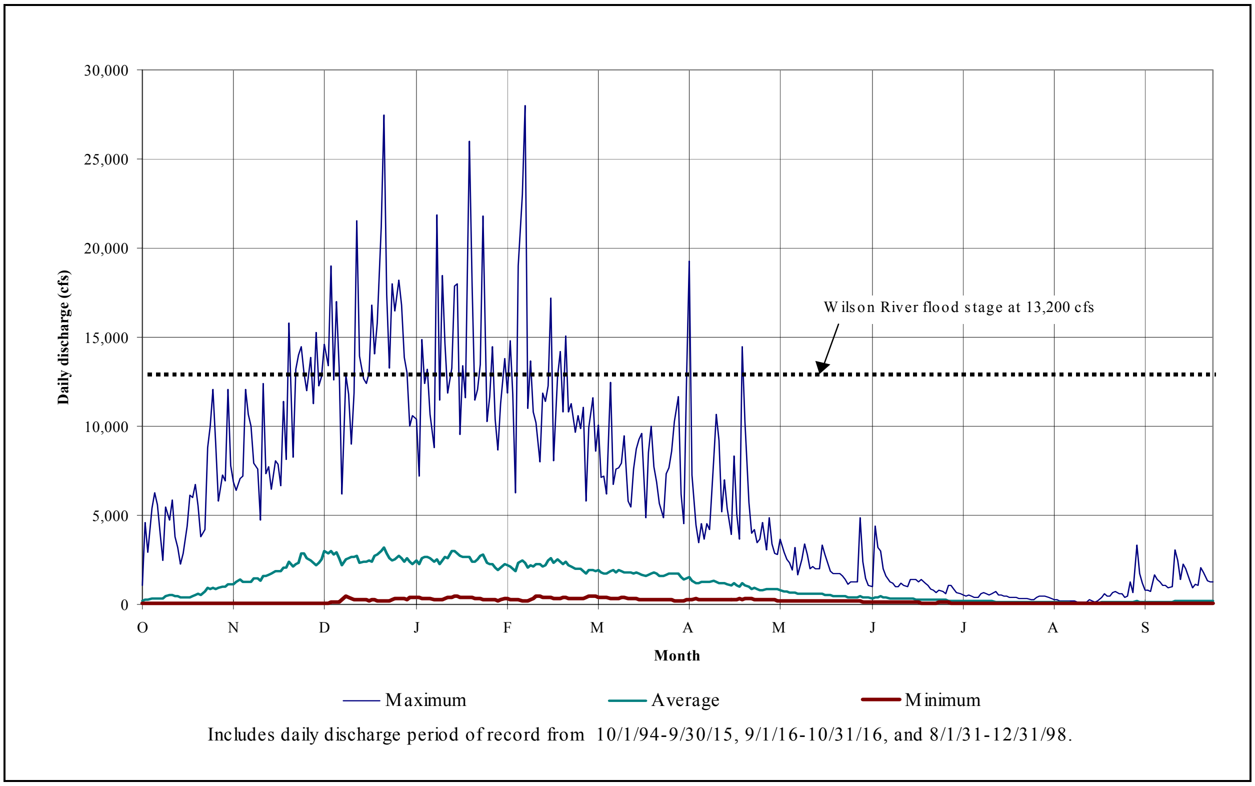


Figure A-3-3. Wilson River Mean Daily Discharge (Maximum Mean Daily Discharge Focus)

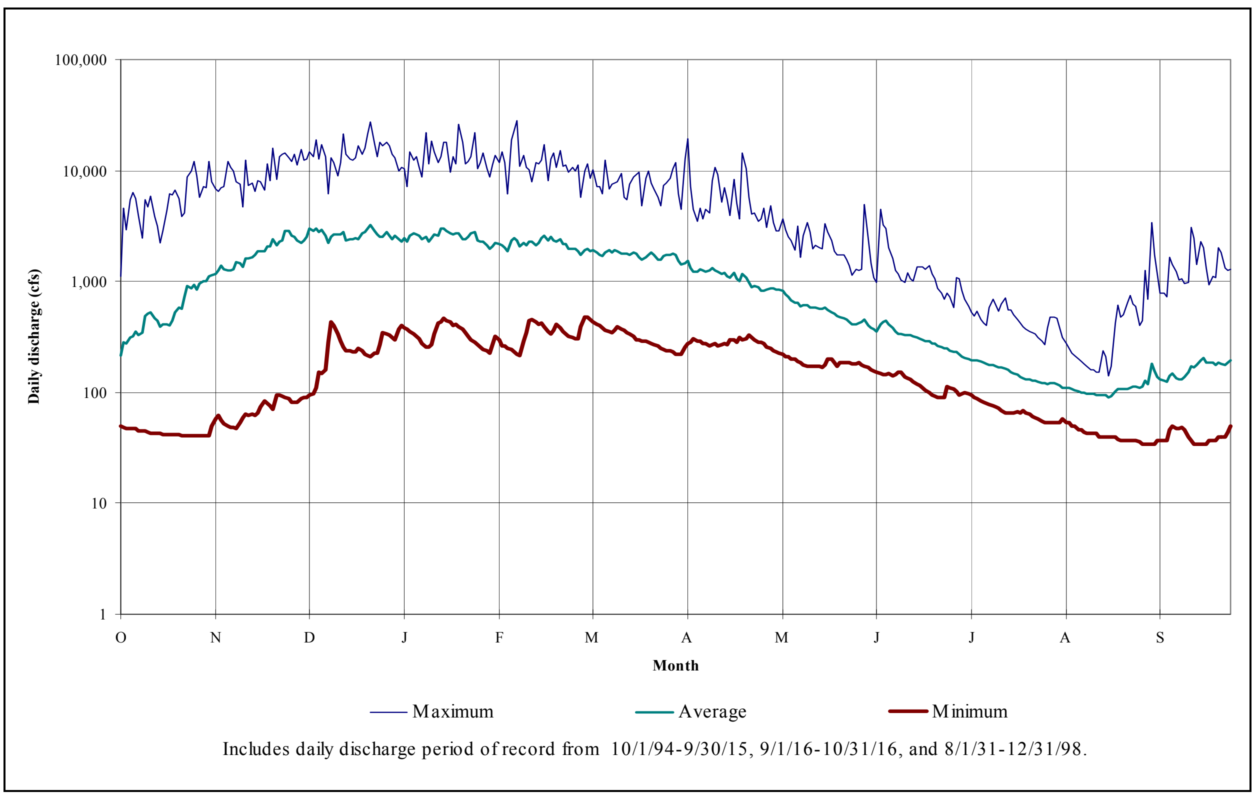


Figure A-3-4. Wilson River Mean Daily Discharge (Minimum Mean Daily Discharge Focus)

A.3.3 Flow Duration

■ Objective

A flow duration curve is a cumulative frequency curve that represents the percent of time during which specific flows were equaled or exceeded throughout a given period of record. The curve summarizes the flow characteristics of a river without consideration for the historic sequence of flow events, and shows the integrated effect of climate, topography and geology on runoff. Flow duration curves are helpful tools to evaluate the overall hydrology of a river, including high, moderate, and low flows. The objective of this assessment was to assemble and interpret flow duration information for the major rivers in the Tillamook Basin to evaluate basin streamflow characteristics.

■ Methods

Flow duration data were generated using mean daily streamflow data obtained from the USGS. Since the stream gauges for the five Tillamook Bay Basin rivers all have different periods of record, two sets of flow duration data were created. The first data set was based on the entire daily record available for each gage. Monthly flow duration curves for the Wilson River, the river with the longest period of record in the basin, are plotted from this exercise to show the seasonal variability of flow (Figure A-3-5). A second set of flow duration data was created using a common period of record for all five watersheds (April 1996-April 1998). While this permits a direct comparison between gauges, the accuracy of the data is limited by the short two-year period of record common to all gauges. Flow values were then divided by the drainage area of each gage to compare hydrologic response among individual basins on a unit discharge basis (cfs per square mile) (Figure A-3-6). The ratio of the 5% to the 95% exceedence flow was calculated for each watershed, as an index of the nonuniformity of the flow regime (Grant, 1997). For higher ratios, the daily flows are more variable or "peakier"; for lower ratios, daily flow is more uniform.

■ Discussion

Monthly flow duration data for the Wilson River (Figure A-3-5) indicate that the 5% exceedence flows can vary by nearly an order of magnitude (up to 8000 cfs) while the 95% flows range up to 500 cfs. The 50% exceedence flows, or average flows, tend to be 2000 cfs or less for all months. An understanding of the probability and range of monthly streamflow rates can be useful for restoration and management efforts that involve elements of the natural system that have seasonal characteristics, such as fish and vegatation life cycles. As a guide for restoration planning and design, flow duration streamflow rates from the nearest gauge can be input to hydraulic models to estimate seasonal river water surface elevations and floodplain inundation limits.

The unit discharge flow duration data (Figure A-3-6) show that the Kilchis River has the highest flow per unit area across the majority of the exceedence probabilities (from 0 to 55%), and the Miami River has the highest flows for the 65% to 100% exceedence range. Flow duration data for the Tillamook, Wilson, and Trask Rivers are very similar and show smaller flows per unit area. The Kilchis River has the greatest range of mean daily flows, as indicated by the highest 5% to 95% exceedence ratio (70) and the Miami river has the lowest ratio (20). The Wilson and Trask Rivers exhibit very similar discharges per unit area for the range of exceedence frequencies, each with median (50%) flow per unit area of 5.8 cfs/mi^2. The Kilchis River basin receives higher amounts of precipitation than adjacent basins, and larger quantities of precipitation are less likely to infiltrate the volcanic formations, resulting in more immediate runoff, higher flood peak flows, and a more variable historical flow record. The higher unit flows from the Miami River may be an indication of a significant contribution of flow from groundwater sources.

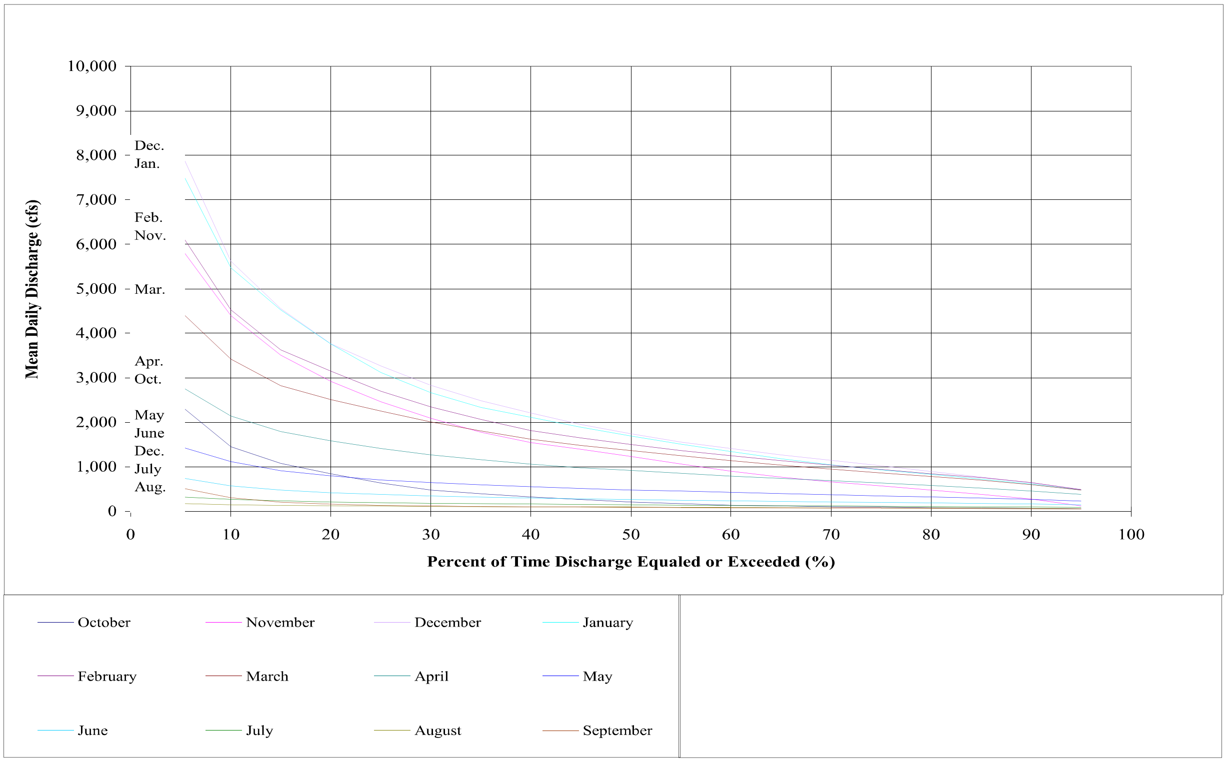


Figure A-3-5. Wilson River Flow Duration Curves by Month near Tillamook Source: Gage 14301500, analysis provided by USGS

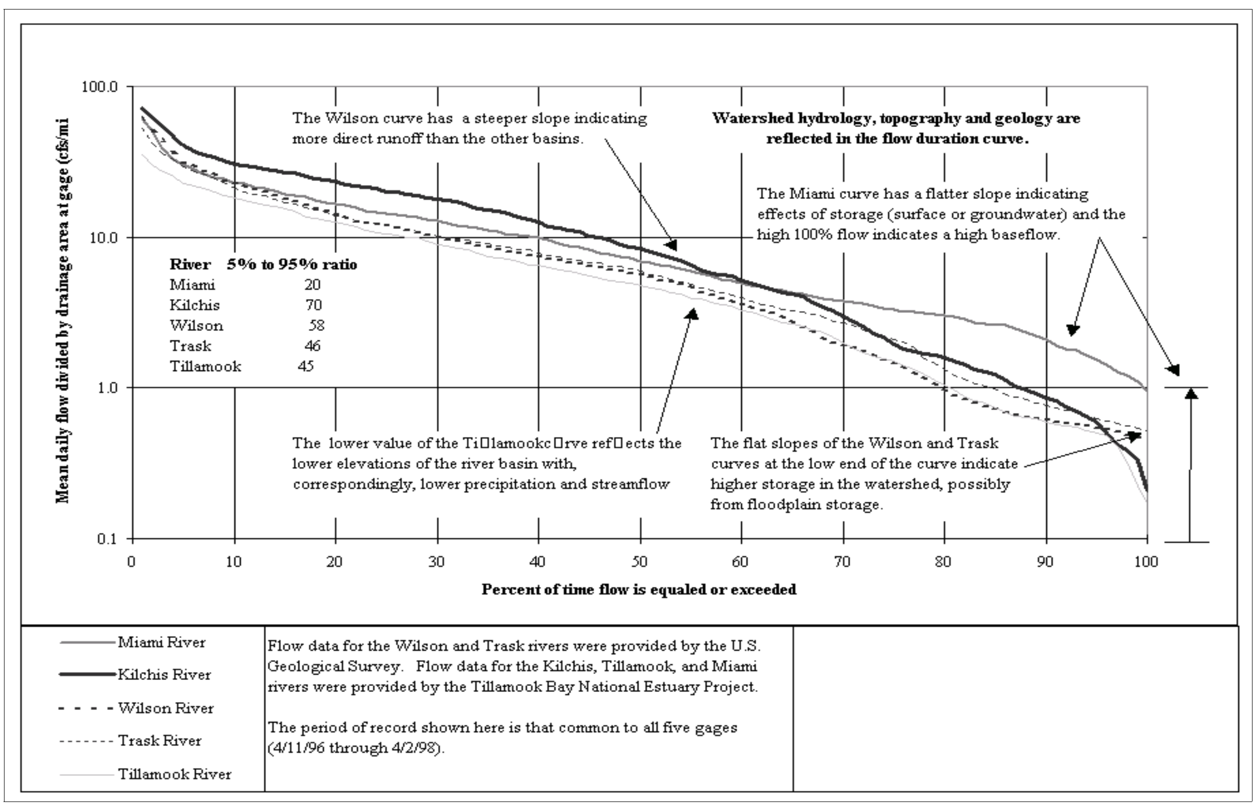


Figure A-3-6. Flow Duration Curves Scaled by Drainage Area

A.3.4 Annual and Monthly Average Streamflows

■ Objectives

River systems exhibit seasonal patterns of streamflow throughout a water year. Some of the most basic hydrologic data available to assess these patterns are annual and monthly average streamflow data. The objective of this assessment was to document these seasonal patterns of streamflow and relate the value of these data to flood management and salmon recovery efforts.

■ Methods

Monthly and annual streamflow statistics were obtained from the USGS (Moffatt et al, 1990). Long-term data and reliable statistics were only available for the Wilson and Trask River gauges. These data are shown for the Wilson River in Figure A-3-7. The USGS document also provides information on drainage area, gauge conditions, and maximum and minimum streamflows.

■ Discussion

Percentage of annual streamflow is an indication of how flow is distributed throughout the year. The annual winter peak in streamflow for the Wilson River is an indication of the response of the watershed to precipitation patterns and the lack of a significant snowmelt contribution to runoff, which is typically characterized by a spring streamflow peak.

Average values of streamflow are useful to detect trends in water availability by providing a baseline from which to judge the relative severity of individual drought and flood conditions and to assess streamflow trends. Average values of streamflow can be converted to volumes of runoff for water balance investigations. Water balance work is traditionally used for agricultural purposes to identify crop water needs and irrigation requirements. In the same way, water balance investigations could be used to plan and design riparian and floodplain revegetation efforts.

The monthly streamflow statistics represent average seasonal conditions and can be useful for ecological planning purposes. By associating streamflows with water stages at various points in the system, these data can be used to estimate the lateral extent and depth of water in the river channel and the amount of riparian area exposed above the water.

The minimum and maximum monthly values can be used to establish threshold conditions. These hydraulic conditions can be used to infer habitat, water quality and botanical characteristics throughout a typical water year.

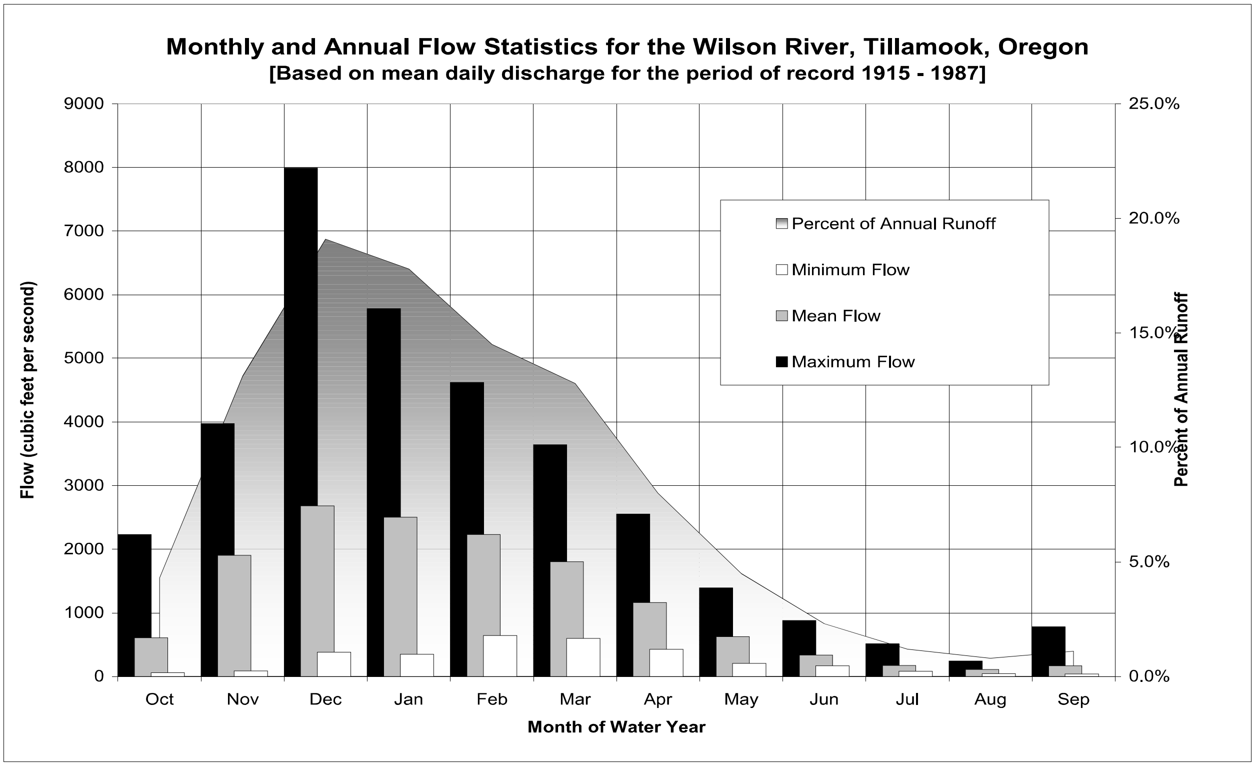


Figure A-3-7. Monthly and Annual Flow Statistics for the Wilson River, Tillamook, Oregon
Based on mean daily discharge for the period of record 1915-1987

A.3.5 Streamflow Flood Frequency and Return Period

■ Objectives

Flood frequency analyses provide an estimate of the probability of occurrence of floods of certain magnitudes. Estimates of flood frequency are the basis of much of the planning that concerns river channels and valley floors. The return period associated with a specific peak discharge indicates the probability of occurrence of a peak flow equal to or greater than a specified discharge**.** This information is useful for engineering design, flood insurance studies, and land-use zoning of flood-prone areas. The objective of this assessment was to understand the relative magnitude of historic and recent floods in relation to established flood frequency return periods.

■ Methods

Discharge records for the maximum instantaneous discharge, or peak flow, for each year of record (an "annual series") were obtained from the USGS over the Internet for the Trask and Wilson Rivers. Only these rivers were used for this analysis, because they had the longest available period of record.

The annual peak flows were compared to return period flood estimates given in the FEMA flood insurance study. Frequency curves for high and low flows on the Wilson River were available from the Soil Conservation Service.

■ Discussion

Annual peak flows recorded by the USGS for the Wilson River are shown in Figure A-3-8. Instantaneous peak flows have ranged from 6,680 to 36,000 cfs. The three largest peak flows on the Wilson River were recorded during January 1972 (36,000 cfs), February 1996 (35,000 cfs), and December 1964 (32,100 cfs). The 1972 and 1996 flood events have been at or near the 100-year return period flow estimate. There appear to have been several flood events in recent years, since the late 1960s, that have exceeded 10-year flood conditions.

Figure A-3-9 shows a frequency analysis of the annual high and low streamflows for different durations. These data show the probability of a given streamflow occurring over a certain number of consecutive days. Data on the duration of a streamflow and the probability of its occurrence can be useful to plan and design floodplain restoration projects where knowledge of the period of inundation or drought is critical to the establishment and survival of riparian plantings.

Public concern for downstream flooding tends to focus attention on larger storm events (e.g., 25 to 100 year return interval storms). Whereas concerns for fish may center upon a more frequent "channel-forming" discharge, thought to be approximately the 5-year return interval flow in most steep mountain streams. Geomorphologists often refer to the bankfull flow as that flow responsible for moving the majority of bed material and forming the channel shape over longer time scales. Although higher flows generally move more material, they persist for shorter durations of time. Thus, more moderate flows that move some material and occur with greater frequency are generally considered more geomorphically "effective." These "effective" bankfull flows generally correlate with flows with a recurrence interval between 1 and 2 years (Leopold, Wolman, and Miller, 1964). A flood frequency analysis was used to establish the 1- and 2-year return period for each basin and determine a general ratio of flow per square mile. This flow is estimated to be between 6,000 and 17,500 cfs (37 to 109 cfs/mi^2) for the Wilson River and 7,500 to 12,250 cfs (51 to 84 cfs/mi^2) for the Trask River.

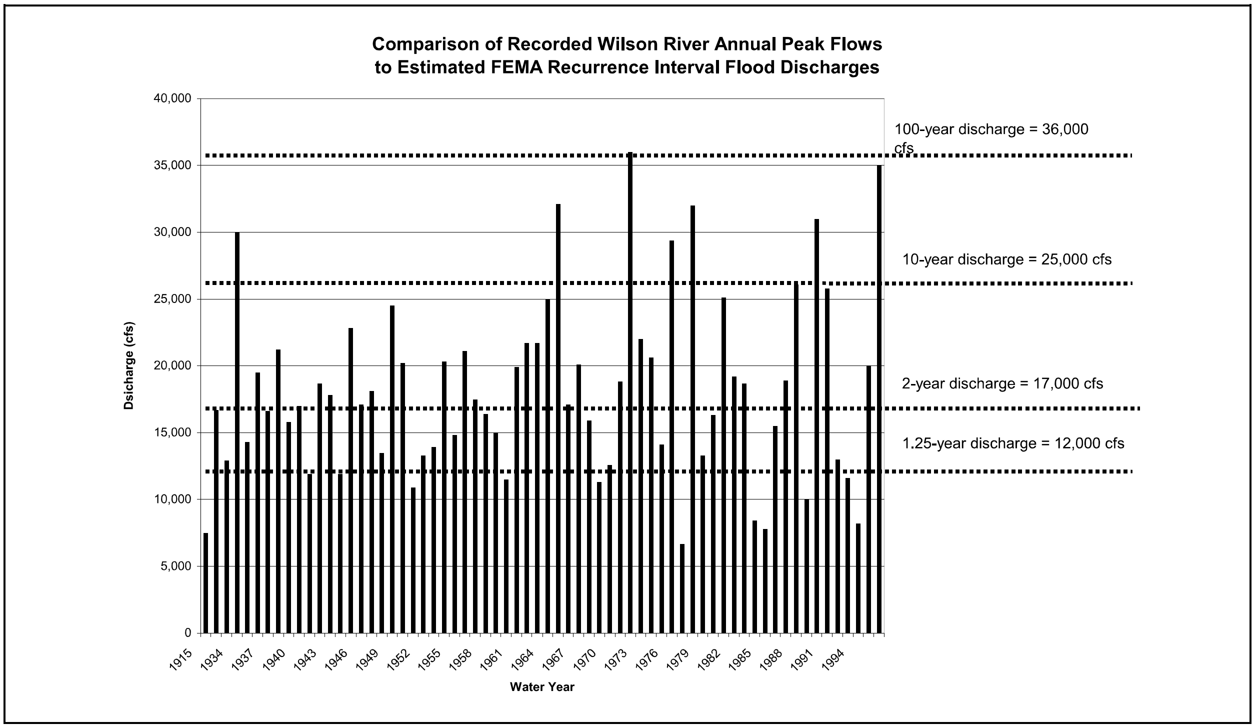


Figure A-3-8. Comparison of Recorded Wilson River Annual Peak Flows to Estimated FEMA Recurrence Interval Flood Discharges

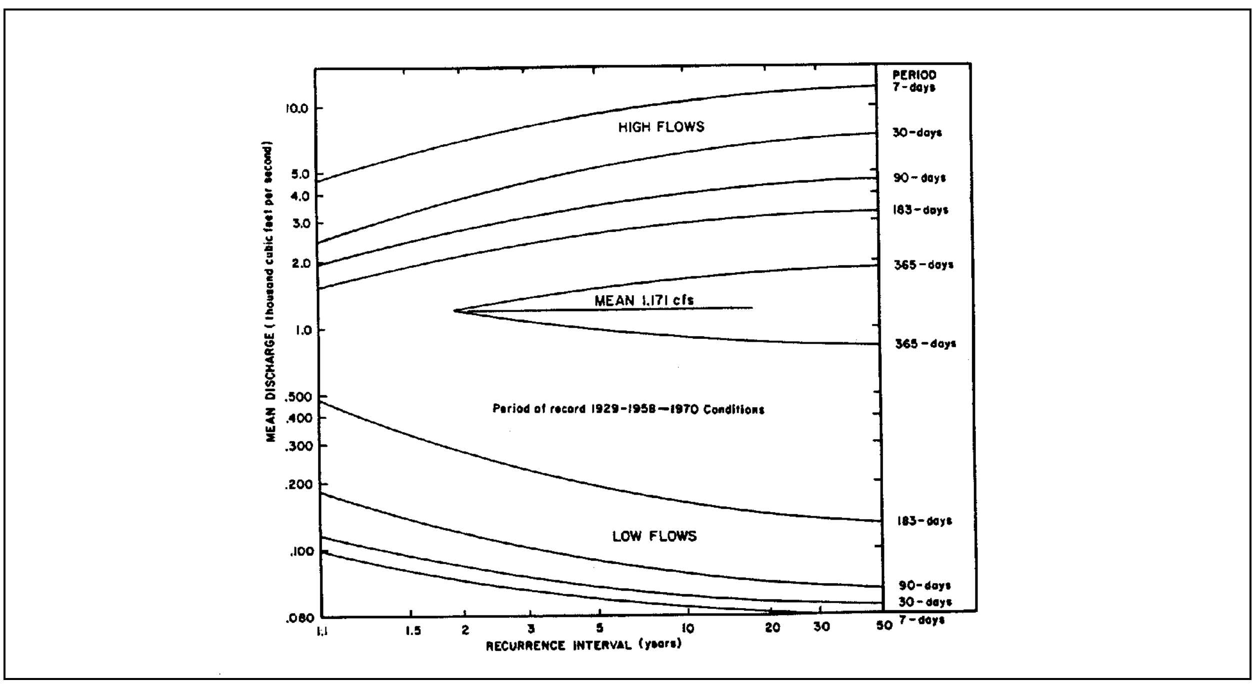


Figure A-3-9 .Wilson River Annual Peak Flows and Recurrence Interval Flood Discharges
Soil Conservation Service, 1978

A.3.6 Flood Event Hydrographs

▪ Objectives

The objectives of this analysis were to compare: 1) the rate of rise and fall of historic flood event hydrographs; and, 2) the duration and volume of flood events, to assess the effects of historic flood hydrograph characteristics on streambank erosion.

▪ Methods

Flow values for bankfull and flood stages were estimated by comparing river stage data from the National Weather Service (NWS) to the recent rating table (stage-discharge relationship) for the Wilson River stream gauge obtained from the USGS. For example, the NWS has designated a 13-foot river stage as "flood stage." This corresponds to a discharge of about 13,200 cfs from the USGS rating table. The area of the flood event hydrograph above flood stage represents the volume of water exceeding flood stage (Figure A-3-12).

Floods travel downstream in a river system as a wave (Figure A-3-10). The flood's wave is recorded at a streamgauge and the resulting record of the wave is the flood event hydrograph. Flood event hydrographs provide a chronology of the variation of streamflow over time. Hydrographs show the peak flow of a given flood event, but they also document hydrologic conditions before and after the peak of the event. Additional hydrologic conditions of interest (Figure A-3-11) are the volume of the flood event (indicated by the area under the hydrograph curve) and the speed at which the flood peaks and recedes (indicated by the slope of the rising and falling limbs of the hydrograph). In the Tillamook Bay basin, the rate of the rise and fall of flood stage is of particular interest because "flashy" floods can saturate and destabilize the soil of levees and dikes, leading to erosion.

Hourly discharge data for the Wilson River gauge were obtained from the USGS for the period from October 1994 through April 1998 (the period of record for which hourly data is readily available). Peak discharges for the five largest flood events were identified, and the range of flood discharge values were selected from the data by including all values greater than an assumed base flow determined from visual inspection. Flood peaks were aligned together at a common time (day number 200) so that hydrograph limbs could be readily compared. Ordinates for the December 1964 flood event were taken from a figure of the flood hydrograph in the Corps post-flood report (Corps., 1972). Figure A-3-13 shows a comparison of flood hydrographs for the Wilson River for flood events for the December 1964 flood and those flood events between October 1994 and April 1996.

▪ Discussion

All flood events appear to have had similar durations above the 13,200 cfs flood stage, typically less than 24 hours. The rate of rise and fall for the lesser flood events (those peaking around 20,000 cfs) are fairly consistent. Although recording equipment malfunctioned soon after the peak of the February 1996 flood, this event appears to have been the largest in terms of peak magnitude, peak duration, and volume above flood stage.

Flood volumes are also noticeably similar for these events, with the exception of the November 29, 1995 flood event, which displays multiple peaks, presumably owing to storm surges producing overlapping flood hydrographs. Multiple peaked flows are significant to streambank erosion because of the increased incidence of wetting (Knighton, 1998).

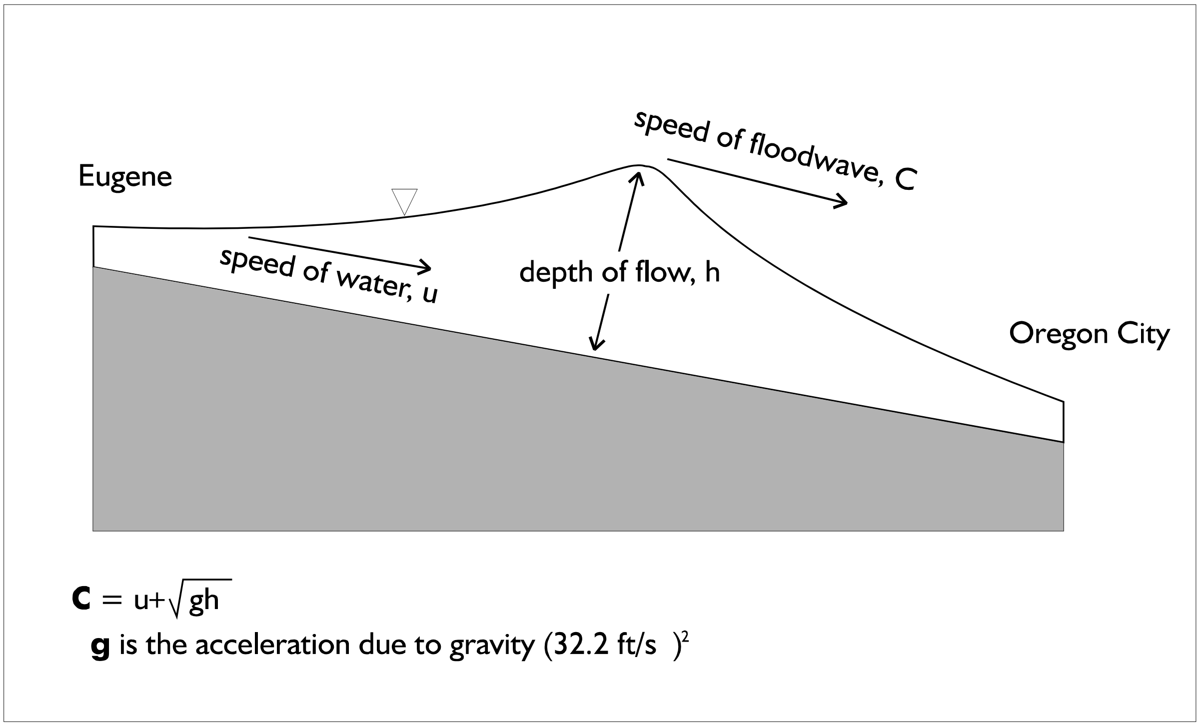


Figure A-3-10. Flood Wave Propagation. Source: Coulton *et al.*, 1996

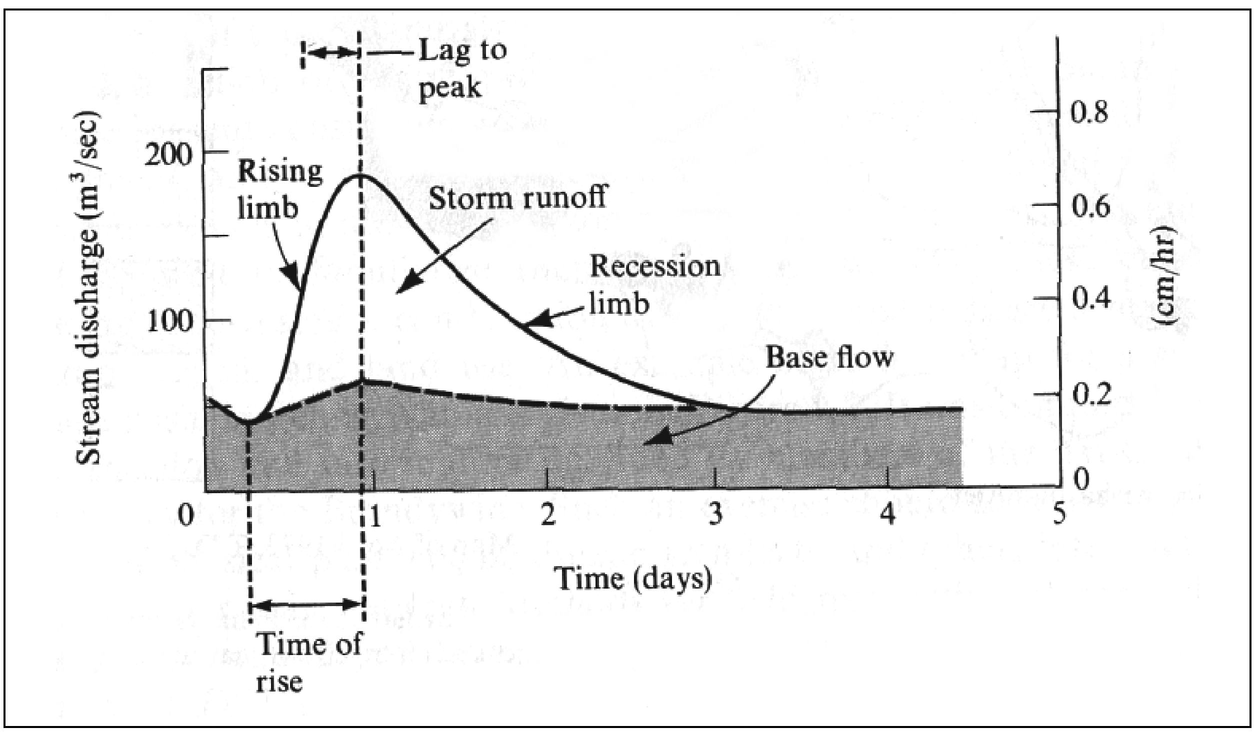


Figure A-3-11. Hydrograph of Streamflow in Response to a Rainstorm from a 100-sq-km Basin. Source: Dunne and Leopold, 1978

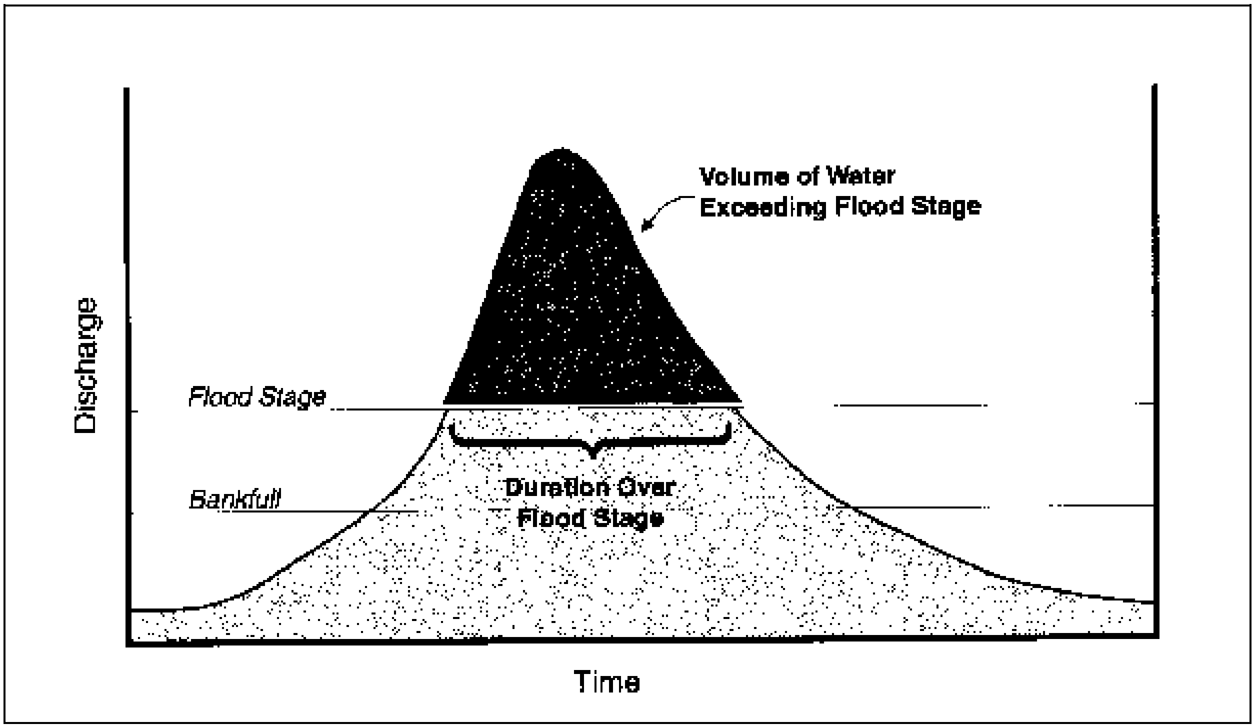


Figure A-3-12. Relationship between flood stage and flood volume

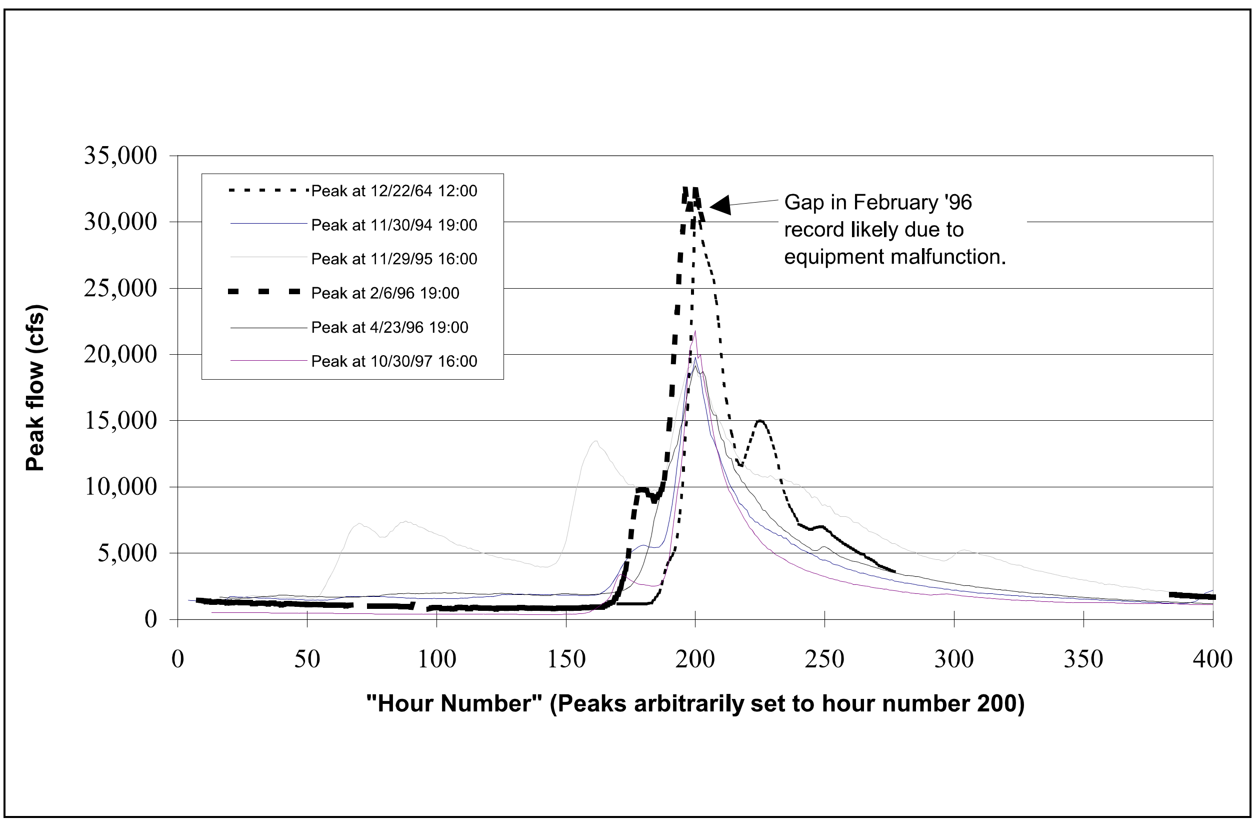


Figure A-3-13. Peak Flows of the Wilson River, October 1994 through April 1998, and December 1994

TABLE OF CONTENTS

LIST OF FIGURES

A.4 River and Tidal Hydraulics

Hydraulics, simply stated, describes the work done by water. A major component of river hydraulics is sediment transport -- the movement of material by water. The mechanisms by which sediment is moved are different in different areas of the landscape. Uplands are generally areas where sediment is picked up. Lowland valley floodplains are areas where deposition and sorting take place. Estuaries are subject to tidal fluctuations, creating a unique transportation mechanism. This section covers sediment discharge, flood stages, overbank flooding, sea-level change, tide gauging, tidal datums, stillwater elevations and coastal flooding, tidal prism relationships, and head of tide.

A.4.1 Sediment Discharge

▪ Objectives

Long-term changes in sediment discharge can reflect changes in land use conditions. Sediment discharge can also vary with the rate of flow in a river. The objective of this assessment was to document historical and current sediment discharge characteristics to understand what influence historical sedimentation rates may have on present day sedimentation conditions, and to explore the relationship of sediment discharge to river discharge.

▪ Methods

Trends in historic gross sedimentation for theTillamook Bay Basin (Figure A-4-1) were available from a 1978 investigation into erosion and sedimentation problems (Tillamook Bay Task Force, 1978). Existing stable watersheds were used to estimate non-disturbed forestland sedimentation rates circa 1875. Observations of exposed tree stumps were used as indicators for depth of soil loss together with precipitation and streamflow data. A comparison of sediment discharge among the five major rivers was made by comparing total suspended solids (TSS) sampling data to streamflow (Figure A-4-2).

▪ Discussion

The long-term estimated sedimentation rates shown in Figure A-4-1 indicate that current rates are about 20 times those from the late 1800s. Sedimentation rates increased dramatically with the major forest fires through the 1900s. The cumulative impact of sequential fires is evident from the stepped rise in estimated sedimentation rates through 1945. Present day sedimentation conditions in the lowland river valleys may have been influenced, or may still be influenced, by the increase in sedimentation from the forested uplands following the fires.

The relationship between total suspended solids and streamflow is very similar for the Wilson, Trask and Kilchis Rivers (Figure A-4-2). The Miami and Tillamook River sediment transport rates are higher than the other rivers, with the Tillamook River transporting the most sediment at the lowest streamflows. Floodplain restoration efforts in river systems with higher sediment transport rates may result in more rapid evolution of desired ecological conditions involving deposition of sediment and colonization by native vegetation.

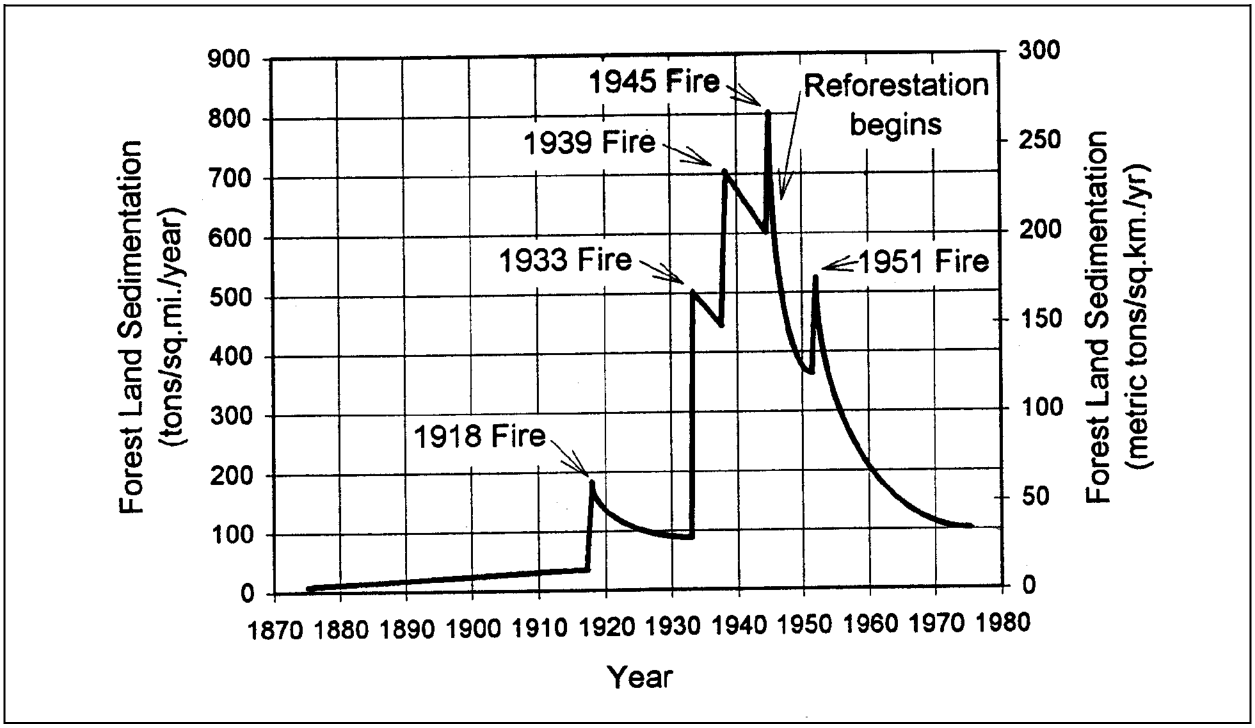


Figure A-4-1. Estimated Sedimentation Rates from Forest Lands in the Tillamook Bay Basin
Source: Tillamook Bay Task Force, 1978

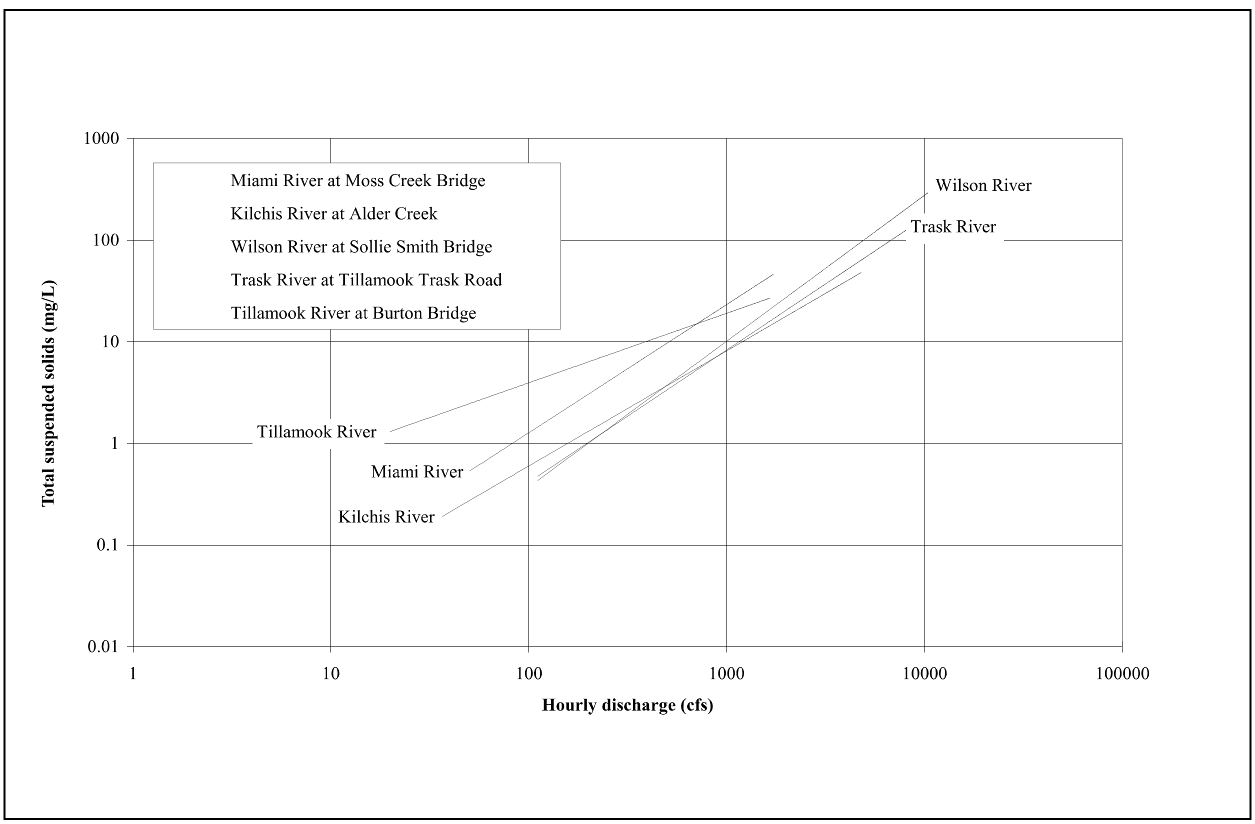


Figure A-4-2. Total Suspended Solids versus Flow for Rivers in the Tillamook Bay Basin

A.4.2 River Flood Stages and Overbank Flooding

▪ Objectives

The objective of this assessment was to compare river stage forecast data with recorded peak steamflow data to evaluate the relative severity, magnitude, frequency and duration of historic overbank flood events in the Tillamook bay basin.

▪ Methods

River stage descriptions for the Wilson river were obtained from the National Weather Service River Forecast Center in Portland (Figure A-4-3). Gauged flood flows were correlated to these river stages using the stage discharge relationship provided on the most recent USGS rating table (stage-discharge relationship) for the gauge (Rating Table No. 15, November 11, 1995). For example, the 14-foot river stage corresponding to moderate flooding was compared to the rating table, and this stage was associated with a river discharge of 15,790 cfs. A similar method was used to develop relationships for the other river stages shown in Figure A-4-3.

An estimate of the duration of flooding -- days above flood stage -- on a water-year basis (October through September) was made by determining the number of mean daily flows at the Wilson River stream gauge that exceeded the NWS-designated flood stage discharge of 13,200 cfs (Figure A-4-3). This evaluation assumes that flows exceeding the NWS flood stage discharge result in overbank flows in the lowland valleys. Hourly flows at the stream gauge were then evaluated to determine the total days of overbank flows within each water year (Figure A-4-5). The same assessment was made for hourly flows from 1994-1998 (Figure A-4-6).

▪ Discussion

The flood stages described in Figure A-4-3 are shown together with annual peak discharges for the period of record of the Wilson River gauge in Figure A-4-4 to provide an assessment of the frequency and magnitude with which flood events exceeded the various flood stages.

Figure A-4-5 indicates that brief periods of overbank flooding (up to one day) appear to have occurred on a more frequent basis throughout the early part of this century and up to the mid-1970s. The clusters of fairly regular annual flood pulses from 1942 to 1950 and 1961 to 1967 occured during a general period of wet, cool weather along the Oregon coast, and soon after the major burns in the Tillamook Basin. Both these conditions would tend to increase the potential for runoff and flooding. Since the 1970s, annual overbank flooding exceeding a day in duration appears to be more frequent, with durations up to three days. This may be an indication of more variable climatic conditions combined with upstream land use practices that are causing runoff to become more “flashy” and less regular in occurrence.

Figure A-4-6 shows the distribution of hourly streamflows for the Wilson River stream gauge, and the frequency and duration of flows exceeding flood stage within the water years 1995 into 1998. The “pulsing” nature of streamflow is readily apparent in this figure, as represented by the dark spikes of hourly flow through the winter months. Overbank flows do not occur on a continual basis, but rather expand and retreat across the floodplain during flooding and drawdown. Floodplain lands within this extent of flood inundation experience high turnover rates of organic matter and nutrients (Bayley, 1995) and are important habitats for fish and wildlife. Figure A-4-6 also shows that most of the annual pulsing in water level occurs below flood stage. This points to the importance of the riparian corridor along rivers channels, and the river banks themselves, as highly productive portions of the river system where the most dynamic interaction between land and water occurs.

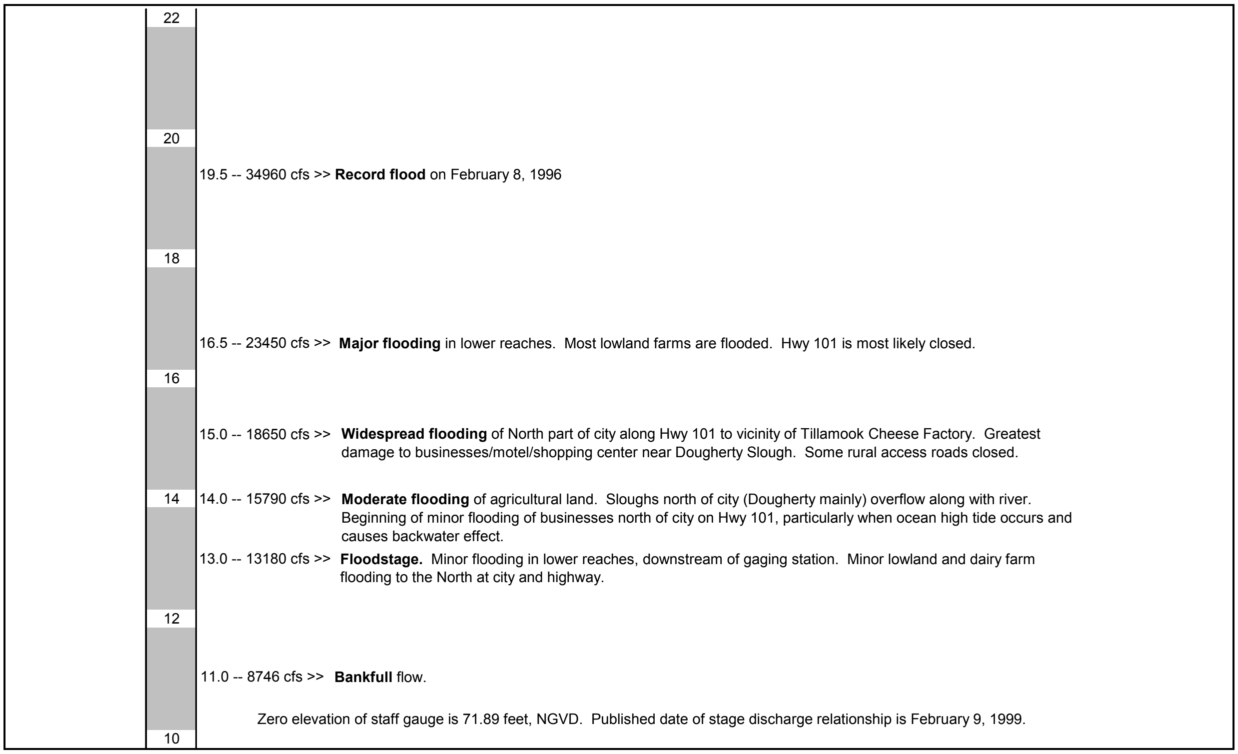


Figure A-4-3. Wilson River Flood Stages Source: NOAA, 1999

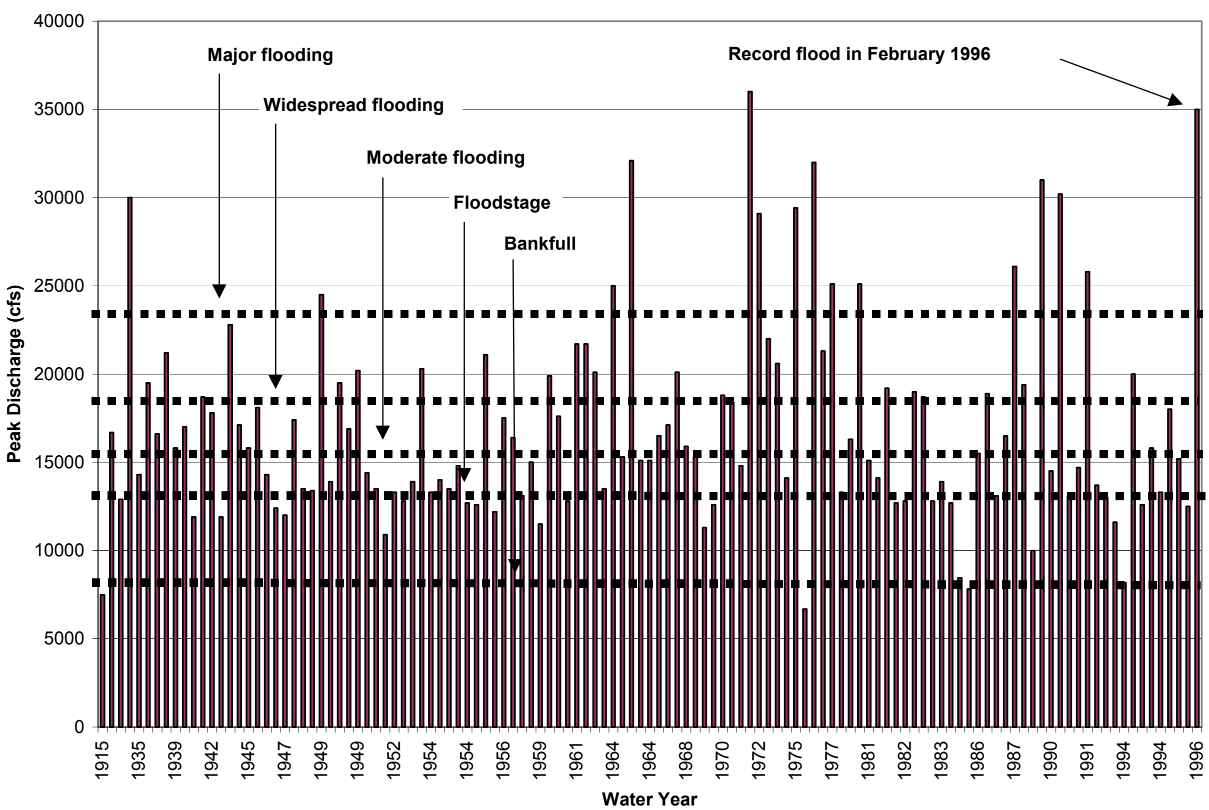


Figure A-4-4. Wilson River Annual Peak Discharges in Relation to Flood Stages

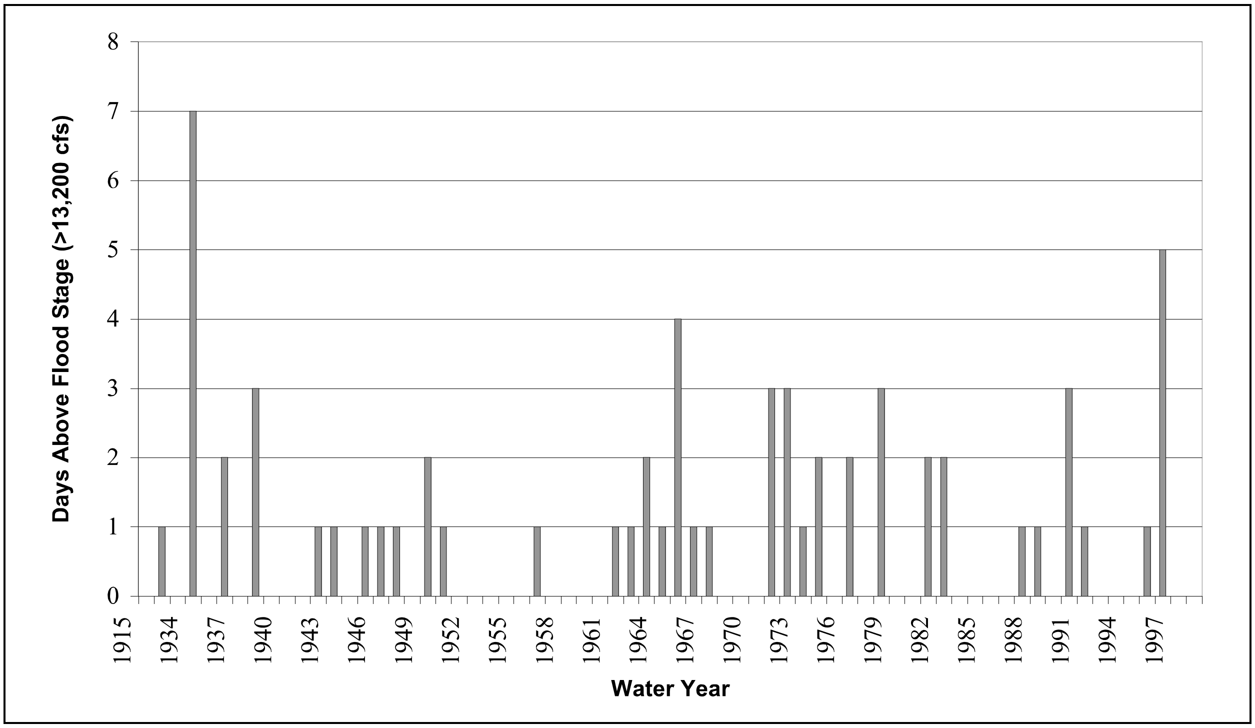


Figure A-4-5. Days above Flood Stage for Historic Wilson River Floods

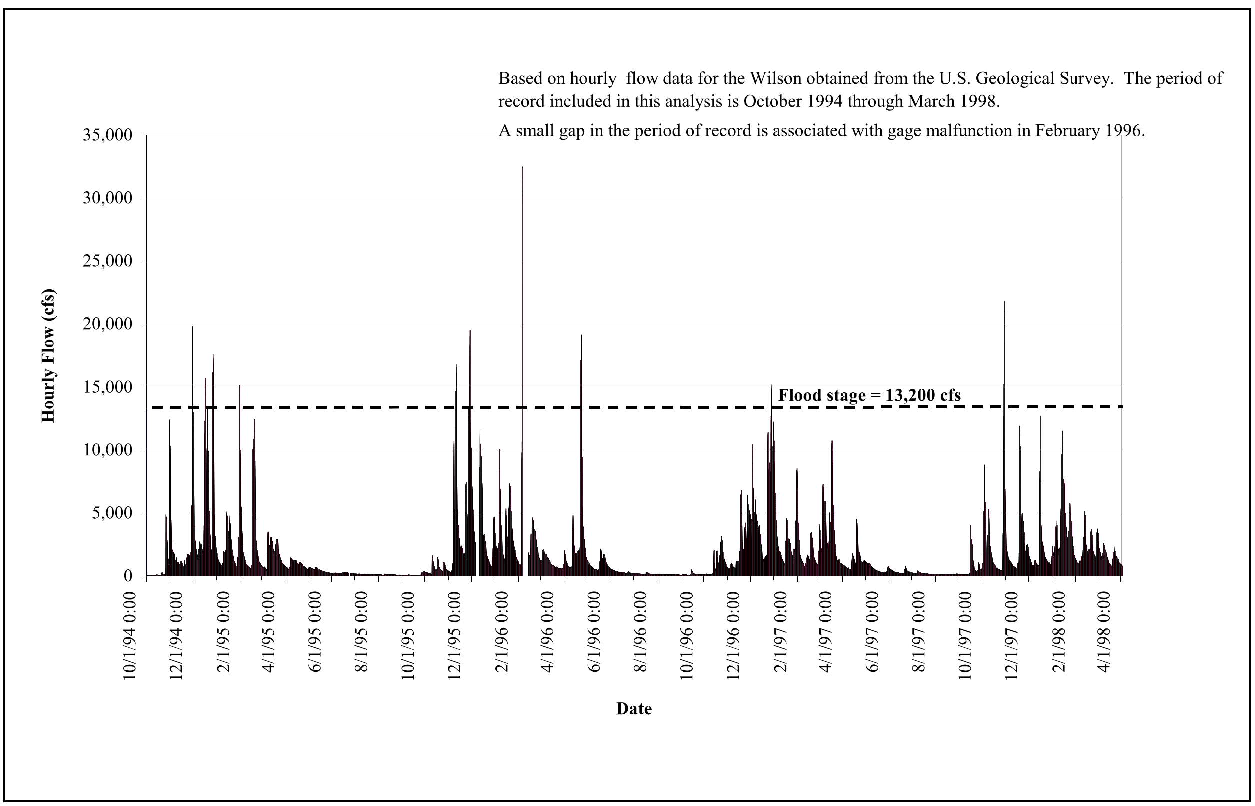


Figure A-4-6. Hourly Flows about Flood Stage for Wilson River

A.4.3 Lowland Valley Flood Characteristics

■ Objectives

Flooding is a dynamic physical process that can be extremely complex in lowland valley floodplains where flood flows combine and interact with the tides. The best method to describe lowland valley flood characteristics is through the use of computer models that can evaluate complex changes in water level and, with some models, the two-dimensional flow patterns of the flood waters. The Tillamook Bay lowlands were modeled in the 1970s as part of a FEMA flood insurance study using a one-dimensional steady state model (HEC-2). However, since the modeling was done about 25 years ago, it was not possible to retrieve from archives. The objective of this assessment was therefore to determine general flood characteristics in the lowland valley using available information and simplified methods.

Since many floodplains in Oregon have been evaluated by FEMA, a simplified method was devised to utilize FEMA data to identify flood characteristics. This method involved using estimated FEMA flood elevations and discharges, and delineating land drainage patterns. These methods should not replace, but rather complement, additional information that may be available from the application of computer models that can better describe the dynamic characteristics of flooding.

■ Methods

Flood elevations from the FEMA flood profiles were compiled at key locations along each lowland mainstem river reach, typically at bridge crossings that were readily defined on the profiles. In the absence of FEMA data, high water marks from flood events can also be used to help define the maximum floodwater surface elevation. FEMA flood profiles show water surface elevations for the 500-, 100-, 50-, and 10-year flood events. From a flood management and aquatic ecology standpoint, the 10-year event is of more interest because of its more frequent occurrence. Water surface elevation contours for the 10-year event were sketched by interpolating between elevation locations (Figure A-4-7).

Stream power values were estimated for the 10-year flood event in the lowland river reaches using FEMA flood insurance study data. FEMA flood profiles were used to determine elevations at key locations along the rivers, and published 10-year flood discharges were associated with these elevations. Flood elevations, and distances between the elevation locations, were used to estimate slopes across the 10-year flood water surface. The slopes were then used to roughly estimate stream power for the 10-year flood event. Stream power is a measure of a river's ability to do work, i.e., to move sediment and erode streambanks. Stream power was estimated using the expression $P = \gamma QS$, where γ is the unit weight of water (generally 62.4 pounds per cubic foot), Q is the discharge, and S is the water surface slope. The average of all values was determined, and stream power values were rated as low or high, based on whether they fell below or above the average value. Figure A-4-8 provides a general indication of the lowland river reaches where stream power is relatively high for the 10-year flood event.

After a flood peaks and begins to recede, land drainage patterns begin to exert control over flood flow characteristics. Drainage patterns were generally identified by sketching flow arrows on a topographic map within the FEMA 100-year floodplain boundary. In this case, the topographic work map used to develop the FEMA floodplain was available and used; however, any large-scale map may be used in this kind of effort. Flow paths can also be observed from historic maps and aerial photographs. Figure A-4-9 shows generalized land drainage patterns, and provides an indication of flow around floodplain encroachments and cross-flow between the lowland river channels.

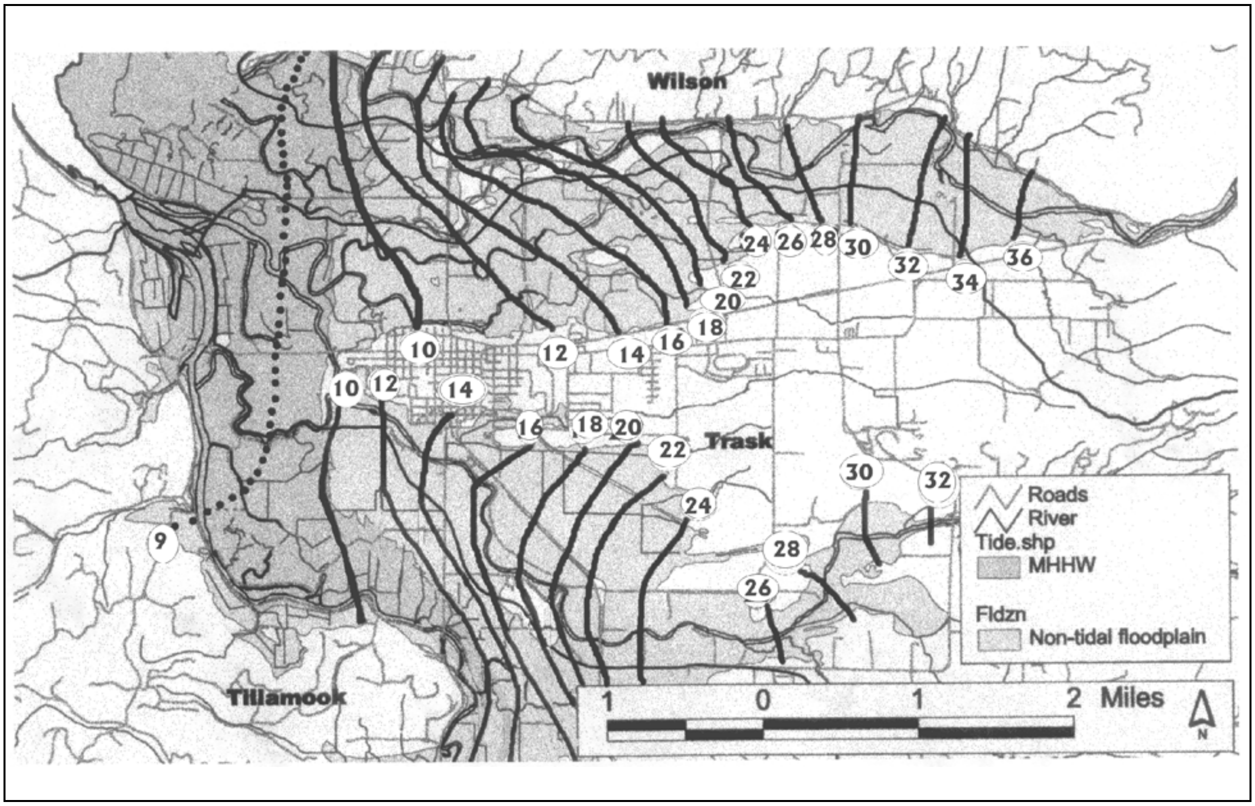


Figure A-4-7. Generalized 10-Year Flood Water Surface Contours

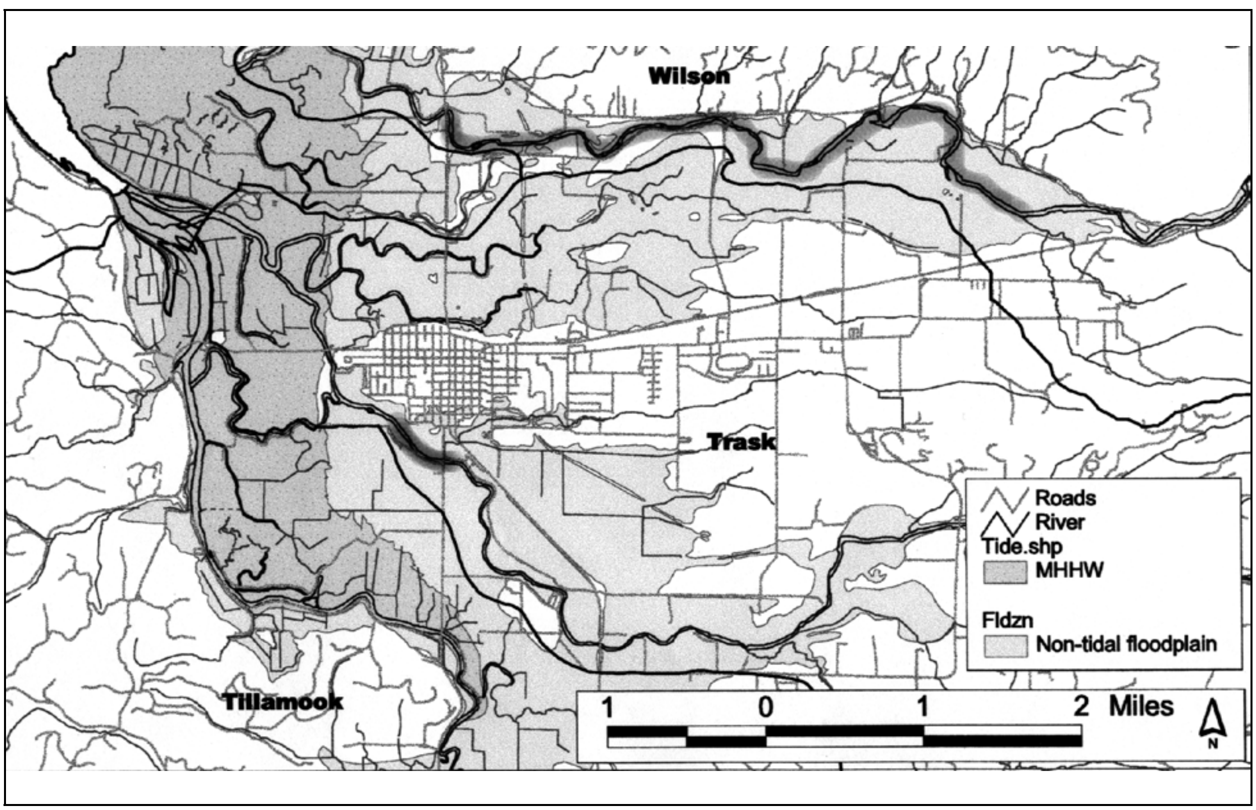


Figure A-4-8. Relative Lowland Floodplain Stream Power Estimates

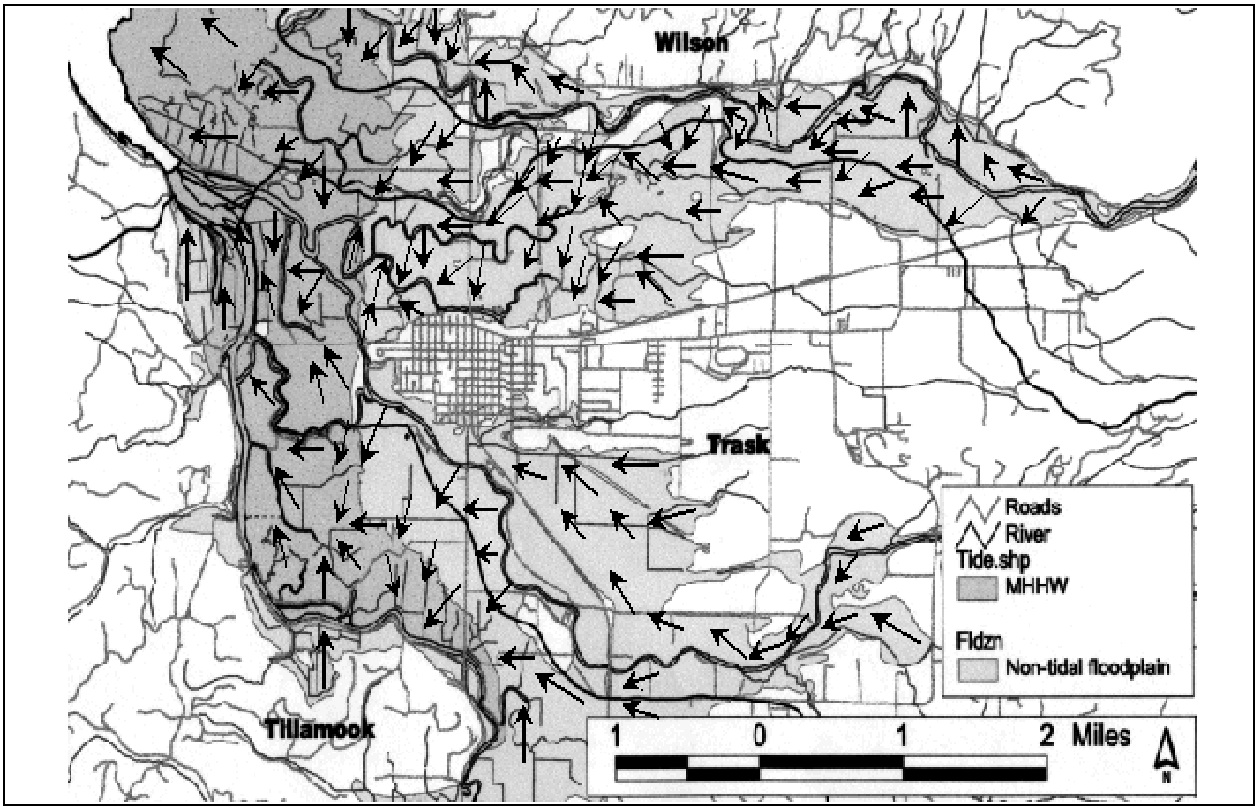


Figure A-4-9. Generalized Land Drainage Patterns

In lieu of the use of a computer model to simulate the complex characteristics of flooding, simplified methods were used to describe lowland valley flood characteristics. The 10-year flood water surface elevation contours provide a glimpse of a hypothetical flood condition, where steeper slopes indicate higher energy flows, and flow directions can be estimated perpendicular to the contours. Based on this simplified assessment of the 10-year flood event, the contours indicate that overbank flood flow paths may be significantly different from river channel alignments. The bulk of the floodwater from the Wilson River flows in a southwest direction towards Dougherty and Hoquarten Sloughs. Trask River flows trend due west into the Tillamook River (Figure A-4-7). Flood management efforts should address high energy flow areas, where flood gradients are steeper, by minimizing floodplain encroachments that may lead to or worsen land and riverbank erosion. Strategies should be developed that accommodate the direction of overbank flood flows between river and slough channel systems.

Estimated stream power values were lowest in the Tillamook River system and highest in the Wilson River system. Figure A-4-8 shows the distribution of high and low power values for the lowland valley. Estimates indicate that a majority of the Wilson River reach upstream of Highway 101, and portions of the Kilchis and Trask River reaches in the vicinity of Highway 101 have high power values. Encroachments along these reaches, such as bridges and levees, should be evaluated carefully, and flood management strategies should be considered to reduce floodwater gradients and increase conveyance.

Land drainage patterns provide an indication of the effects of natural and human encroachments on floodplain water flow and cross-flow between river channels. The drainage patterns generally support the patterns observed from the 10-year flood contour mapping. One of the important items gained from this exercise is the identification of low points in the terrain, especially those at encroachments in the floodplain

(Figure A-4-9). Flood management efforts should prioritize the conservation or restoration of low elevation floodplain land areas where flood overflow would occur and recede, in order to minimize the duration of floodwater inundation of other land areas used for farming and roads.

A.4.4 Sea Level Change

■ Objectives

The increasing evidence of global climate change suggests that sea level change will play an increasing role in shaping future estuarine landscapes, including those along the margins of Tillamook Bay. Tectonic movements of the earth's crust can result in locally varying rates of sea level change. The objective of this assessment was to document trends in global sea level rise, and the associated tectonic movements along the Oregon coast in the vicinity of Tillamook.

■ Methods

Trends in global sea level rise are published in several sources (Shepard and Curray, 1967, Curray, 1965). Figure A-4-10 shows the rise in sea level over the past 8,000 years.

Sea level trends in the Tillamook Bay area are a product of the combined effect of global sea level rise and local tectonic movements (Figure A-4-11). Although the coastal margin of the Pacific Northwest has been tectonically rising for hundreds of thousands of years (Komar, 1998), the rate of land uplift relative to that of sea-level has varied along the coast.

■ Discussion

Along the Oregon coast, the effects of a rising sea level are most pronounced in the Tillamook area (Figure A-4-11) because the land mass in that area is rising at a slower rate than the sea level rise. Land in the Tillamook area is being submerged at an estimated rate of 2 millimeters per year. Although this rate is relatively small, cumulative effects can be pronounced on flat tidal land areas, such as estuarine tide flats and marshes. For example, over a period of 100 years, 2 mm per year would amount to 200 millimeters, or about an 8 inch rise in sea level. This amount of rise would raise the Mean High Water tidal datum to the elevation of the current Mean Higher High Water datum. With a typical intertidal mudflat slope in Tillamook Bay assumed to be one foot vertical to 250 feet horizontal, this could cause tidal marsh vegetation zones to shift inland as much as 170 feet. Similar changes may occur in Tillamook Bay, and the conversion of estuarine habitats (e.g. from tidal to subtidal), may have implications on flood and sediment transport processes and associated management plans.

Sea level rise may also need to be considered in long-term flood mitigation strategies. Local governments need to develop policies that address potential impacts from sea level rise on estuarine habitats and economic activities (Association of Bay Area Governments, 1992). In estuaries and coastal areas, sea level rise may necessitate the relocation or protection of low-lying facilities, such as wastewater treatment plants. The design of new construction in coastal areas should be done with consideration for local sea level trends (Roos, 1995).

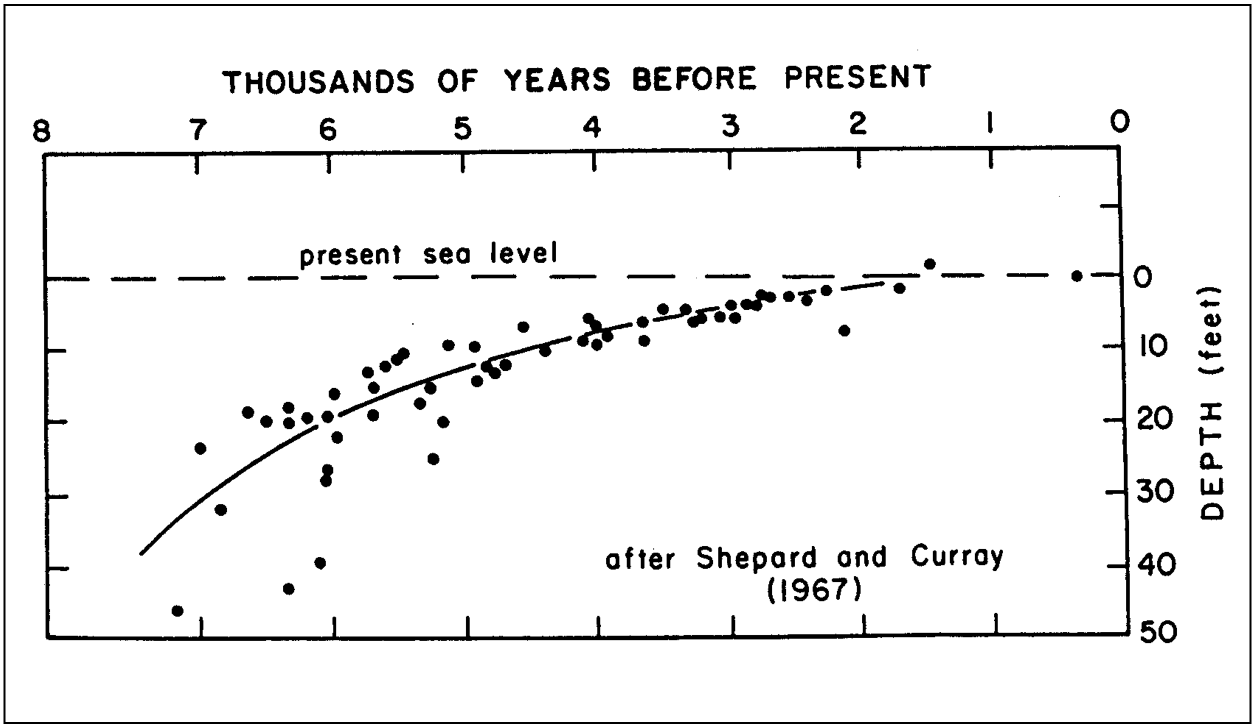


Figure A-4-10. The Rise in Sea Level over the Past 8,000 years After Shepard and Curray, 1967

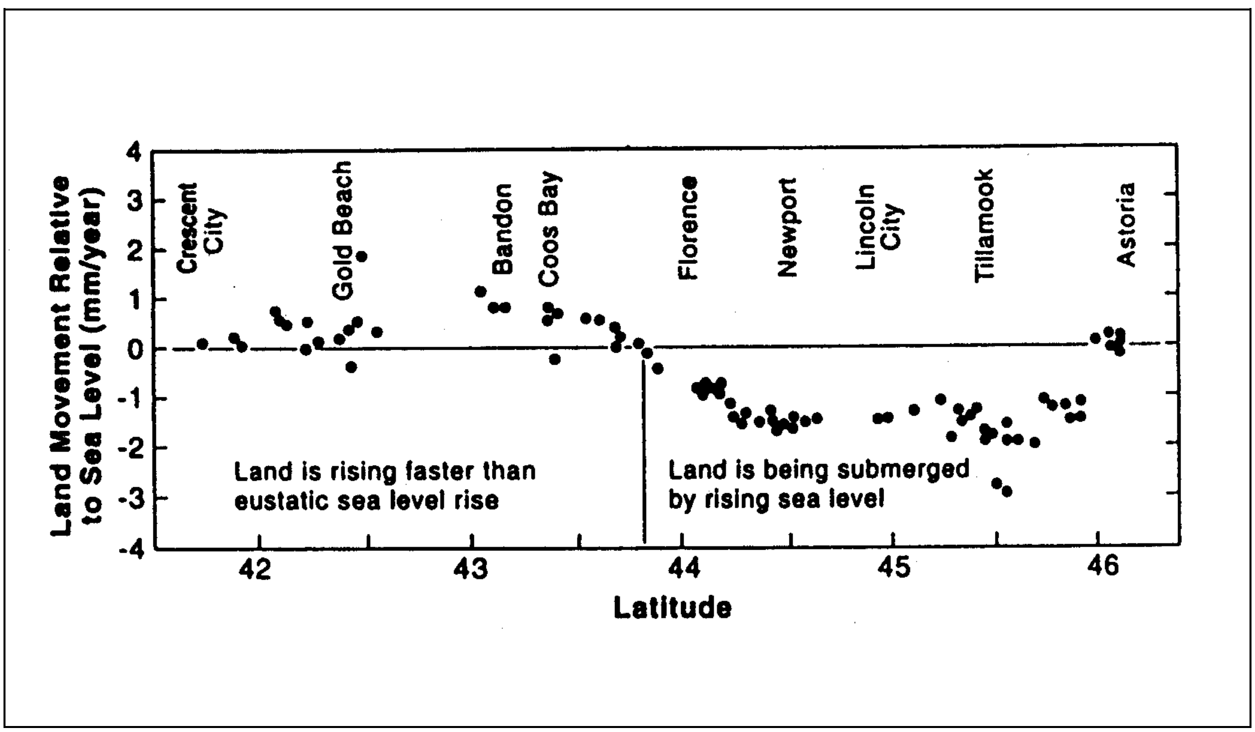


Figure A-4-11. Elevation Changes along the Length of the Oregon Coast from Crescent City in Northern California north to Astoria on the Columbia River. Derived from P. Vincent's analyses of geodetic surveys (Vincent, 1989). Elevation changes relative to the varying sea level, with positive values represeting a rise in the land realtive to the global rise in sea level, and negative values the progressive submergence of the land by the sea (1"=25 mm).

A.4.5 Tide Gauging and Tidal Datums

■ Objectives

The tides play a significant role in flooding and in the evolution and sustenance of estuarine ecosystems in the Tillamook Bay system. The objective of this assessment was to document available tide gauge data and to develop relationships between these recorded elevations and local tidal datums, which designate significant ecological zones in the estuary and tidal river reaches.

■ Methods

Tidal elevations have been monitored in Tillamook Bay very sporadically since the 1920's. Up to six tide gauges have monitored water elevations in the bay, with the gauge at Garibaldi operating with the longest continuous period of record (Figure A-4-12). Statistical data for tidal elevations for the bay are dependent on the Garibaldi gauge due to the lack of a continuous period of record for all the other gauges. The Garibaldi gauge was in operation between 1972 and 1981 and has recently been reactivated as part of a TBNEP initiative.

Monthly high and low tide elevations were obtained from NOAA for the period of record of the Garibaldi gauge. Hourly tide elevations are also available from NOAA, but these data were not used in this level of assessment. Predicted high and low tides were obtained using the nautical software Tides and Currents, version 2.5. This software provides summaries of astronomical tides. The gauged monthly high tides and astronomical monthly high tides were compared (Figure A-4-13) to assess the magnitude and trend in differences between predicted and actual tide elevations. Predicted tide elevations were selected for those dates and times most closely matching the date and time of the gauged high tide.

Monthly high tide data were also plotted against estimated tidal stillwater elevations and the MHHW and MLLW tidal datums to assess the relationship of recorded tidal elevations to these estimated values. These tidal datums represent the average height of the high and low tides observed over a specific time interval.

Guidelines for the restoration of estuarine systems in the Pacific Northwest have been developed related to landscape principles. Two approaches consider the habitat requirements of birds and juvenile salmon (Shreffler and Thom, 1993). An example of the feeding guilds of waterbirds is shown in Figure A-4-15, related to tidal datums. Habitat zones for waterbirds are determined by elevation, tidal inundation frequency, salinity and sediment conditions, which determine the arrangement of intertidal food organisms.

■ Discussion

As expected, gauged tidal elevations are typically higher than predicted values (Figure A-4-13). Elevation differences range from 3.7 feet to zero. Gauged tides have been lower than predicted tides sporadically, but in no instance have the monthly high tides been lower than the MHHW tidal datum.

In Tillamook Bay, discrepancies between predicted and recorded tides at Garibaldi may also be attributed to navigation improvements at the bay entrance and channel that possibly affect the tidal response of the bay (Levesque, 1980).

Tides may be higher than predicted because of the effects of offshore winds, resulting in an increase in sea level known as a storm surge. Along low-lying coasts, where movement of water is restricted by land, increases in local sea level may be several feet or more. Local residents of Tillamook have observed that certain wind patterns can increase flood waters by two feet. (This paragraph inserted into original manuscript by Fish and Wildlife Service staff in response to public comment.)

The normal tidal range within the approximately 9,000 acre bay is about 7.5 feet with this range attenuated to about 5.2 feet at the southern end of the bay, the farthest location from the channel entrance. Diurnal tide extremes of up to 13.5 feet MLLW have been recorded, with a highest observed mean tide at the Garibaldi gauge of 14 feet, MLLW (Levesque, 1980). Although the ecological focus of floodplain and tide marsh restoration tends to be on salmon, consideration should also be given to habitat changes for other species, such as waterbirds. The use of tidal datums in restoration planning can provide a common basis from which to compare estuarine habitats and multiple species benefits.

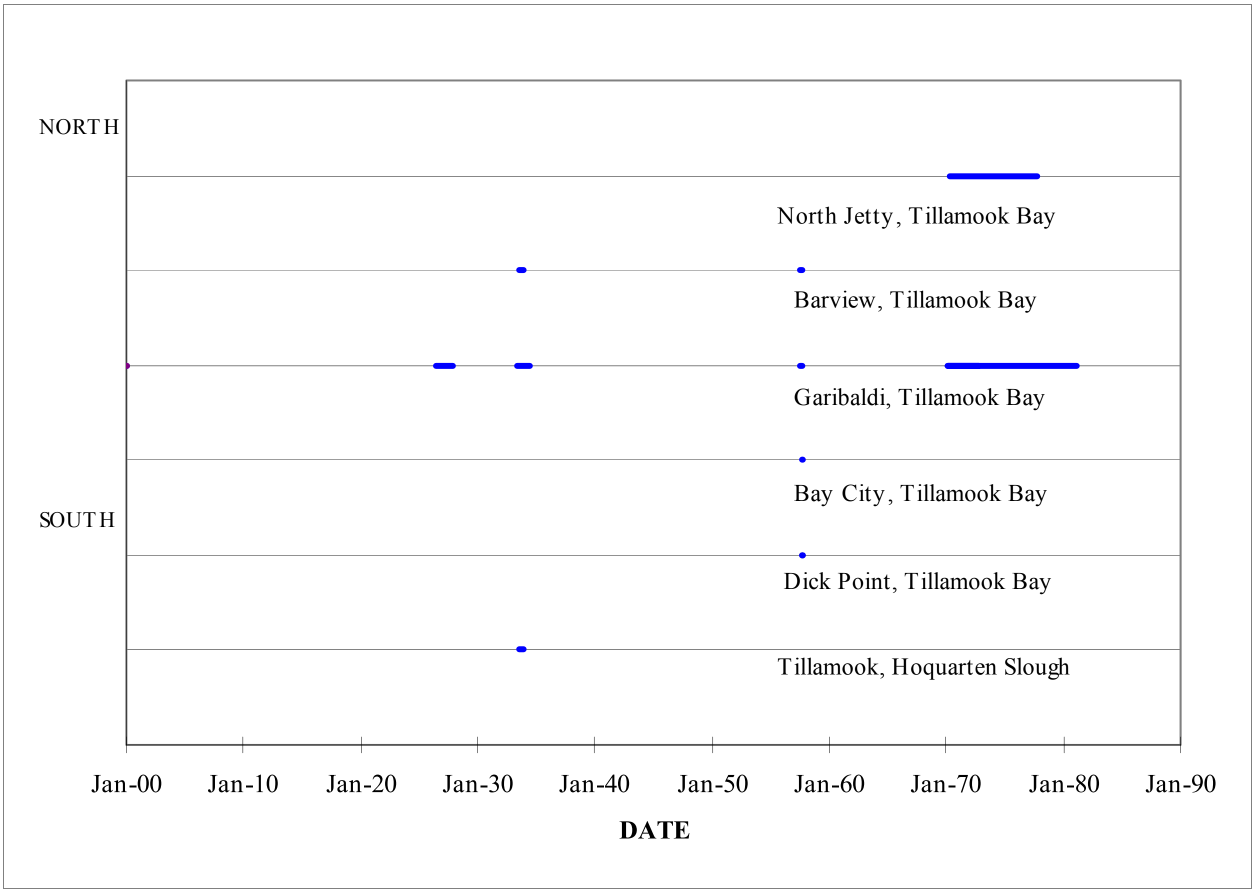


Figure A-4-12. Periods of Record for Tide Gauges in Tillamook Bay

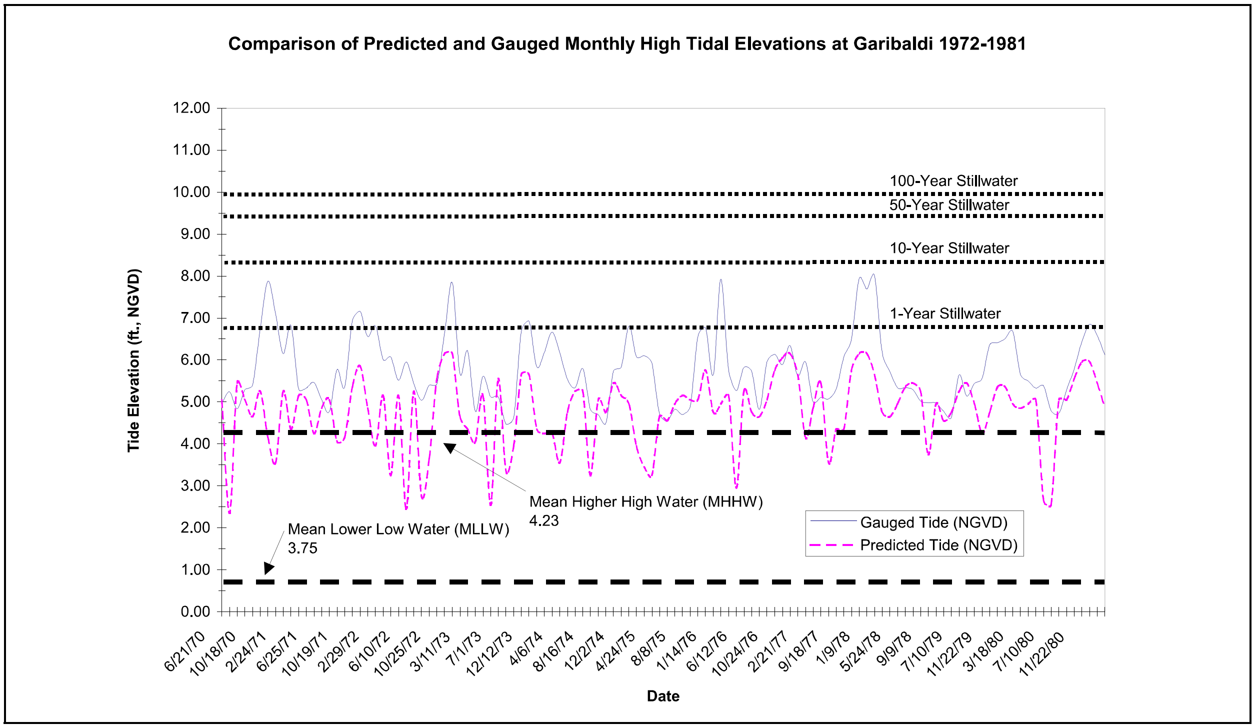


Figure A-4-13. Comparison of Predicted and Gauged Monthly High Tidal Elevations at Garibaldi 1982-1981

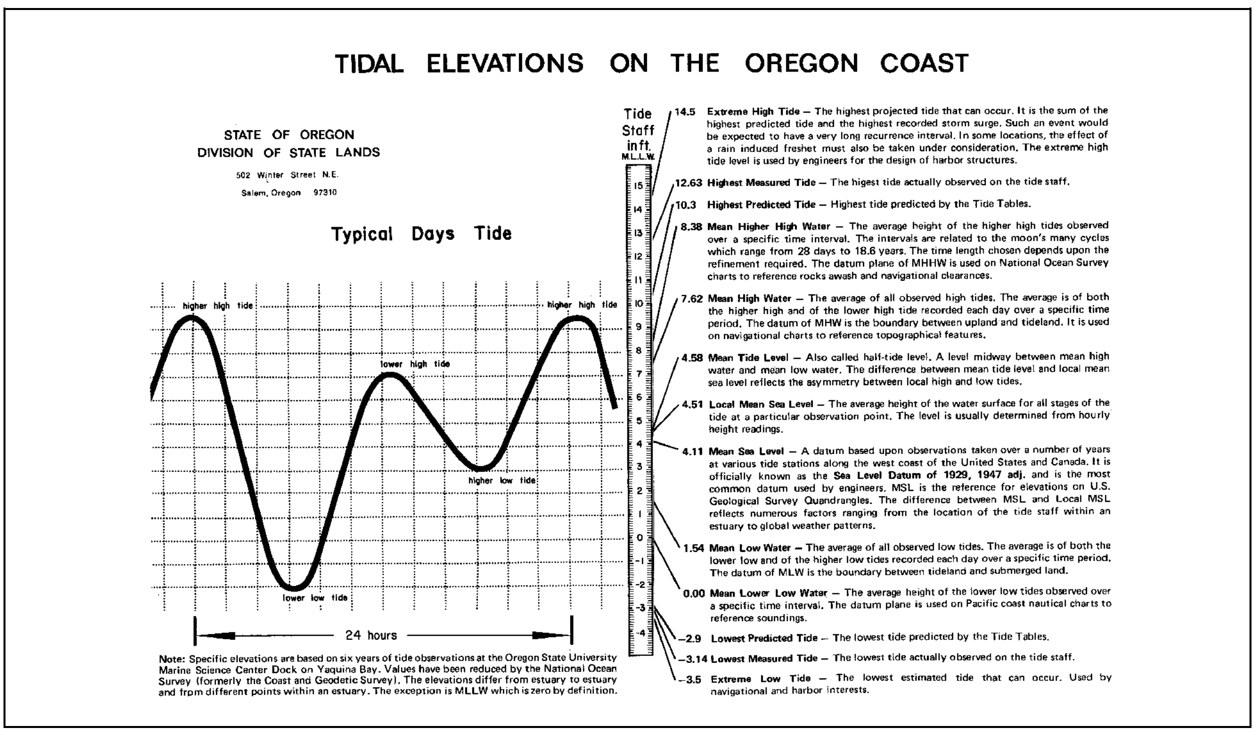


Figure A-4-14. Tidal Elevations on the Oregon Coast Source: ODSL, 1973

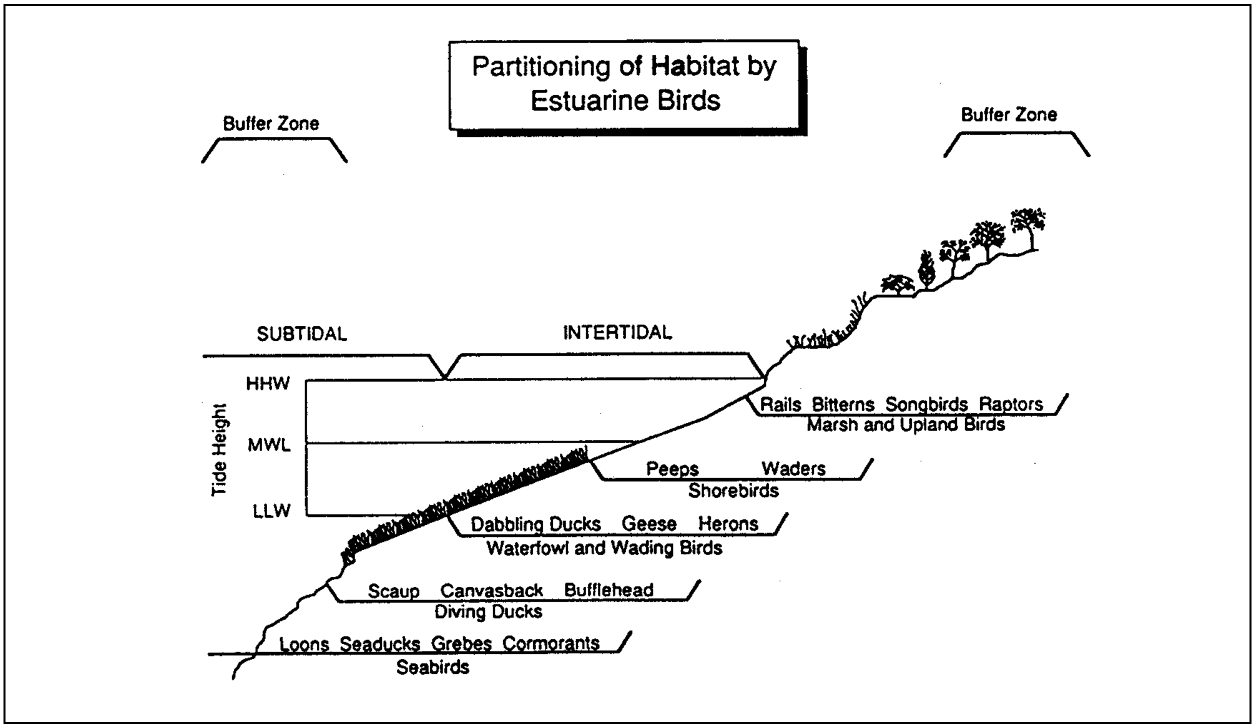


Figure A-4-15. Partitioning of Habitat by Estuarine Birds According to Group-Specific Feeding Requirements Source: Shrettler, 1992

A.4.6 Stillwater Elevations & Coastal Flooding

▪ Objectives

The most significant flooding in Tillamook Bay and the river floodplains occurs when peak river flooding occurs in conjunction with tidal flooding (Levesque, 1980). The objective of this assessment is to develop an understanding for the elevation and spatial extent of extreme tidal water levels—stillwater elevations—that cause or contribute to lowland valley flood effects. This information can be used to guide river management strategies within the area of influence of extreme tidal action.

▪ Methods

Astronomical tides, or the predicted tides published in tide tables and charts, are exceeded during tidal flooding events due to storm surges. A storm surge is a rise in the local ocean water level caused by the landward progression of a low barometric pressure zone which literally "lifts" the water surface above normal levels, or by the effect of strong winds "piling up" water in shallow coastal estuaries like Tillamook Bay, or by a combination of the two effects.

Stillwater elevations represent the combined effects of astronomical tide and water level rise from storm surges. Estimates of extreme stillwater elevations for the north Oregon coast are available from published FEMA coastal flood insurance studies for Oregon coastal communities participating in the National Flood Insurance Program (NFIP). Figure A-4-16 provides a comparison of return period stillwater elevations from various flood studies along the North Oregon Coast, including Tillamook Bay (Garibaldi). The spatial extent of flooding in the lowland valley from the Tillamook Bay 100-year stillwater elevation (Figure A-4-17) was estimated by mapping the 10-foot elevation contour on a 10-meter DEM obtained from the USGS. The DEM provides a digital representation of the USGS 7.5 minute quadrangle maps at a 10-meter grid cell resolution.

▪ Discussion

Stillwater elevations for Astoria are lower than those for Garibaldi, possibly because the seaward flow of water from the Columbia River has a dampening effect on the landward movement of storm surges. The tidal stillwater limits shown in Figure A-4-17 should be used only for general planning purposes to define the extent of coastal flooding, because topographic data from the DEM is not highly accurate and does not include local topographic features, such as dikes and levees, that would control the extent of stillwater flooding. Land patterns and upstream extent of inundation is readily apparent. The portion of the 100-year stillwater inundation area in the southern lowland valley is an indicator of where flood problems may be attributed to a large degree to coastal flood effects alone.

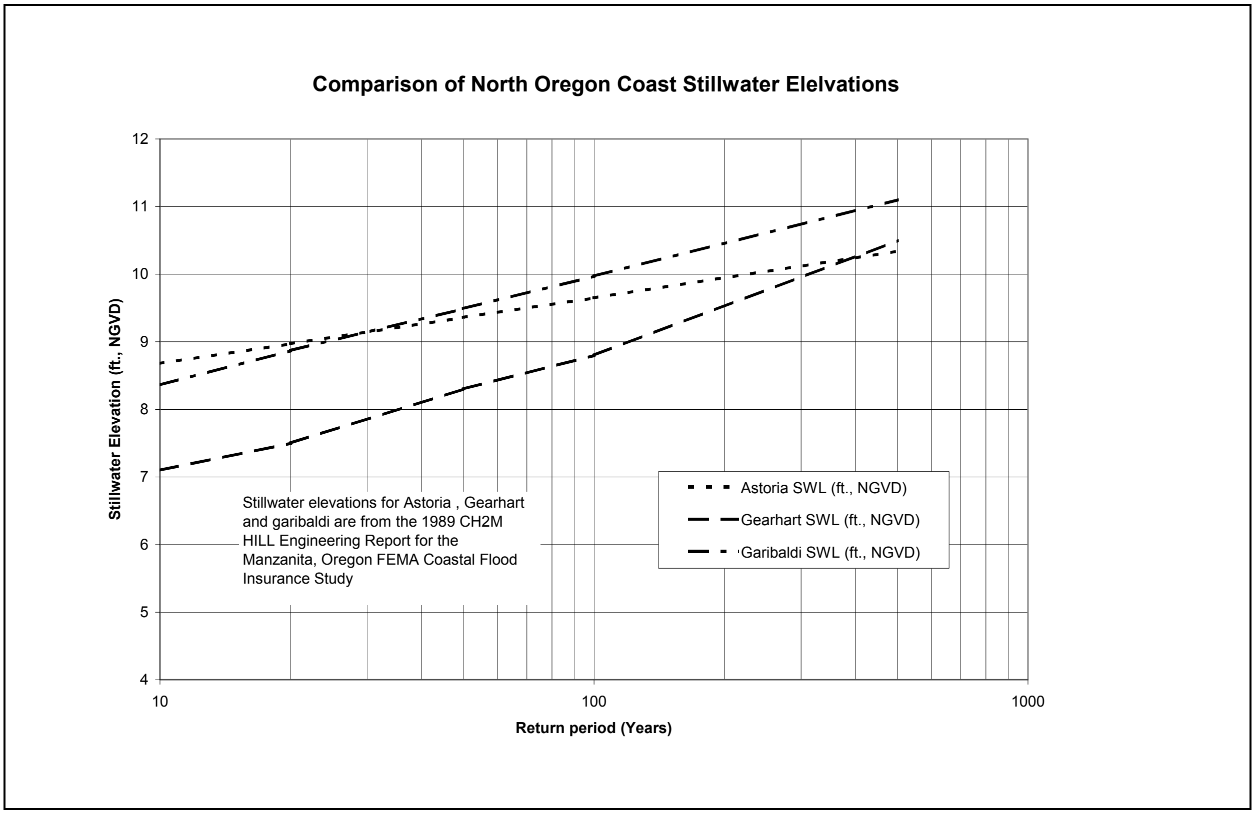


Figure A-4-16. Comparison of Garibaldi Stillwater Elevations with other North Oregon Coast Data

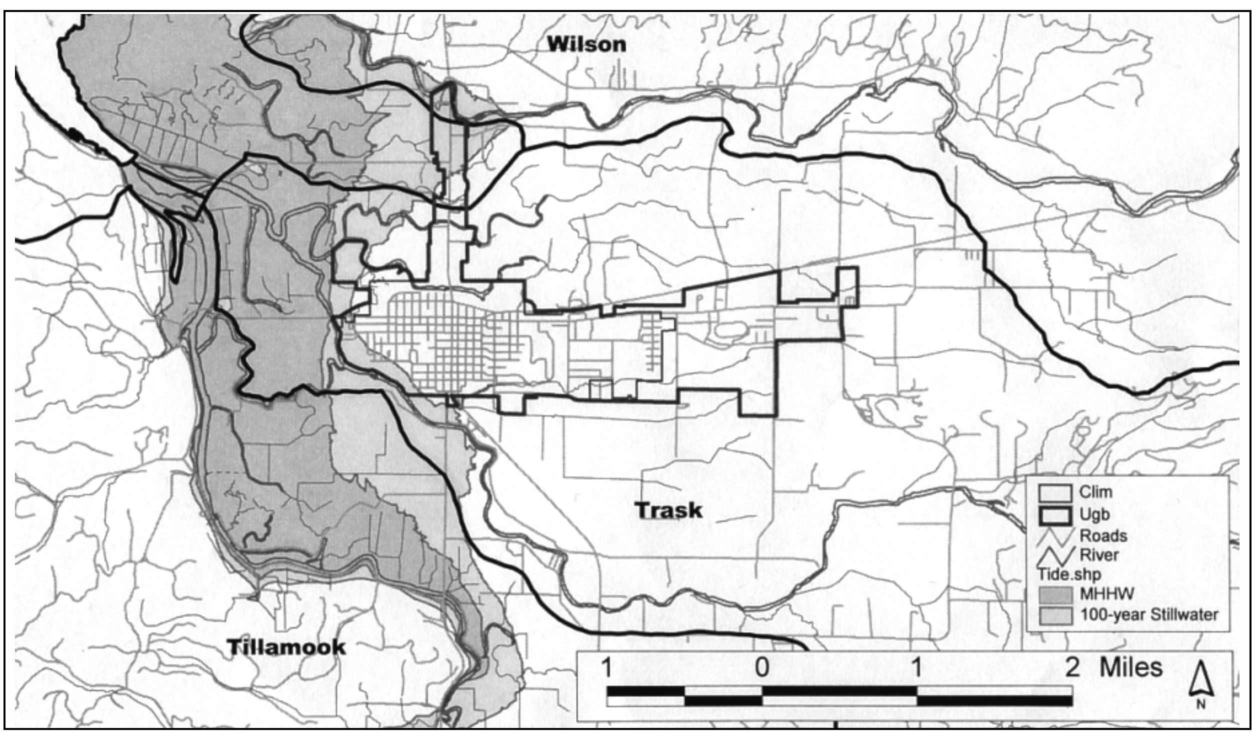


Figure A-4-17. Extent of Extreme 100-Year Tidal Stillwater on the South Tillamook Bay Lowland Valley

A.4.7 Tidal Prism Relationships

▪ Objectives

Tidal prism refers to the volume of water contained between the tidal datum planes of Mean Higher High Water (MHHW) and Mean Lower Low Water (MLLW) for a given area, such as Tillamook Bay. It represents the volume of water that is exchanged during the typical half-day tide cycle. The ebb and flood movement of this volume of water provides energy to the estuary system, producing significant forces that shape the morphology of bay entrance channels--the hydraulic connection to the ocean--and tidal slough channels--the inland expression of the estuary system on the lowland valley floor. The objective of this assessment is to establish the importance of tidal prism in the management and restoration of estuary systems, and to show the relationships between tidal prism and morphological features of the estuary system.

▪ Methods

Available information on tidal prism relationships pertinent to Tillamook Bay were collected to provide background for the development of management strategies for the estuary system. Figure A-4-18 provides a schematic depiction of a tidal prism volume and its relationship to the area of a bay entrance channel below mean sea level (MSL). The relationship between tidal prism and bay entrance channel area is further illustrated for the major Pacific Coast bays, including Tillamook Bay, in Figure A-4-19.

The tidal prism relationship to channel area and hydraulic depth (channel area divided by width) is shown for three Oregon estuaries (not including Tillamook Bay) in Figures A-4-20 and A-4-21.

Tidal prism relationships to slough channel morphology and marsh areas are not available for the Tillamook Bay estuary system. However, these data have been developed for estuary systems in the San Francisco Bay area and are presented in Figures A-4-22 through A-4-23 for reference. Tidal prism relationships to marsh area and slough channel width are useful for restoration design because these parameters can be readily determined from aerial photographs and maps.

▪ Discussion

Tillamook Bay has a relatively large tidal prism compared to other bays on the Oregon coast (Figure A-4-19). Figures A-4-20 and A-4-21 show trends in increasing channel depth and area, respectively, for increasing values of tidal prism. These data could be consulted if estuary management actions involve modifications to tidally-influenced channels. Modifications to channel areas and depths that fit the relationships shown may be more sustainable in the long term because the modified channel dimensions would conform to a naturally-occurring and self-correcting shape. Similarly, the design of management actions to modify or restore tidal slough channels (Figures A-4-22 and A-4-23) could use the general relationships developed for California slough channels as a guide, until a similar data set is prepared for Tillamook Bay or Oregon estuaries.

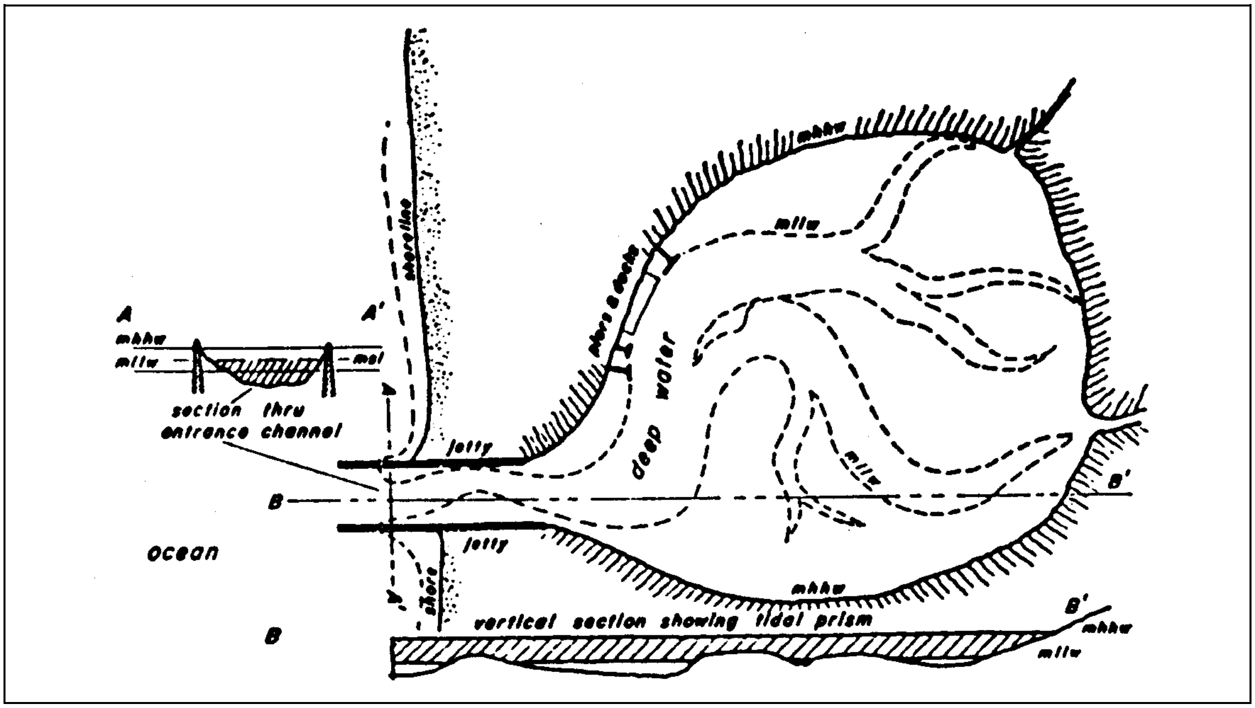


Figure A-4-18. Bay Harbor Showing Tidal Prism the volume of water between (MHHW and MLLW Source: Bascom, 1964)

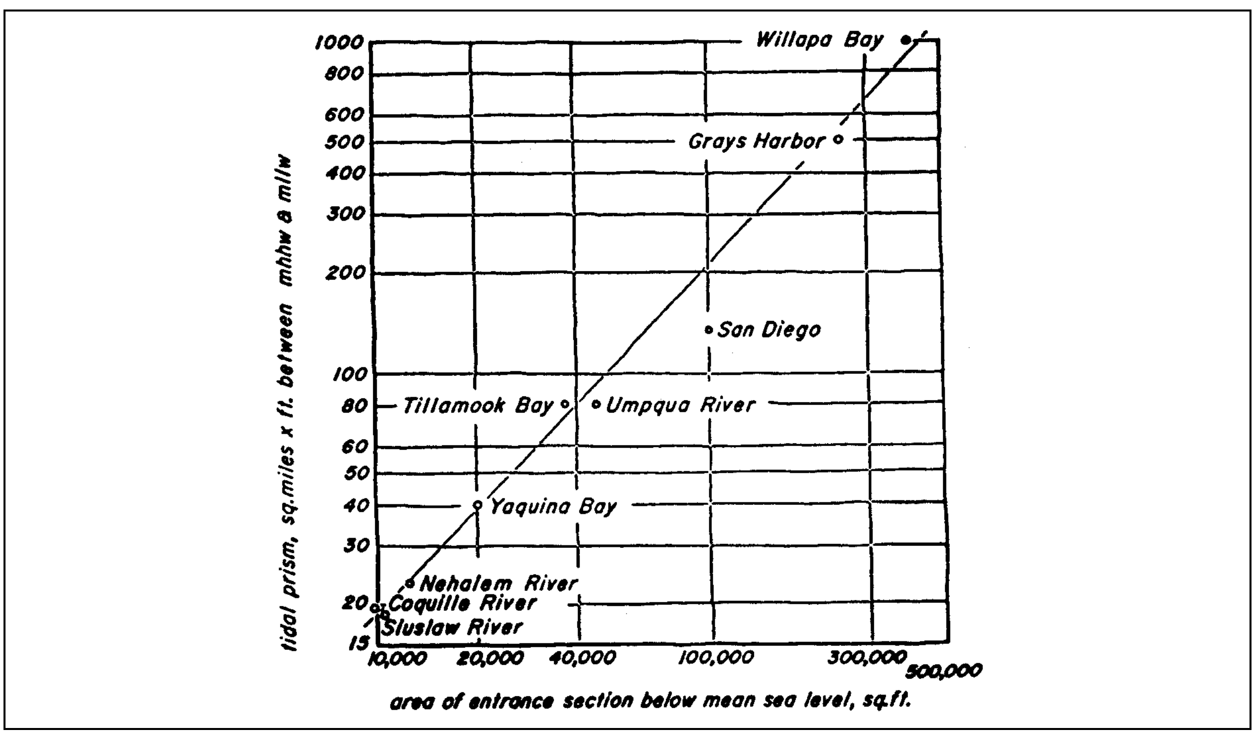


Figure A-4-19. Relationship Between Tidal Prism and Entrance Section Source: Bascom, 1964

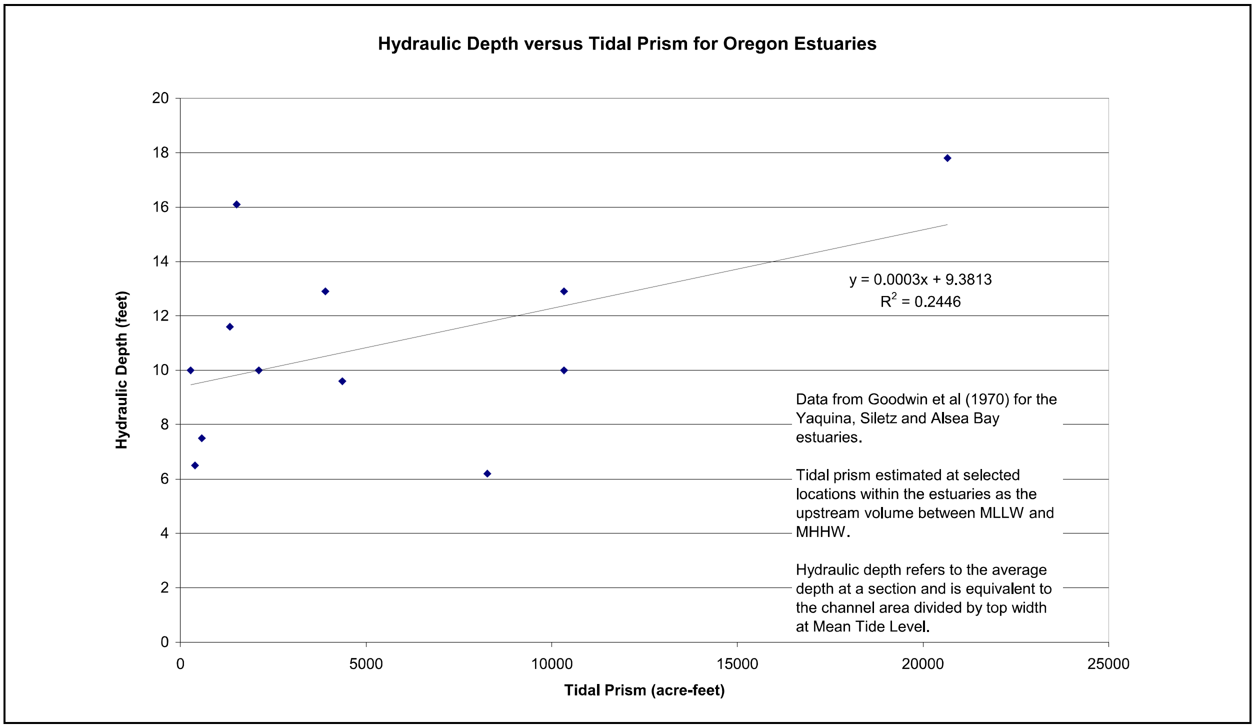


Figure A-4-20. Tidal Prism versus Hydraulic Depth for Oregon Estuaries

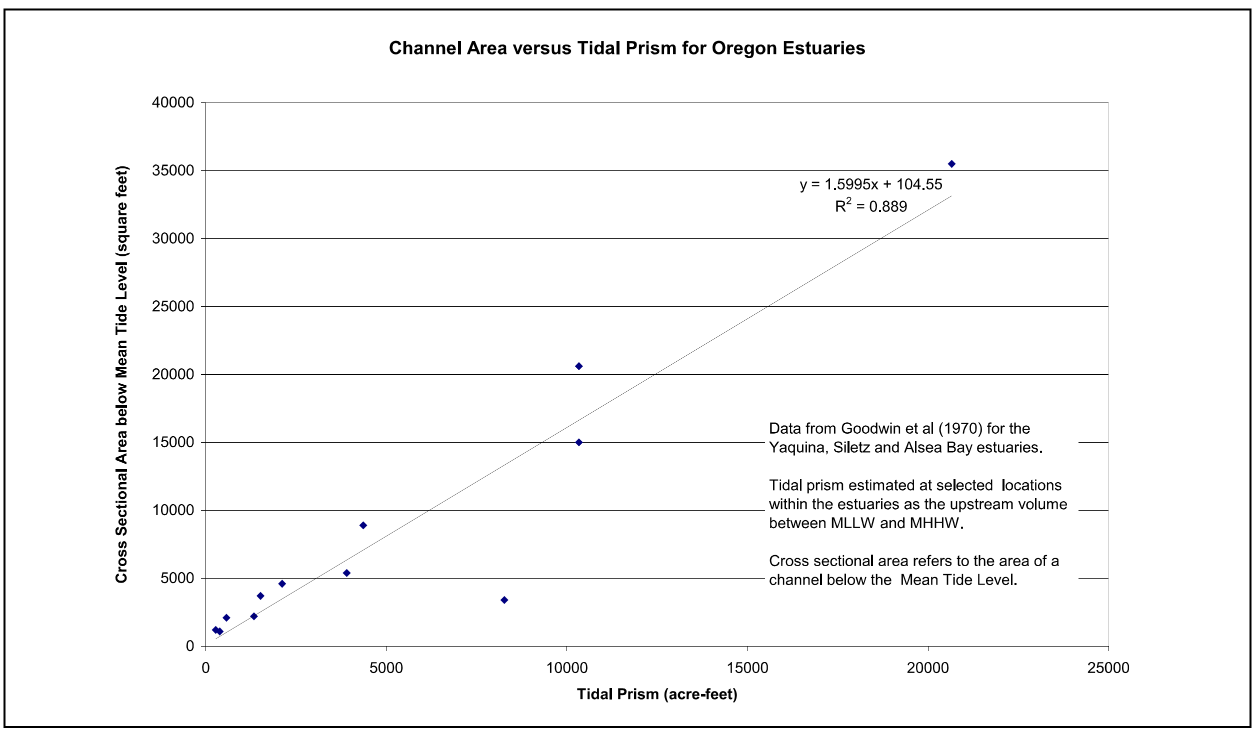


Figure A-4-21. Tidal Prism versus Channel Area for Oregon Estuaries

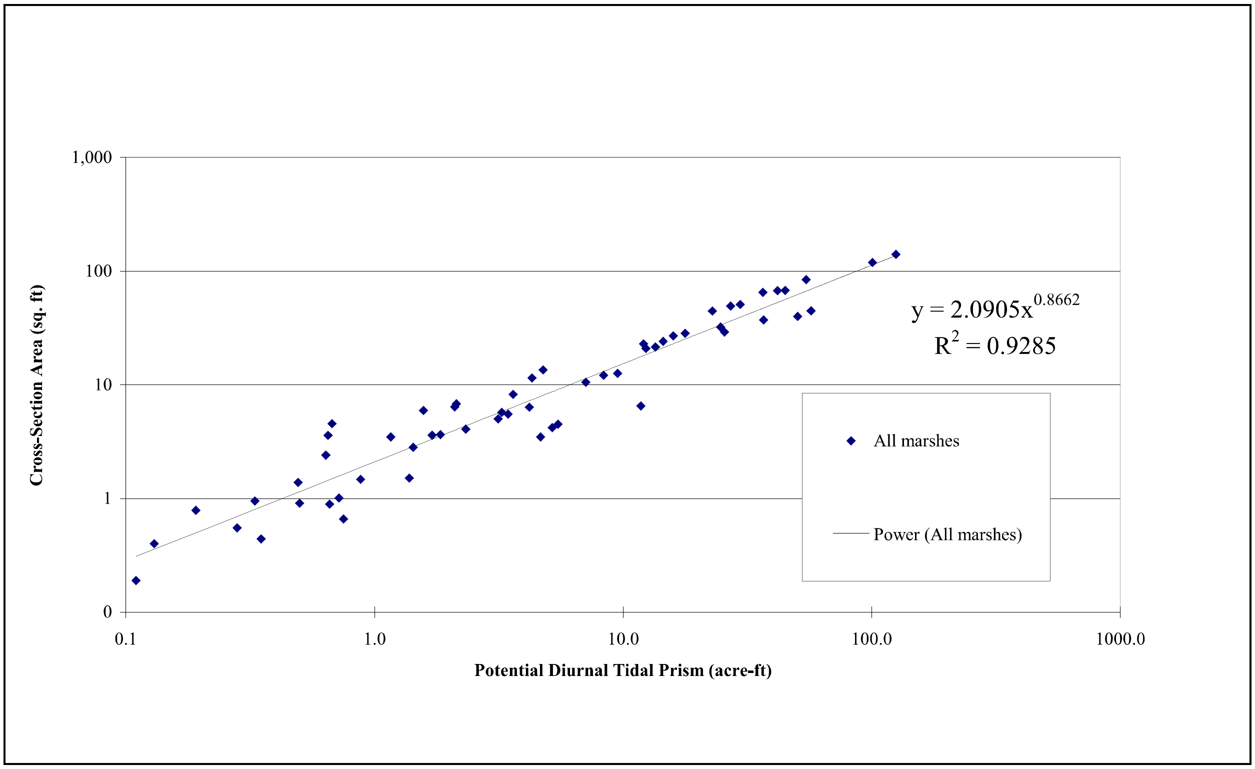


Figure A-4-22. Tidal Prism versus Marsh Area in Tidal Sloughs Source:Coats et al., 1995

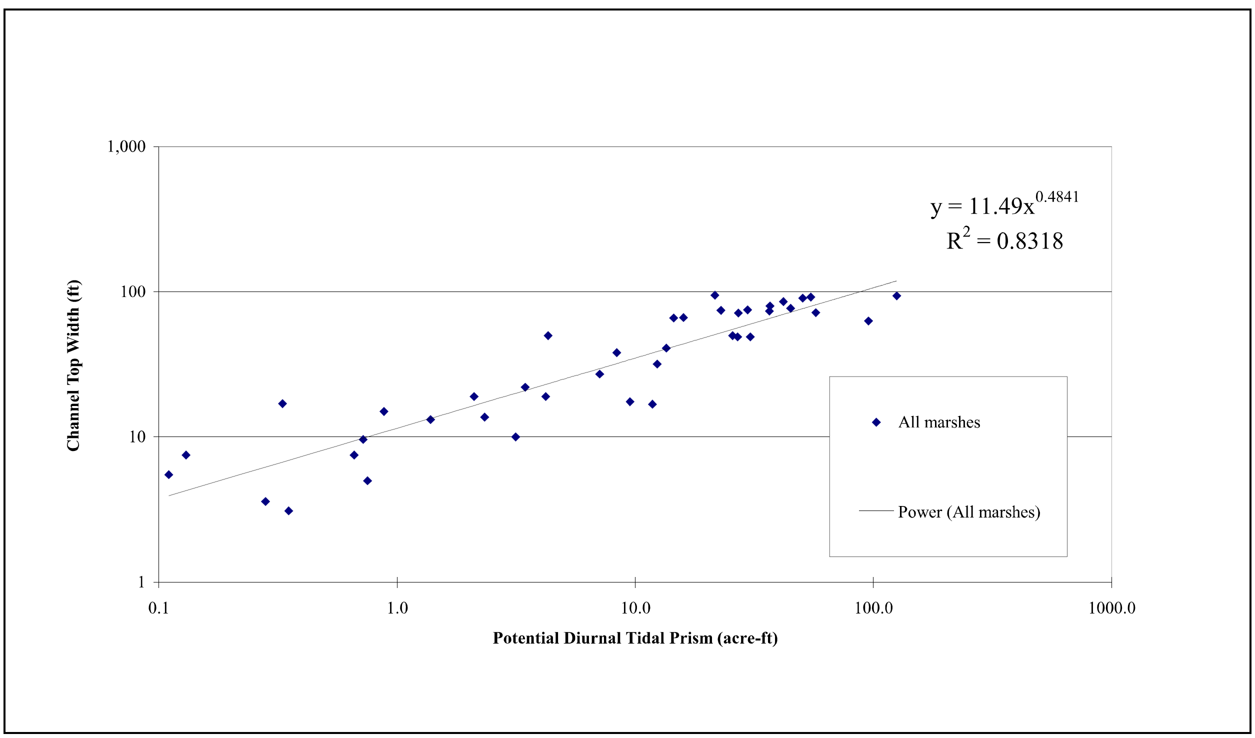


Figure A-4-23. Channel Top Width versus Tidal Prism in Tidal Sloughs Source: Coats et al., 1995

A.4.8 Tidal River Reach Assessment

■ Objectives

The preservation of tidal flows is important for maintaining water quality, protecting the stability of tidal channels, and sustaining tidal wetlands throughout the lowlands. Tidally-influenced areas are essential parts of the complete ecosystem of Tillamook Bay, providing habitat, refuge and rearing for several key species of fish and wildlife. Tidal influences in the lowland river reaches include tidal effects on water levels, as well as water quality effects due to salinity. The objective of this assessment is to define the spatial extent of tidal influences and to explore the relationship of these influences to a river management strategy.

■ Methods

'Head of tide' is a colloquial expression for the furthest inland extent of tidal influence on river water surface elevation. The heads of tide for each of the five major rivers entering Tillamook Bay were identified from the Oregon Water Resources Department North Coast Basin map (Oregon Water Resources Department, 1992). Figure A-4-24 shows the heads of tide for the Wilson and Trask Rivers.

The variation of salinity in lowland river reaches results, in large part, from the characteristics of flood tide (inland flow) and ebb tide (seaward flow), combined with river flow. During any given flood tide, the water entering an estuary is composed of a mixture of 'new' ocean water, and water which exited the estuary during the previous ebb tide and is now re-entering. This tidal exchange governs the overall flux of salinity and nutrients into and out of the river reaches and adjacent floodplain wetlands, but the distribution and concentration of salinity is strongly influenced by the mixing processes that take place throughout the system. Winds, waves, tides, and freshwater flows all contribute to the mixing of waters and help to distribute salinity within the lowland river system.

General aquatic subsystems have been defined for Oregon estuaries (Division of State Lands, 1984). In the lower reaches of the rivers, the division between brackish and freshwater subsystems has been generally located as shown in Figure A-4-25 for the Wilson and Trask Rivers. The brackish subsystem is defined as having summer water salinities of 0.5 to 15 parts per thousand, compared to 0.0 to 0.5 parts per thousand for the freshwater subsystem (Division of State Lands, 1984).

Freshwater inflow to an estuary system provides another mixing mechanism and is a key component in estimating the boundaries of different plant community types. In addition to adding a continuously discharging flow component, freshwater flow may create density differences which result in stratification of the water column. A salt wedge may be formed which moves back and forth in the estuary with changes in tide (Figure A-4-25), while turbulence at the interface produces mixing between the two layers. The mixing power produced by the tide depends on the density difference, the tidal velocity, the freshwater inflow and the estuary morphology, and in turn determines the density stratification which will be present in the estuary (Fischer et al., 1979). The degree of density stratification, in turn, dictates whether density-driven currents will significantly influence flows within the lowland river system. If stratification exists in the river channels and tributary sloughs, it is the lower-salinity water at the surface that flows out of the river channels and across the floodplain first, resulting in lower salinities than if the flows were fully mixed. This may be an important process if there is concern about maintaining a particular salinity range to favor or discourage certain types of plant communities.

Tillamook Bay is classified as a partially-mixed estuary (Fischer, 1989), where river flow discharges against a moderate tidal range (The Open University, 1989). Mixing of the water column is induced by turbulence created at the saltwater-freshwater interface and by friction along the bed of the bay and river channels. Additional mixing processes occur through wind and through circulation patterns in the Bay and tidal channels. A detailed description of these processes is provided in the literature, for example Fischer *et al.*, 1979, or the Open University, 1989. An illustration of water velocities and salinity concentrations in a typical partially-mixed estuary is shown in Figure A-4-25. This figure also illustrates one reason for maintaining the natural geomorphic characteristics of tidal channels. If levees are constructed adjacent to the channels, or if the marshplain is filled, the flows over the marshplain may divert only surface waters, which will be fresh under stratified conditions. Under a different channel cross-section, the high tide may allow a mixture of fresh and saline water to flow across the marshplain. Thus, salinity structure and mixing processes are complex, influenced by river discharges, tidal flows, geomorphic characteristics of the tidal channel, and dominant physical processes. Prediction of hydroperiod and salinity in tidal channels and wetlands requires monitoring and/or the use of computer models.

■ Discussion

The significance and continuing loss of tidal wetlands in the western states has been well documented (Cowardin et al., 1979, Salveson, 1990 and Fretwell et al., 1996). The importance of taking a long-term planning perspective of tidal wetland preservation can be seen when considering the effects of sea-level rise (Houghton et al., 1990). The natural response of tidal wetlands to a sea-level rise would be to gradually migrate inland (French et al., 1995; Nuttle et al., 1997). However, if tidal channels have levees at their banks, there is no room for tidal vegetation zones to retreat. Further, the depth of the tidal channel cross-sections would be expected to gradually increase over time, resulting in bank stability problems. Planning to allow a buffer adjacent to tidal channels would therefore avoid channel stability problems and maintain some minimum acreage of intertidal habitat.

The tidally-influenced areas of the Tillamook Bay tributaries are the most dramatically diminished habitat type in the Tillamook watershed. These areas provide critical rearing and refuge habitat to several ESA-listed fish, and other organisms essential to the sustainability of the ecosystem. Functioning properly, they are likely to produce the most biomass per unit area (Tiner et al., 1984) of the entire basin, and form an important ecological link.

These tidally-influenced areas also correspond with some of the most expensive flood damages and channel protection activities, and highest revenue generated per unit area, in the basin. Restoration of these areas could provide several key flood reduction benefits for the people of Tillamook County, including:

- Diffusion of flood flow energy
- Reduction of wave action against levees and banks with the use of shallow vegetated buffers
- Improvement of water quality by removing nutrients and fine sediments

These tidally-influenced areas should therefore be prioritized for implementation of the IRMS, for both ecological and economic reasons.

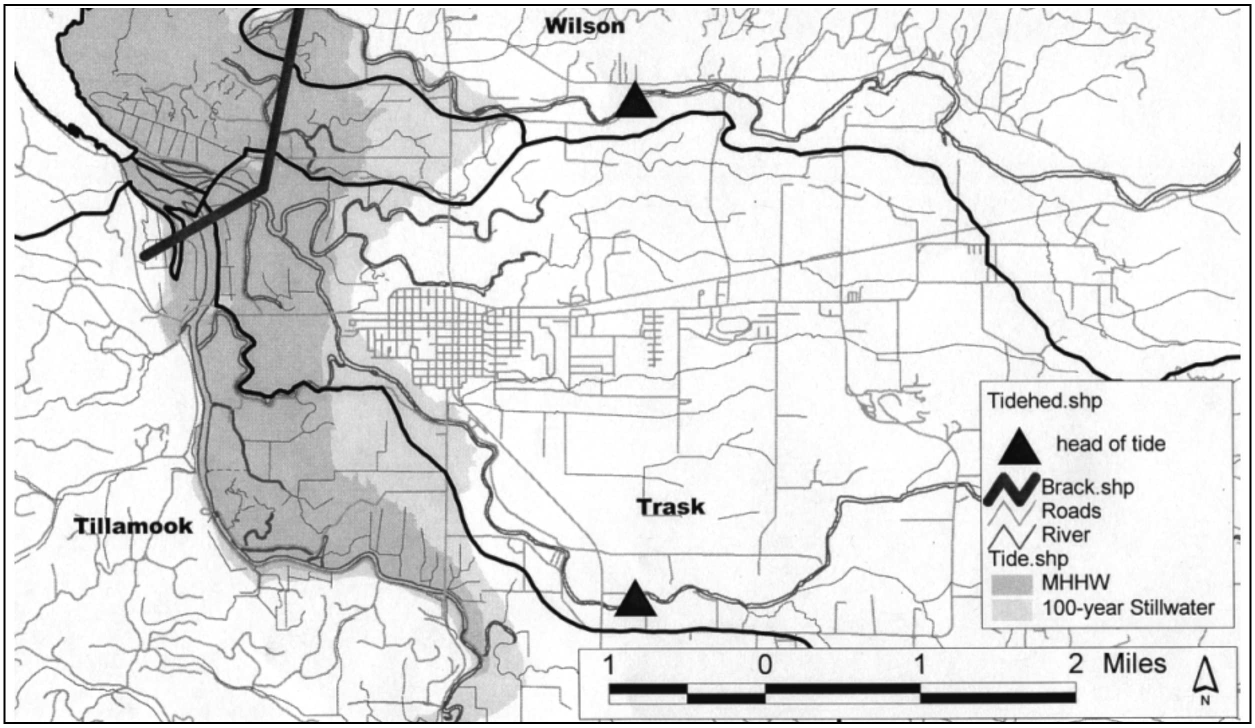


Figure A-4-24. Tillamook Bay Lowland Valley Heads of Tides and Brackish/Freshwater Interfaces

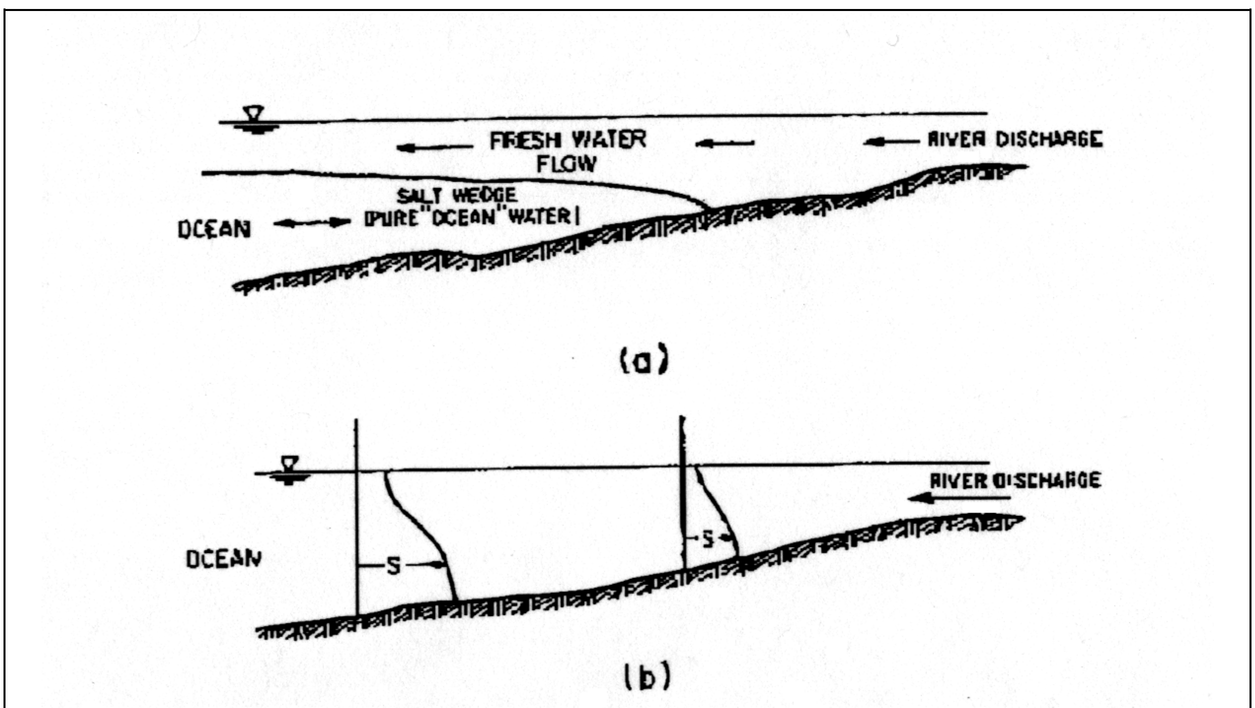


Figure A-4-25. Salinity distributions in (a) a "salt wedge" estuary and (b) a "partially mixed" estuary

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A.5 Vegetation

The extent and growth of vegetation is dependent upon the interaction between land and water. Because of this interdependence, vegetative communities are often associated with specific types of physical processes. In this way, vegetation is an indicator of potential past and present river and tidal processes, and can be used to identify areas where those processes can be preserved or enhanced. In addition, the presence or absence of certain plant communities can guide decisions about what processes to preserve or enhance at a given location. This section describes vegetation zones in the Tillamook Basin, including the uplands, lowland valley floodplains, riparian areas, and tidal marshes. Historic forest and riparian conditions are reviewed, and characteristics of the large wood in lowlands are assessed.

A.5.1 Vegetation Zones of Tillamook Basin: Upland, Valley and Estuary

▪ Objective

Using vegetation to coarsely categorize the landscape into zones provides a framework for understanding the processes at work in each zone, and for making spatially-specific planning-level recommendations. The objective of this assessment was to delineate the major plant communities in the Tillamook Bay Basin and assess the relative importance of the communities to fish and wildlife habitats.

▪ Method

Written and mapped data were integrated to define meaningful delineations among the major vegetative communities in the Tillamook basin using GIS. The zones were designed to represent a correlation between vegetative community, slope, and the extent and duration of inundation by either fresh or salt water. In each instance, the zone represents a maximum spatial extent for each community (Figure A-5-1).

▪ Discussion

Two major upland vegetation zones occur in the Tillamook Bay Basin: the Sitka spruce (*Picea sitchensis*) forest zone and western hemlock (*Tsuga heterophylla*) forest zone. The Sitka spruce forest zone extends a few miles inland within the zone of tidal influence, and up the major river valleys to an elevation of about 500 feet (Franklin & Dyrness, 1988). The most common trees in this forest zone are Sitka spruce, western hemlock, Douglas fir (*Pseudotsuga manziesii*) western red-cedar (*Thuja plicata*), and red alder (*Alnus rubra*) (Franklin & Dyrness, 1988).

The western hemlock forest zone tolerates a mild, maritime climate, with a greater tolerance range of temperature and moisture than the Sitka spruce zone. In the Tillamook Bay Basin, the western hemlock/ Douglas fir forest zone occupies most uplands above approximately 500 ft. Major tree species in this zone include Douglas fir, western hemlock and western red cedar. Dominant early seral trees include red alder and big-leaf maple (*Acer macrophyllum*). These species typically occupy the zone near the channel because of their tolerance for high water table and for flooding. A diverse understory of shrubs, herbaceous perennials, annuals and grasses is complimented by high diversity in mosses, lichens and fungi for both forest types.

Lowland valley floodplain riparian forests are characterized by western red cedar, red alder, big-leaf maple and black cottonwood (*Populus trichocarpa*) (Franklin & Dyrness, 1988). A highly diverse understory of shrubs and herbaceous perennials is featured in floodplain plant communities. Topographic variation provides distinct habitat niches according to moisture regime and groundwater levels, from former channels such as oxbows and other floodplain wetland types to natural levees and alluvial terraces. These variations are important for fish and wildlife habitat.

Estuarine plant communities are distinguished by water regime. Tillamook Bay historically contained low salt (brackish) marsh below mean high water, high salt marsh above mean high water, swamp at higher tidal elevation, and wet meadows at the saltwater/freshwater interface. Brackish marshes support herbaceous plants such as pickleweed (*Salicornia virginica*), sedges (*Carex lyngbyi*), and bulrush (*Scirpus maritimus and americanus*). High salt marsh typically includes hairgrass (*Deschampsia caespitosa*), silverweed (*Potentilla pacifica*), Baltic rush (*Juncus balticus*) and meadow barley (*Hordeum brachyantherum*). Swamps have high water table and support woody plants such as willows (*Salix spp.*), alder, Sitka spruce, Douglas spirea (*Spiraea douglassii*) and herbaceous species. Wet meadows typically support grasses, sedges, and rushes, particularly slough sedge (*Carex obnupta*) and soft rush (*Juncus effusus*). Most of these have been converted to agricultural uses.

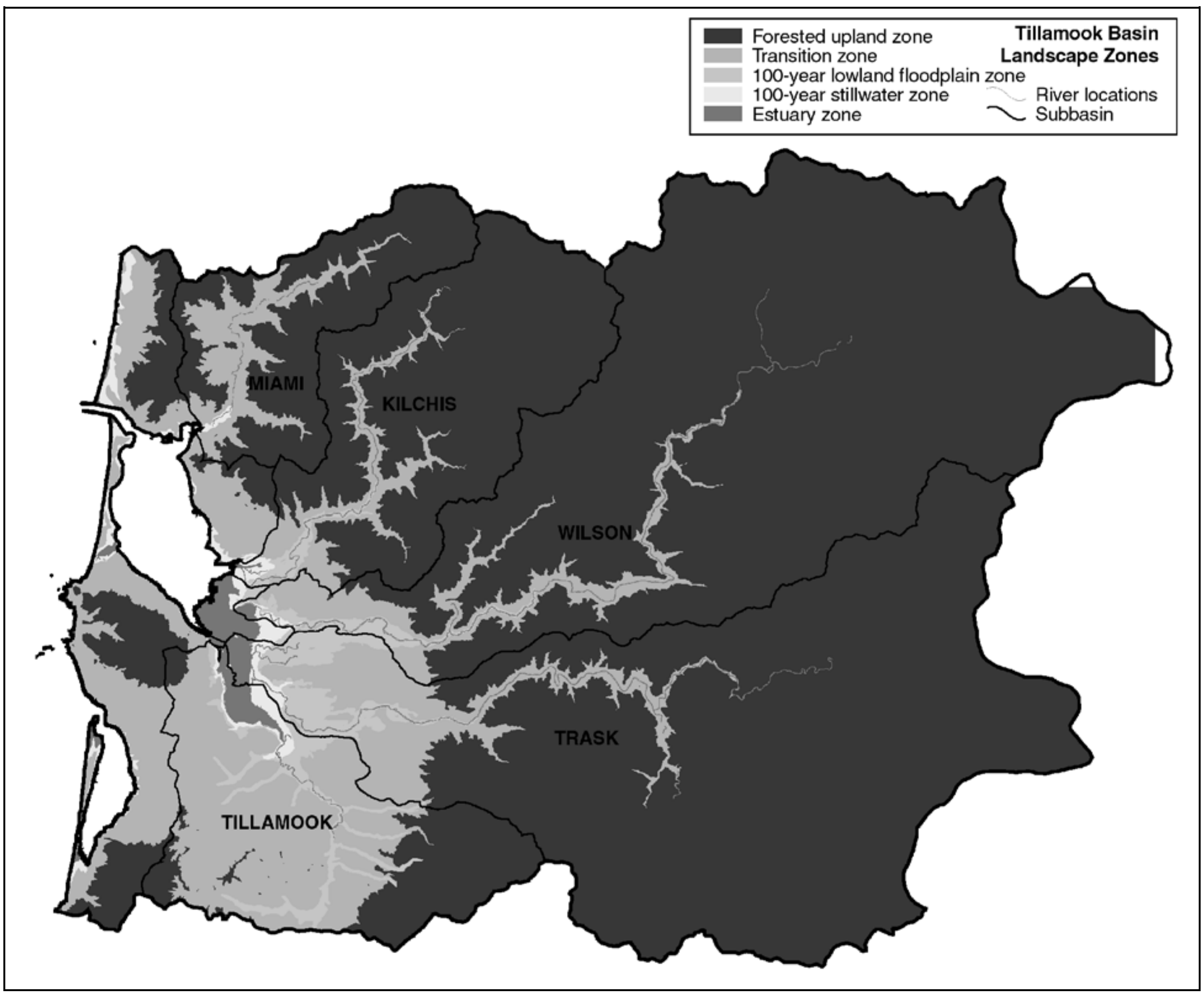


Figure A-5-1. Vegetation Zones of the Tillamook Basin

A.5.2 Upland and Lowland Forest Historic Conditions

■ Objectives

Forest stand structure is important for landscape-scale processes, because large trees buffer the impacts of storms on the upland landscape, and moderate the force and speed with which rain and stormwater are delivered to the stream network. The structure and distribution of large wood in channels plays a key role in the stability of upland streams. Therefore, large trees are critical to the stability of the upland landscape and the rates of sediment delivery to the stream network. The objective of this assessment was to review available spatial data on landscape-scale vegetation structure and distribution, with special reference to human impacts on the historic landscape.

■ Methods

Available GIS data layers for the Tillamook Basin relevant to terrestrial analysis were reviewed. Few of the available data layers were reliable for site-specific analyses, but some did provide data for larger scale landscape analyses of historic change. The resulting maps provided a basic outline of forest cover changes in the basin uplands and lowlands from the 1850s to 1992, focusing on the presence or absence of forests and the distribution of mature forest (over 100 years in age).

■ Discussion

In the 1850s the Tillamook basin uplands were almost entirely covered by mature forest. Extensive burns (Figure A-5-2) and human land use in the 1900s caused a changing mixture of mature and young forest in the uplands (Figure A-5-3) (Williams/Cushman, 1999).

In the uplands by the 1890s a non-forest area increased in the west along upland/lowland border, while the small southern area that was non-forest in 1850 closed in. By 1890, most of the basin uplands remained mature forest. In 1920, young forests encroached even further on the last remaining non-forested areas. The portions along the shore of the border area remained non-mature forests. By 1945, drastic upland landscape changes included massive fires, which burned most of the basin's forest starting in the 1920s (Figure A-5-3). Salvage logging operations began in areas affected by fires. Burned trees were seen as "wasted wood" and forests that were already damaged by fires were further devastated by salvage logging operations. By the 1950s, most of the mature forest was gone, and that which remained was in the southern portion of the basin. An area to the South and an area to the East along the border between the uplands and lowlands remained forested. By 1974-75, forests regenerated in a patchy, fragmented network. Young forests dominated the landscape with numerous small patches of mature forest throughout. In 1986, forest land cover was similar to 1974-75, and a high degree of fragmentation remained. 1992 maps showed most of the basin covered in young forest, with small patches of mature forest fragments throughout. The historic trends in upland forest cover show the dramatic reforestation that occurred in the latter half of the 1900s, as forest lands were allowed to grow back from the devasting fires. This growth potential in the uplands is encouraging for the development of timber harvest management plans that seek to balance ecological and economic interests.

Lowland forest cover maps were created only for the 1974-75 and 1986 time periods from available GIS data, and thus do not provide significant historical information (Figure A-5-3). A 20 percent coverage of the lowlands by forest in 1857 was assumed based on estimated conversion of lands to pasture at that time. The lowland estimates provide a reasonable landscape-scale view of forest cover during those periods. Unlike the uplands, it is evident that lowland forest cover has not had the opportunity to increase due to established

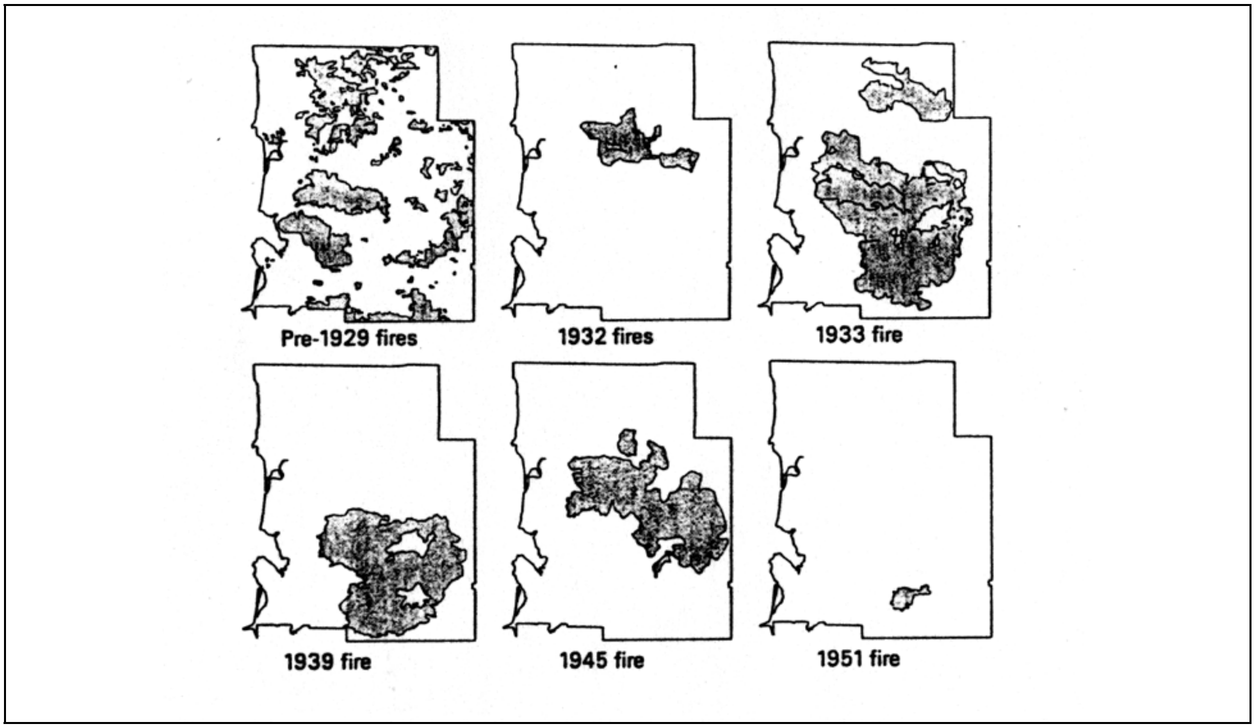


Figure A-5-2. Historic Burn Areas in Tillamook County Source: Chen, 1997

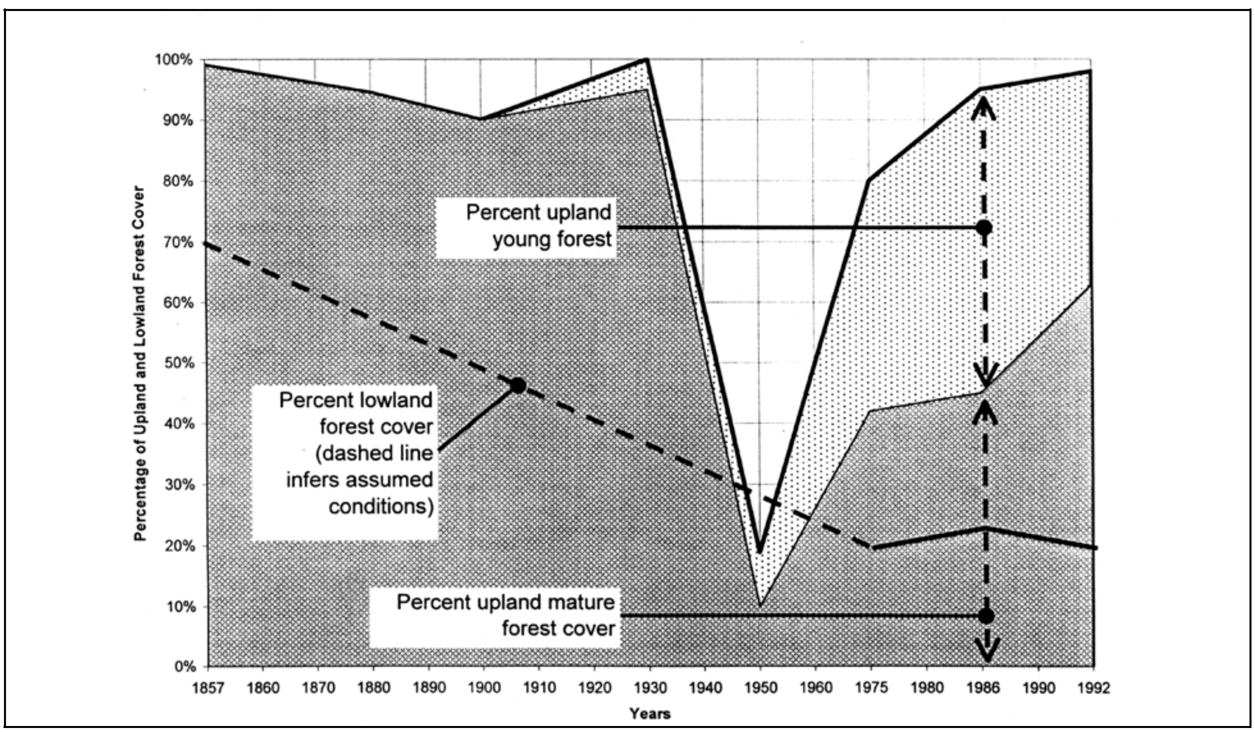


Figure A-5-3. Historic Trends in Tillamook Upland and Lowland Forest Cover

agricultural and urban land uses. Restoration and integration of riparian corridors along the lowland rivers and sloughs would add to ecological diversity in the lowlands and create fish & wildlife habitats.

In many cases, GIS data layers used in this assessment were not compatible, did not have the same resolution, or did not have the same accuracy and could not be used to analyze terrestrial ecology at less than a landscape scale. In some cases, it could not be determined if these differences occurred within a single data layer. These are typical limitations to GIS-based ecological analyses. Since the Tillamook project is potentially a pilot for such studies throughout the region, protocols should be based on methods feasible in areas where GIS data are not available.

A.5.3 Lowland Valley Floodplain Conditions, Vegetation and Large Wood

■ Objectives

The objective of this assessment was to document historic changes and recent conditions with respect to vegetation and large wood in the lowland valley channels and floodplains of the Tillamook Basin. Lowland valley forests with abundant large wood in channels were historically dominant, key elements in the hydrologic and ecological function of lowland streams in the Tillamook Bay basin. This situation has changed dramatically over the past 150 years (Coulton *et al.*, 1996; TBNEP, 1998a). Historic spatial information on these channels and floodplains provided a basis for understanding the pattern and timing of the environmental changes that have occurred. These changes are of importance because the streams, off-channel areas, wetlands, and sloughs within these lowland areas have the capacity to provide critical and highly productive habitats for salmonids and other aquatic species, if restored to better condition.

■ Methods

Three methods were used: 1) a comparison of historic and contemporary air photo data, 2) use of General Land Office (GLO) survey data (1859), and 3) a more detailed analysis of recent channel conditions from air photos. GIS data from the TBNEP were used to assess the extent of floodplain vegetation removal from the basin's lowlands since the mid-1800s. Reconstructed maps of Tillamook Bay's lowland vegetation from the 1850s (Figure A-5-4; Coulton, 1996a) were compared to maps of contemporary lowland conditions interpreted from air photos (Figure A-5-5). Historic changes in floodplain vegetation were calculated as the percent reduction in area of each natural community's extent.

The complete sets of 1953 and 1990 air photos of the basin's lowlands were assembled from the Tillamook Farm Services Administration. These were analyzed for large-scale similarities and differences at the river sub-basin scale. Based on this preliminary photo work, lowland sections of the Wilson and Miami rivers, plus the full channel networks associated with Hall and Dougherty Sloughs, were selected for further analysis. The Wilson River below the Little North Fork of the Wilson River was selected to represent the lowland mainstem reaches of the Kilchis, Wilson, and Trask subbasins that were dramatically affected by the Tillamook Burn and salvage logging. The Miami River below Prouty Creek was selected to represent lowland rivers in the Miami and Tillamook subbasins which were less affected by historic burns, but more affected by recent timber harvest activities.

Lowland channels were identified for analysis from 1939, 1953, 1967, and 1994 black-and-white air photos. The analysis measured changes in riparian forests and large woody debris in pre-selected, equally spaced 300-foot sections of both the freshwater and tidal portions of each river or slough. A total of 74 channel sections were examined in each set of photos, with at least 10 sample sections along the above-tide portion of each river or slough and a minimum of 5 (but preferably 10) within the tidal areas of each river or slough. Tidal areas were identified from maps provided by Levesque (1980). Riparian conditions for each channel section and period were classified in terms of forest canopy (dense [>67%], sparse, or none), forest continuity (continuous, discontinuous, or absent), and forested width (>150 ft, 30-150 ft, <30 ft, or none). These classes were subsequently aggregated into a smaller number of categories to simplify the analysis. Individual pieces and clusters of large woody debris visible in the air photos were counted and recorded for each 300-ft section of channel and time period.

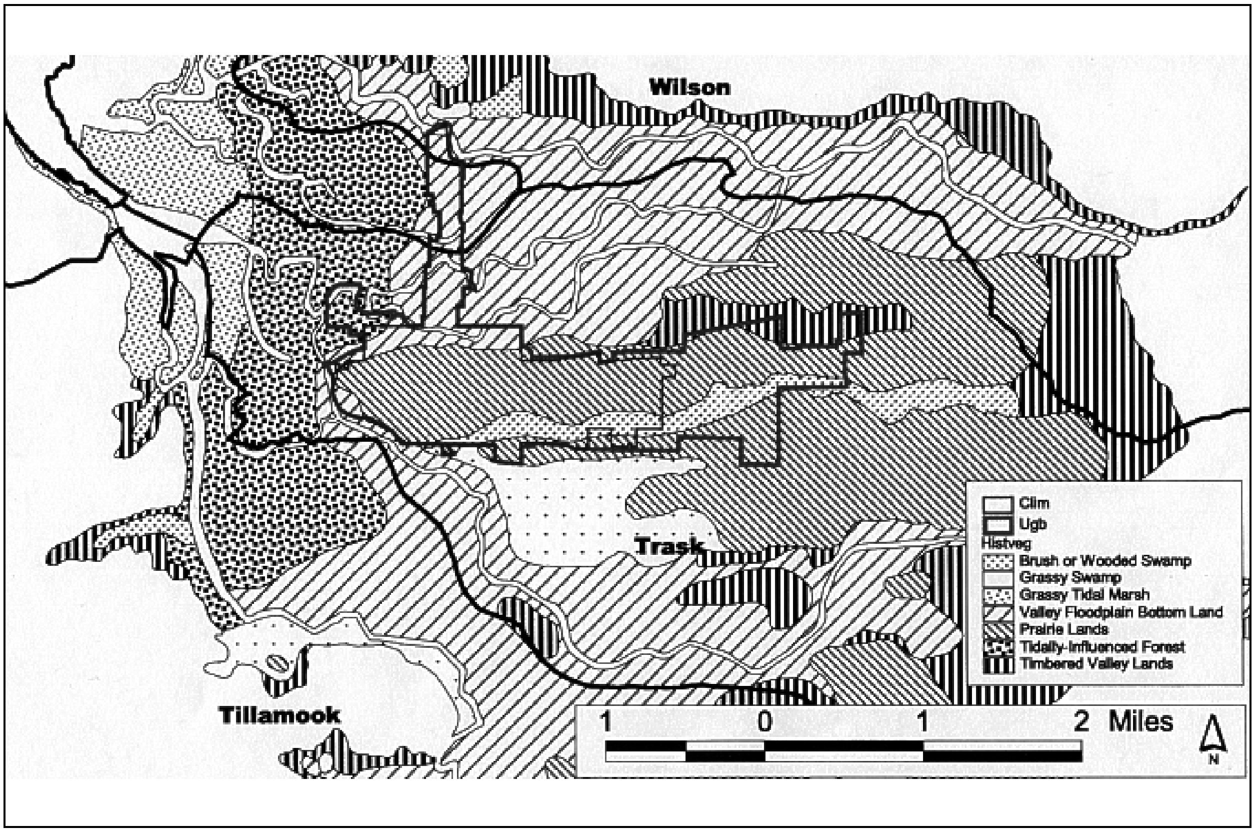


Figure A-5-4. Sample of TILAHIST Coverage Around the City of Tillamook Source: TBNEP, 1999

■ Discussion

The GLO maps show the area of land between the uplands and estuary as lowland floodplains. Historic plant communities were dominated by "main valley floodplain bottomland", described as cottonwood, spruce, hemlock yellow fir, maple, alder and dense undergrowth (Coulton et al., 1996). Other vegetation types include extensive "prairie lands", which may have been predominantly grasses and forbs growing above the 100-year floodplain, "brush or wooded swamp", which may have been willow-dominated riparian corridors, and "tidally-influenced forest", which is certain to have been Sitka spruce forest. Beyond the tidal forest is "grassy tidal marsh", which may be the high marsh community. An extensive "grassy swamp" is shown to the north of the lower Trask floodplain (Figure A-5-4).

Based on the GIS analysis, there has been a reduction of about 94% in the areal extent of natural floodplain plant communities within the Tillamook Bay lowlands (Table A-5-1). These losses have been due primarily to agricultural conversion and have been most severe for the main valley floodplain bottomlands that were all converted to human uses. Only two community types appear to be even 10% as extensive as they were historically. Upriver valley timbered floodplains cover about 17% as much of the lowland surface as they did in the 1850s. Tidal marshes cover about 35% as much area today as they did in 1850. Much of the tidal marsh now found in the lowlands has been formed by recent extensions of river deltas at the southern end of the bay, which do not provide the complex channels and aquatic habitats found in the older marshes that were converted to agricultural use.

The analysis of historic air photos confirms the perceptions of older basin residents that most dramatic

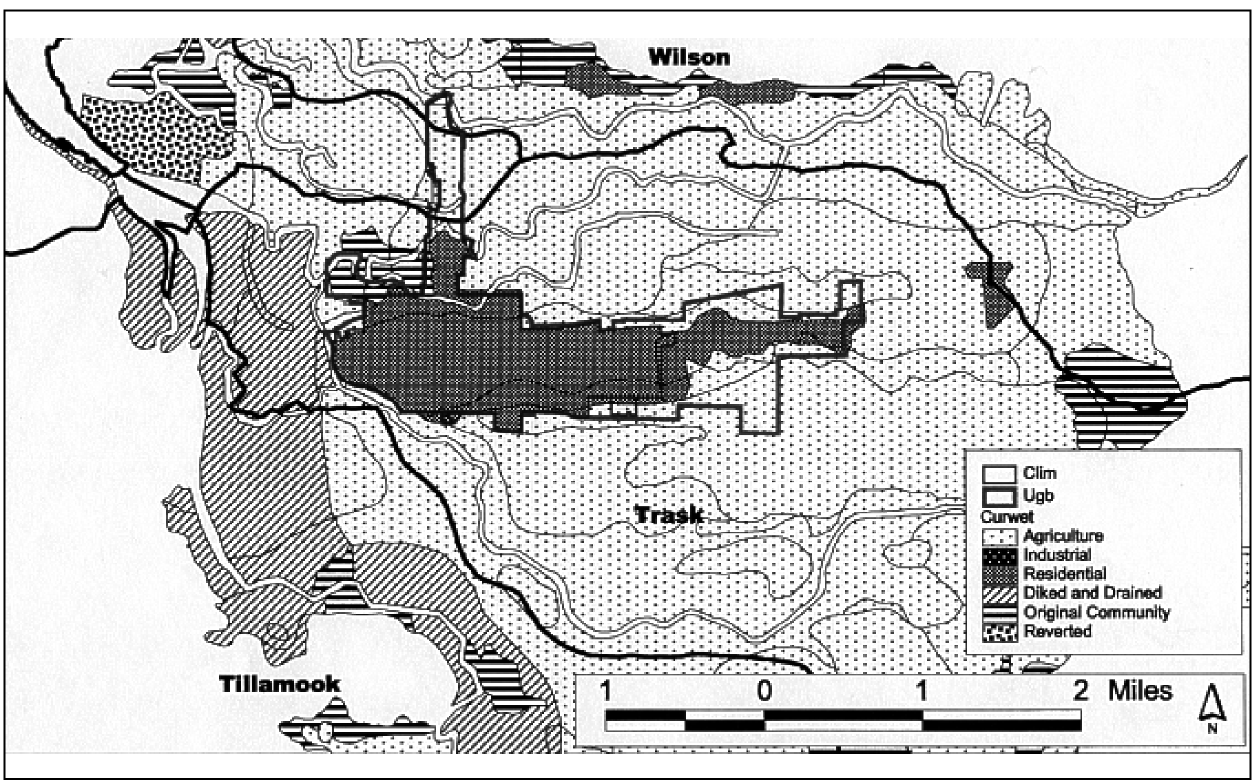


Figure A-5-5. Sample of CURWET Coverage Around the City of Tillamook Surce: TBNEP, 1999 changes to lowland riparian forests occurred a very long time ago. Lowland rivers in these sub-basins appear to have more extensive gravel bars and greater channel instability in 1953 than in 1990. Air photos did not show noticeably improved channel stability between 1953 and 1990 for the Miami and Tillamook sub-basins. Riparian forests along each of the lower rivers and sloughs examined were highly fragmented by 1939, and the areas they once occupied have been dominated by sparsely forested, highly discontinuous, or treeless conditions since that time (Table A-5-2).

This assessment found that:

- Fully functioning (e.g., dense and continuous) riparian forests have been restricted along the studied rivers and sloughs since at least 1939, although such areas appear to be increasing slowly in extent along the above-tide portion of the lower mainstem Wilson River.
- Mature conifers appear to be declining in abundance across the lowland surface.
- Of the areas studied, riparian forests appear to be in poorest condition now along the above-tide portions of the drainage networks of Hall and Dougherty sloughs, where riparian corridors have become increasingly narrow, sparsely vegetated, and treeless since 1939.
- The upper end of Dougherty Slough in 1939 was a side channel actively connected to the mainstem Wilson River at modest flows, but has since become disconnected from the river. Other slough networks appear to have become disconnected from the rivers or streams that created them before there was a photo record.
- In 1939, tidal segments of the rivers and sloughs examined had relatively low abundance of large woody debris compared to historical levels, but contained considerably more wood per unit length than did their above-tide sections. With recent low abundance of large wood in the Tillamook Bay lowlands, no new side channels or sloughs have formed between 1939 and 1994.
- There was no clear trend in the abundance of near-channel (within 150 ft) roads or buildings in the areas studied between 1939 and 1994.
- There was a steady decline in the amount of large wood in the tidal segments of the Miami River, Wilson River, and Hall and Dougherty sloughs between 1939 and 1994.
- Quantities of large wood in the lowland portions of the mainstem Miami and Wilson rivers above tidewater were low in 1939 photos, were highest in the 1967 photos taken just a few years after the 1964 flood, and reached lowest levels in the 1994 photos.
- Large wood in the above-tide drainage networks of Hall and Dougherty sloughs appears to have dropped to very low levels by 1953 and has not recovered.

Table A-5-1. Historic Losses of Natural Floodplain Communities in the Tillamook Bay Lowlands, Oregon (Coulton *et al*., 1996 and TBNEP, 1998a)

Floodplain/Wetland Community	Historic Occurrence (sq mi)	Recent Occurrence (sq mi)	Percent loss
Brush or wooded swamp	0.8	0.08	90
Grassy swamp	1.1	0.04	96
Grassy tidal marsh	1.7	0.58	65
Main valley floodplain bottomland	10.3	0.00	100
Tidally influenced forest	3.0	0.11	96
Timbered valley lands	13.7	0.70	65
Upriver valley timbered floodplain	2.7	0.46	83
All natural communities	**33.3**	**1.97**	**94**

Table A-5-2. Photo Interpretations of Riparian and Wood Debris Conditions along Selected Lowland Rivers and Sloughs in the Tillamook Bay Basin, 1939-1994
Standard errors are given in parentheses for mean LWD values.

Stream channel(s)	Section	Sample sections	Year	LWD/mile		Percent of sections by riparian class* (canopy density and width of treed zone)					
						Dense and continuous			Sparse or strongly dis-continuous		
				Pieces	Clusters	>150'	30-150'	<30'	>30'	<30'	No trees
Wilson R.	RM 2.4-8.5 (above tide)	10	1939	7.0 (3.9)	0.0 (0.0)	0	0	0	55	30	15
			1953	1.8 (1.8)	0.0 (0.0)	10	5	0	70	5	10
			1967	22.9 (10.8)	0.0 (0.0)	11	5	0	16	26	42
			1994	1.8 (1.8)	0.0 (0.0)	25	0	0	45	20	10
Wilson R.	RM 0.0-2.4 (tidal)	10	1939	29.9 (17.2)	0.0 (0.0)	0	0	0	30	65	5
			1953	15.8 (10.6)	1.8 (1.8)	0	0	0	60	20	20
			1967	10.6 (8.8)	0.0 (0.0)	0	0	0	20	55	25
			1994	5.3 (2.7)	0.0 (0.0)	0	0	0	35	40	25
Miami R.	RM 0.4-5.5 (above tide)	10	1939	3.5 (2.3)	0.0 (0.0)	0	0	0	50	40	10
			1953	17.6 (7.9)	0.0 (0.0)	10	5	0	35	20	30
			1967	17.6 (7.9)	1.8 (1.8)	5	0	0	32	11	53
			1994	0.0 (0.0)	0.0 (0.0)	0	5	0	50	35	10
Miami R.	RM 0.0-0.4 (tidal)	5	1939	14.1 (10.3)	0.0 (0.0)	0	0	0	50	50	0
			1953	7.0 (7.0)	0.0 (0.0)	0	0	0	20	80	0
			1967	7.0 (7.0)	0.0 (0.0)	0	0	0	10	90	0
			1994	3.5 (3.5)	0.0 (0.0)	0	5	0	50	35	10
Dougherty and Hall sloughs	full lengths above tide	24	1939	13.9 (4.5)	0.0 (0.0)	0	0	0	55	34	11
			1953	0.0 (0.0)	0.0 (0.0)	0	0	0	31	44	25
			1967	0.0 (0.0)	0.0 (0.0)	0	0	0	23	50	27
			1994	1.5 (1.0)	0.0 (0.0)	0	0	0	33	35	31
Dougherty and Hall sloughs	full lengths below tide	15	1939	35.2 (16.1)	1.4 (1.4)	0	0	0	36	32	32
			1953	19.9 (9.2)	1.2 (1.2)	0	0	0	23	37	40
			1967	14.1 (9.1)	0.0 (0.0)	0	0	0	20	60	20
			1994	4.7 (4.7)	0.0 (0.0)	7	3	0	20	50	20

* Dense riparian stands of trees were distinguished from sparse ones by having less than 1/3 of the ground exposed.

A.5.4 Contemporary Stream and Riparian Conditions

■ Objectives

The objective of this assessment was to document contemporary conditions of freshwater non-tidal stream reaches, streambanks and floodplains in the Tillamook basin. Stream and riparian conditions throughout a drainage basin reflect the cumulative history of past disturbance and recovery processes. Although historic data do not exist for the streams of the Tillamook basin, field data can reveal the extent to which a stream currently provides conditions favorable to many native species of fish and wildlife. Stream conditions are also of concern for flood management, because these conditions contribute to flooding resilience at both the basin and reach scales.

■ Methods

Methods used follow OWEB (1999). Available stream inventory data collected in the Tillamook Bay basin during the period 1990-97 were acquired (Figure A-5-6). These data were stratified by region into upland (269 reaches in 253.2 mi.) and lowland channels (41 reaches in 52.7 mi.). Conditions measured within individual stream reaches were compared to ODFW habitat 'qualitative' benchmarks (desirable, intermediate, and undesirable) based on multiple stream characteristics. Based on a similar assessment that Moore et al. (1995) performed on a subset of the inventory data (1990 - 1993), this assessment tripled the number of reaches and broadened the geographic coverage. Patterns of variation in specific stream characteristics within the uplands and lowlands were not evaluated beyond assigning qualitative ratings to stream conditions.

Patterns of variation were assessed more carefully for two stream characteristics within the Tillamook Bay basin: 1) percent bank erosion and 2) the abundance of riparian conifers with near-term potential to contribute large wood, measured as number of trees per 1000 feet greater than 20 inches in diameter. For each of these characteristics, exceedance curves were developed for the cumulative frequency of habitat conditions found in the surveyed reaches. The exceedance curves were similar to those that the US Geologic Survey (Riggs, 1968) uses when assessing variability in streamflows. These have been used by Huntington (1997) to evaluate landscape-level variations in stream conditions.

■ Discussion

Results of the benchmark analysis are consistent with those Moore *et al.* (1995) reported for a smaller sample of upland stream reaches in the basin, and reflect that most channels have been simplified (Table A-5-3; Figure A-5-7). "Undesirable" stream conditions were found to be widespread in both upland and lowland areas. These features included:

1. low abundance of large wood and an associated lack of diverse habitat structure and complex pools;
2. low abundance of riparian conifers big enough to contribute large wood to streams in the near future, width/depth ratios that were frequently higher than would be expected in stable channel networks; and
3. low spawning gravel quality due to high levels of fine sediment and (presumably) elevated rates of bed load movement.

Pool abundance and depth tended to be in the desirable range more frequently in lowland than in upland streams within the basin (Table A-5-3). Upland streams, historically bordered by conifers, tended to be well-shaded by mature alders, while many segments of the basin's lowland streams no longer had riparian forests and were poorly shaded. Secondary channels accounted for a smaller portion of available habitat along lowland streams (5%), where they would be

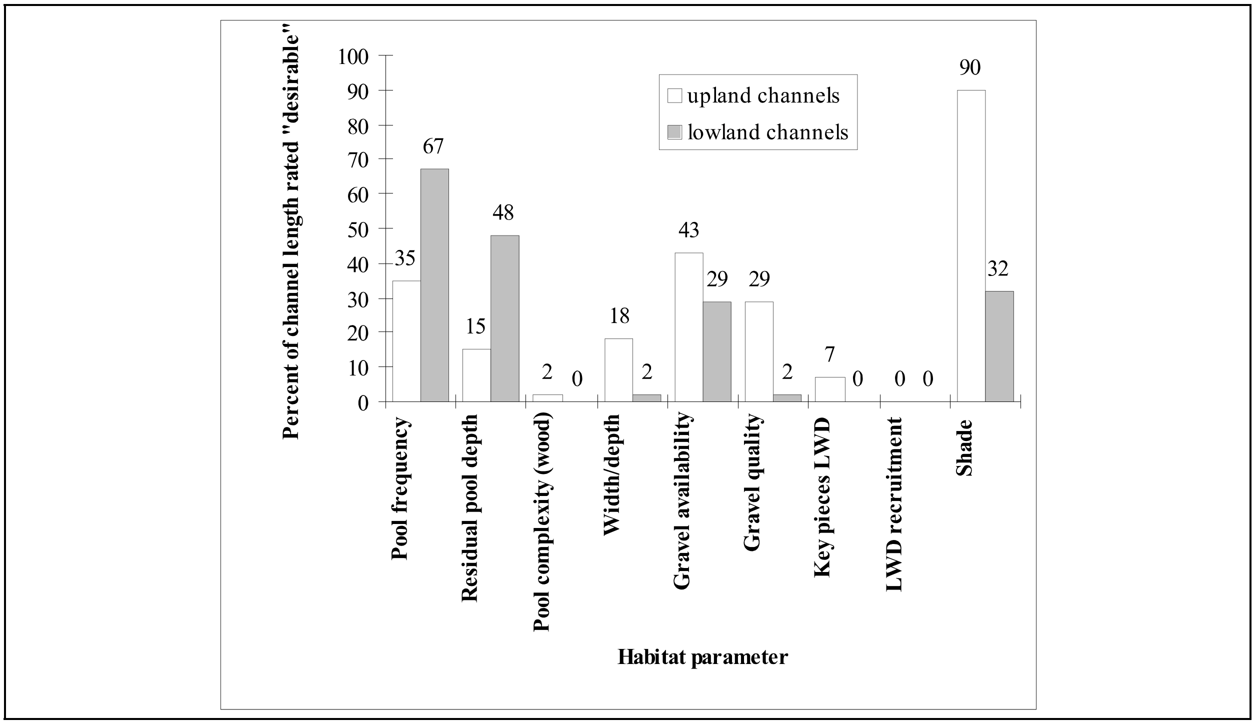


Figure A-5-6. Percent of Total Channel Length Surveyed in the Tillamook Bay Basin Rated "Desirable" for Specific Parameters, per ODFW Habitat Benchmarks, 1990-1997

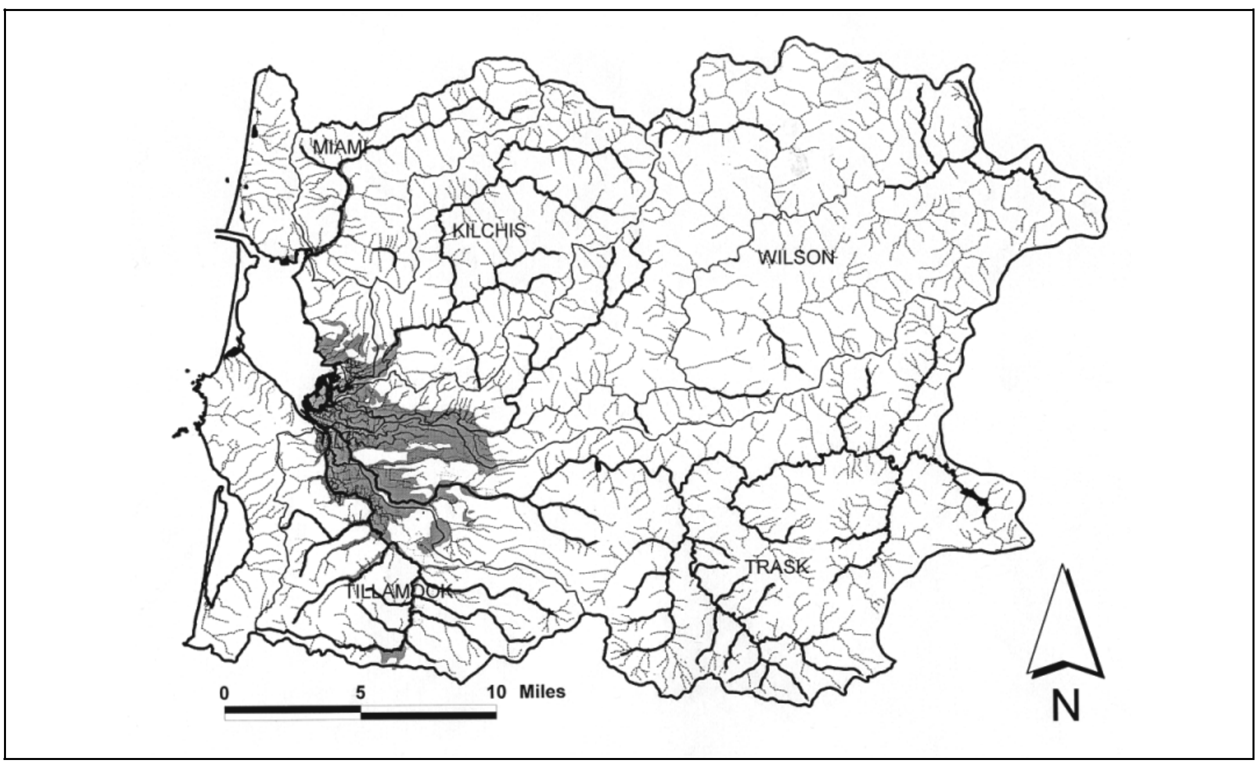


Figure A-5-7. Stream Channels Surveyed in the Tillamook Bay Basin (bold lines), 1990-1997

Table A-5-3. Qualitative Ratings of Fish Habitat Parameters for Stream Channel Surveyed in the Tillamook Bay Basin, 1990-1997

		Rating (percent of stream length)*		
Habitat parameter	**Area**	**Undesirable**	**Intermediate**	**Desirable**
Pools				
Pool area (% total stream area)	Uplands	29	49	23
	Lowlands	11	31	58
Pool frequency (channel widths/pool)	Uplands	37	28	35
	Lowlands	30	3	67
Residual pool depth	Uplands	11	74	15
	Lowlands	21	31	48
Pool complexity	Uplands	95	3	2
	Lowlands	100	0	0
Riffles				
Width/depth ratio	Uplands	20	62	18
	Lowlands	51	47	2
Gravel availability (% gravel in riffles)	Uplands	6	51	43
	Lowlands	0	71	29
Gravel quality	Uplands	44	27	29
	Lowlands	52	46	2
Large woody debris (LWD)				
Key LWD pieces ** (large conifer logs)	Uplands	70	23	7
	Lowlands	95	5	0
Total LWD pieces (includes alder and small pieces)	Uplands	37	26	37
	Lowlands	89	11	0
Total LWD volume (includes alder and small pieces)	Uplands	43	10	47
	Lowlands	100	0	0
Riparian conditions				
LWD recruitment (riparian conifers)	Uplands	99	1	0
	Lowlands	100	0	0
Stream shade (percent canopy closure)	Uplands	3	7	90
	Lowlands	67	1	32

* Qualitative ratings were based on habitat benchmarks the Oregon Department of Fish and Wildlife developed from regional summaries of survey data and conditions in reference streams.

** The Oregon Department of Fish and Wildlife's habitat benchmark for the "desirable" condition is more than 80% lower than the general standard NMFS (1996) uses to assess properly functioning stream habitat on federal lands in coastal Oregon watersheds.

expected to be naturally abundant, than along upland streams (6%). Our own field observations suggest that many of the secondary channels remaining in the system are relatively unstable braids rather than the kinds of well-vegetated and wood-filled side channels that provide complex, protected fish habitats.

Recent survey data suggest that bank erosion and a lack of large riparian conifers are significant and widespread problems in the Tillamook Bay basin (Figure A-5-8). NMFS has proposed a criterion for properly functioning conditions, that less than 10% of banks are actively eroding. The combined average value for all of the upland reaches surveyed in the basin (18%) exceeded this threshold, as did nearly half of the individual reaches studied. Erosion problems are even more severe in the basin's lowlands, where surveyed reaches averaged 23% raw banks and more than 60% of the reaches exceeded the NMFS criterion, despite the fact that many lowland streams have had substantial sections of their banks armored with protective rock surfaces.

The lack of larger-sized (>20" dbh) riparian conifers in the basin's forested uplands is so pronounced that the lowland reaches surveyed did not have dramatically fewer of these trees per unit distance (Figure A-5-8). While the ODFW benchmark for "desirable" riparian zones calls for 300 or more larger-sized conifer trees per 1000 feet of stream channel, fewer than 30% of the upland reaches surveyed in the basin have any such conifers. Only about 1% of the upland reaches surveyed had as many as half the number of these trees considered desirable. Alder trees dominate most riparian zones along surveyed upland reaches, although small conifers may be present within many of them.

The low abundance of large wood in streams tributary to Tillamook Bay, combined with poor near-term prospects for natural replenishment (the lack of large conifers in riparian areas), suggests that a key element of properly functioning aquatic habitats in the basin's uplands and lowlands will be deficient well into the future. This is of particular concern when future flooding effects are considered. Large wood has the capacity to dampen excessive inputs of coarse sediment during major storms, as well as to help create or maintain off-channel habitats like alcoves, side channels, and connected wetlands that provide critical fish refuge from the high storm flows.

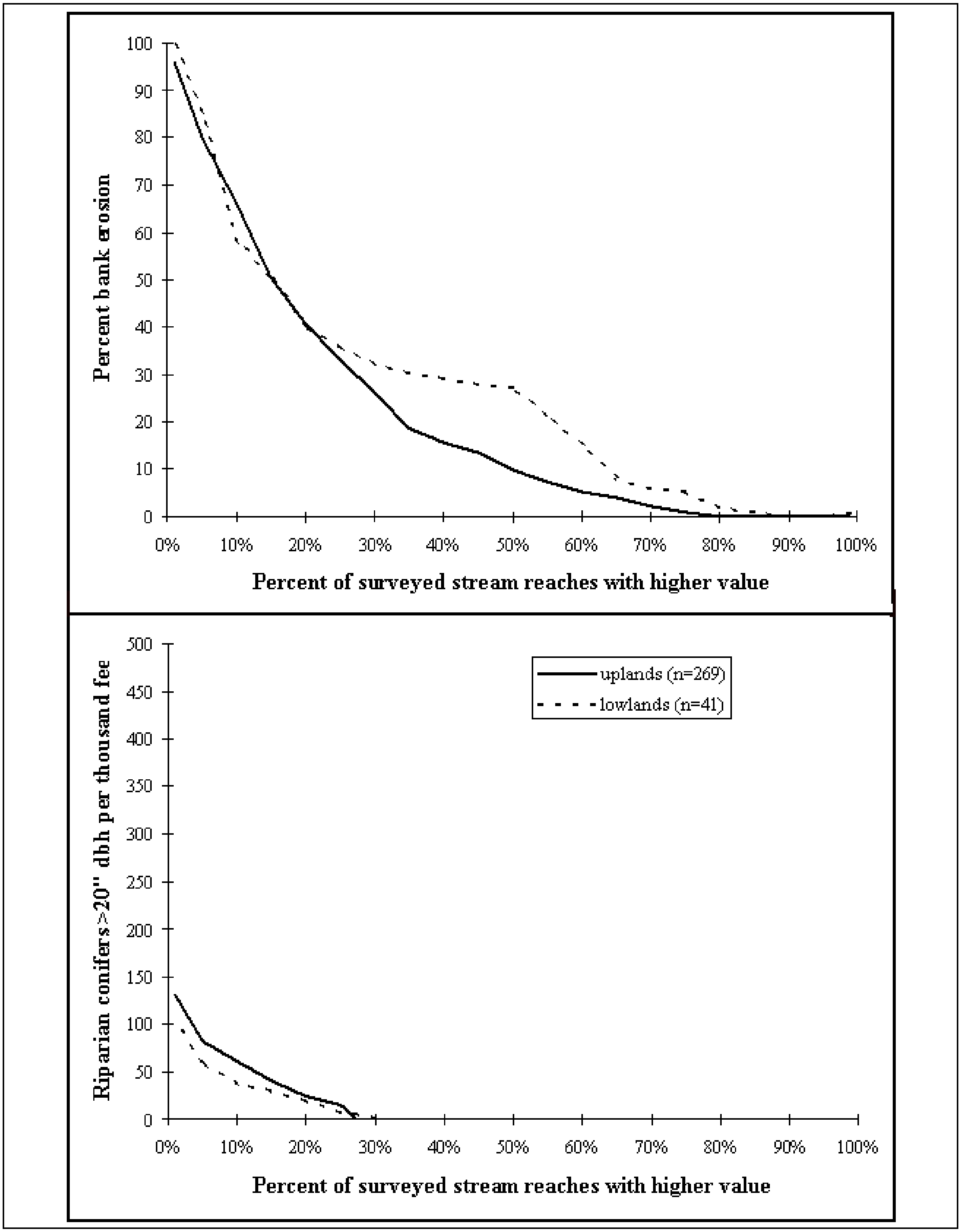


Figure A-5-8. Exceedance Curves for Percent Bank Erosion (top) and for the Abundance of Riparian Conifers > 20" dbh per 1000 feet of Surveyed Channel (bottom) in Upland and Lowland Areas, Tillamook Bay Basin, 1990-1997

TABLE OF CONTENTS

LIST OF FIGURES

A.6 River Morphology

A.6.1 River Channel Planform Changes

■ Objectives

Rivers display a dynamic pattern of meandering over time. A comparison of river channel planforms — channel width and alignment — over time can provide a record of past changes in the channel and indicate future meandering and bank erosion tendencies. The focus of this assessment was the lowland valleys of the Tillamook Bay basin, because planform changes are more discernable in these low-relief, unconstrained areas, and because bank erosion concerns are more predominant here. The objectives of the assessment were to evaluate: 1) the change in river channel widths over time; 2) the trends in channel migration; and, 3) the trends in channel stability.

■ Methods

Current USGS digital 1:24,000 topographic maps of the Tillamook Bay lowland valleys were used as base maps for the comparison. These maps were developed from aerial photographs taken between 1975 and 1980. The first topographic maps for the area were published in 1942 by the U.S. Army War Department at a scale of 1:62,500. These early maps were developed from aerial photographs taken in 1939. The 1939 maps were enlarged to the same scale as the current maps and compared together over a light table. The planforms of the 1939 rivers were transferred to the current maps by tracing. There may be significant errors associated with a comparison of different editions of USGS maps because of inaccuracies or inconsistencies in the horizontal plane coordinates. Errors were minimized by aligning road intersections, benchmark locations and other spatial features common to the two map periods and comparing discrete reaches of river only in the immediate vicinity of the aligned cultural features. A similar exercise was done with the 1955 quadrangle map series, with river planforms transferred to the current map base. Figure A-6-1 shows a close-up of the Wilson River combining planforms from the three time periods. Due to the error involved in this type of a comparison, the resulting maps of river planform change are not necessarily accurate representations of river location, but they provide a general indication of river channel changes over time.

■ Discussion

The river channels in the Tillamook Bay lowlands display noticeable patterns of both meandering and stability. Meandering is most apparent in the head of the lowlands, where the rivers rapidly change gradient from the uplands. The upper reaches of the Trask and Wilson Rivers display progressive downstream channel migration over the time periods assessed. These river reaches generally coincide with reaches where riverbank soils are prone to erosion. Many stable reaches of river are apparent further downstream in the lowlands. Stability may be an indication of resistant geology or soils, the use of revetment or, conversely, of shallower river channel conditions where flood flows are not constrained to the channel, but overflow onto the floodplain before excessive flow velocities and bank erosion occur.

The actively meandering reaches of the rivers should be managed in a way that conserves and protects this natural function of the river. Meandering dissipates energy in flowing water and regulates the movement of sediment through the river system. The aerial photograph of the Wilson River after the November 1998 flood (Figure A-6-2) shows sediment deposition on floodplain lands and patterns of remnant channels and swales on the floodplain. This complexity of changing channel, bank and floodplain conditions creates aquatic habitat for salmon and other species.

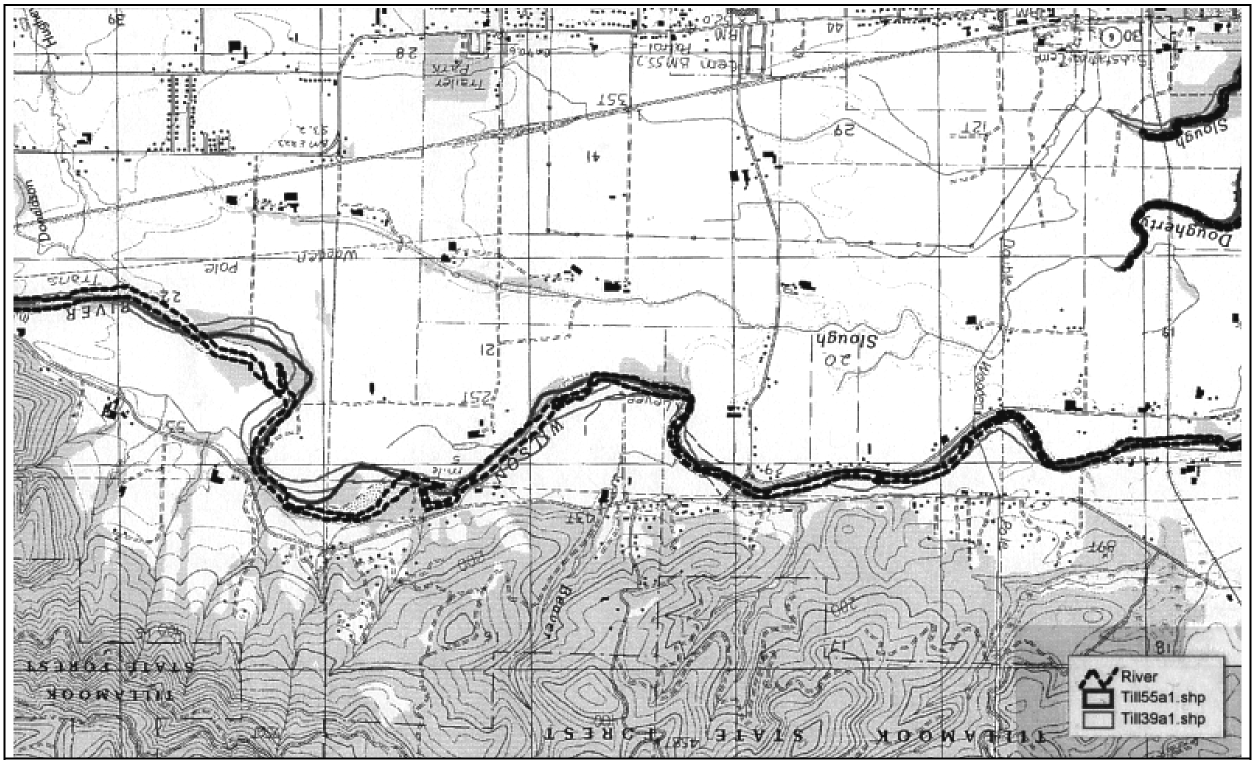


Figure A-6-1. Detail of Wilson River Historic Planform Comparison Mapping

Figure A-6-2. Aerial Oblique Photograph of 1998 Wilson River Flooding

A.6.2 River Channel Hydraulic Geometry Changes

■ Objective

Trends in river aggradation or degradation can often be documented by repetitive cross section measurements of the channel. Bridge crossings of rivers represent good opportunities for obtaining multiple channel measurements over time, because river channel measurements are typically taken at bridges when: the bridge is designed and built; as part of flood insurance studies; and, in recent years, as part of bridge scour evaluations. The objective of the bridge channel geometry assessment was to obtain and compare available historic bridge cross section data and assess trends in channel change at bridge crossings in the Tillamook Bay lowland valleys.

■ Methods

Historic and current bridge cross section information was requested from the ODOT Bridge Design Section and the Tillamook County Public Works Department. Original bridge design drawings were available for only a small selection of the bridges in the lowland valley (Figure A-6-3). ODOT provided bridge data associated with bridge scour studies. These studies began in the early 1990s in response to state and federal concerns for the safety of public infrastructure over waterways.

The available original drawings of bridge sections were provided in a variety of scales, and in some cases no scale was given. For some of the original bridge design drawings, the accuracy of the underwater portion of the river channel section was questionable because it did not appear to be a well-defined channel shape (Figure A-6-4). Manual measurements were made of river bottom elevations versus horizontal stationing, based from noticeable and common features of a particular bridge, such as piers or abutments. Where repetitive river channel section data were available, the topographic relief of the channel was aligned based upon a comparison of these same bridge features (Figures A-6-5 through A-6-8).

■ Discussion

Repetitive channel measurements were only available for the Sollie Smith and Tone Road bridges. A foot or so of deposition is shown at the Sollie Smith bridge between 1978 and 1990, perhaps reflecting a long-term trend of channel-filling in this reach of the Wilson River.

This data base should be expanded to include all bridge crossings in the lowland valleys. Bridges offer a relatively easy platform for repetitive measurements of changes in lowland river channel morphology. These measurements would be especially important after flood events so that more comprehensive trends in river channel behavior may be compiled.

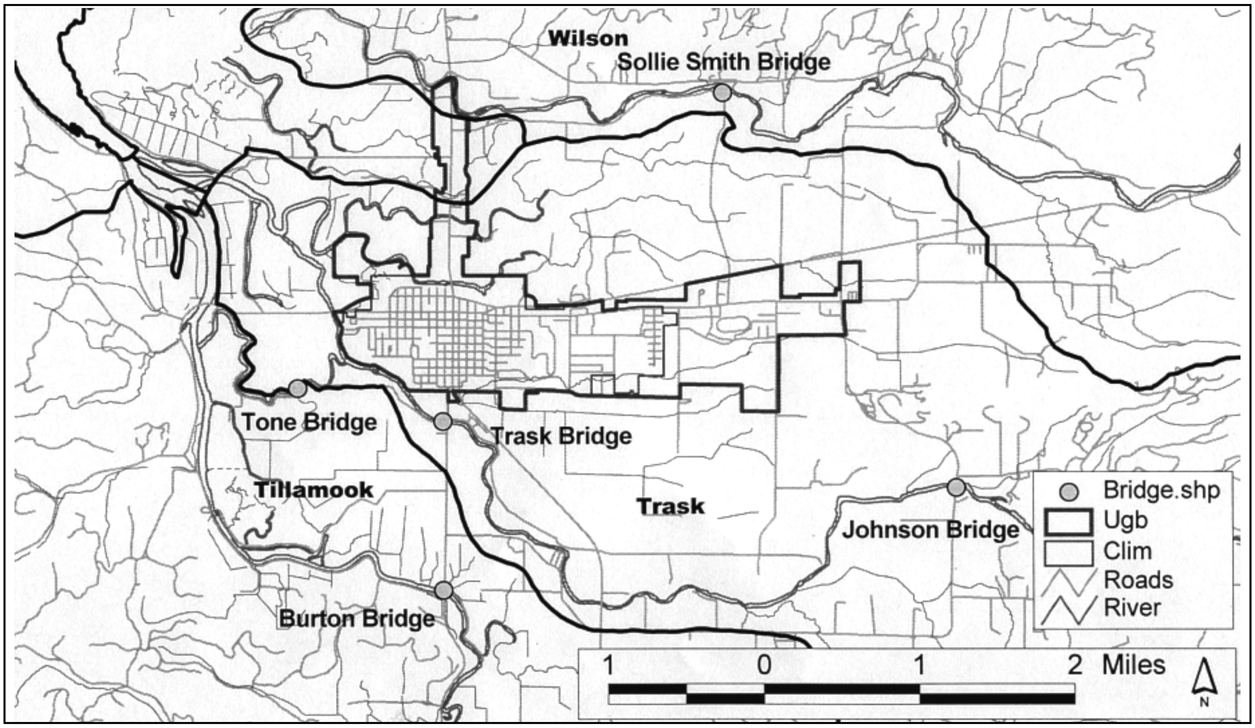


Figure A-6-3. Locations of Bridges use to Assess River Channel Morphology

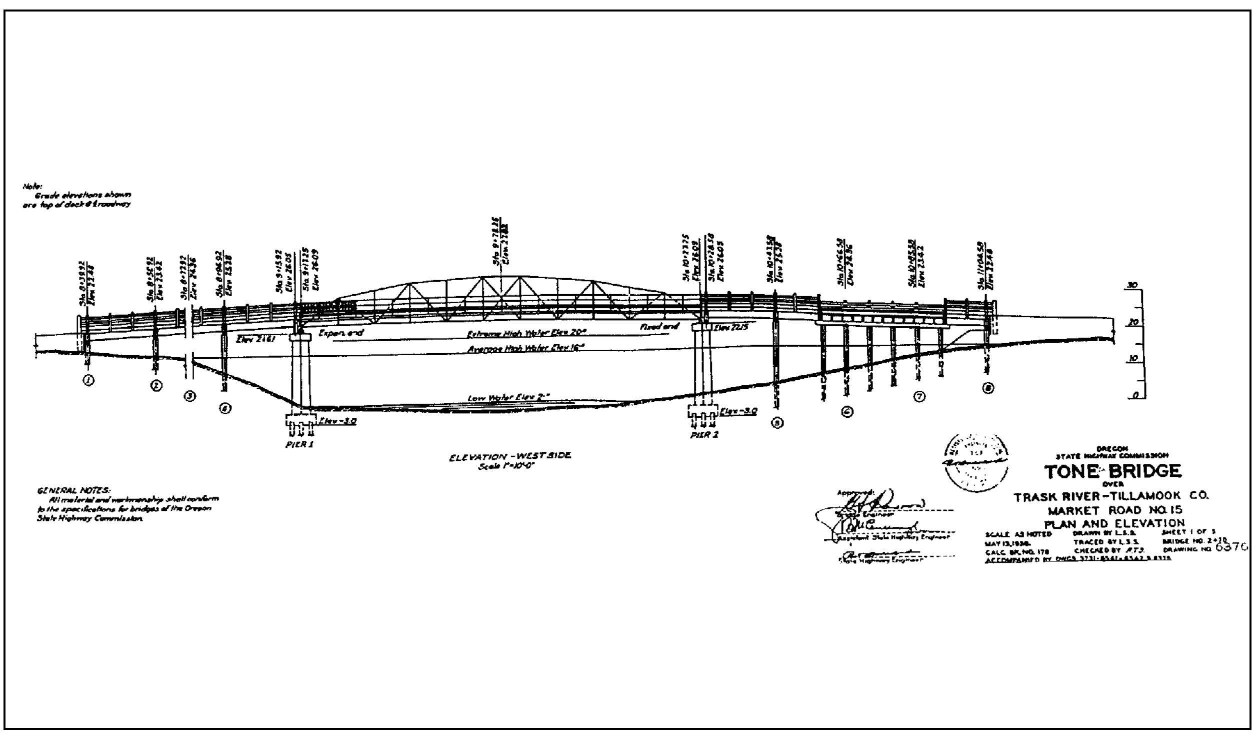


Figure A-6-4. Example of Original Bridge Design Drawing Showing River Channel Geometry

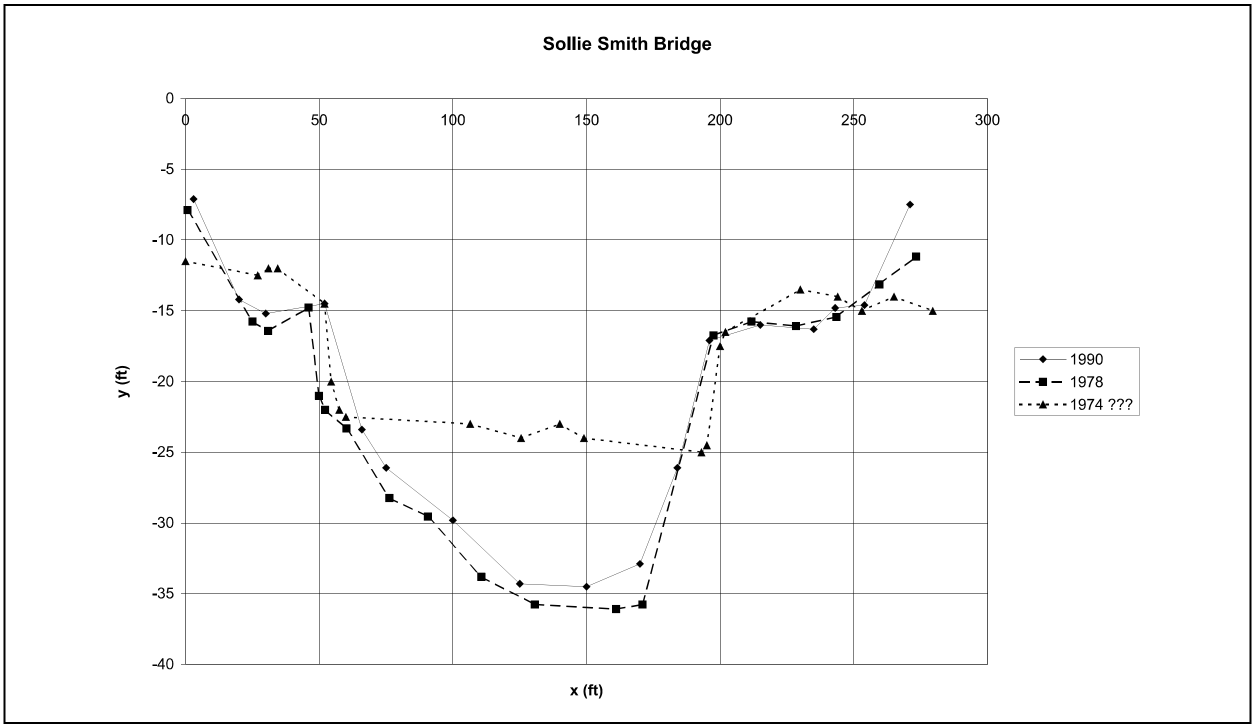


Figure A-6-5. Sollie Smith Bridge

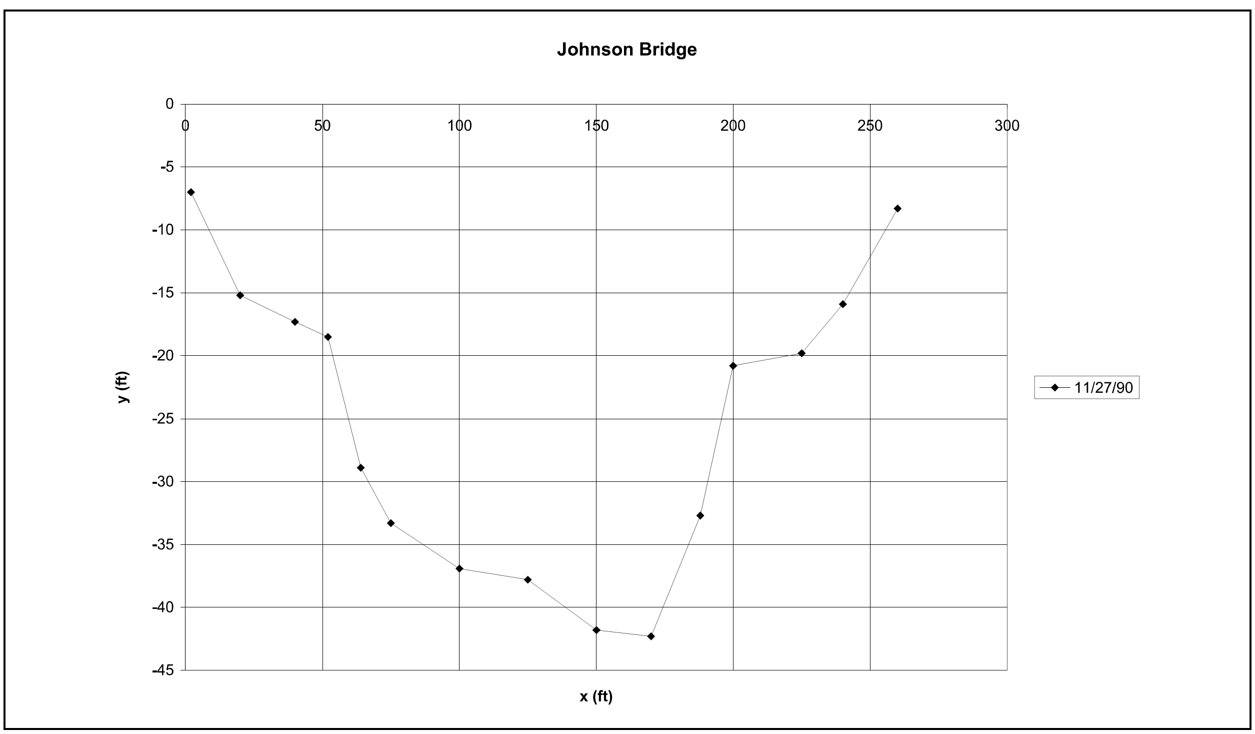


Figure A-6-6. Johnson Bridge

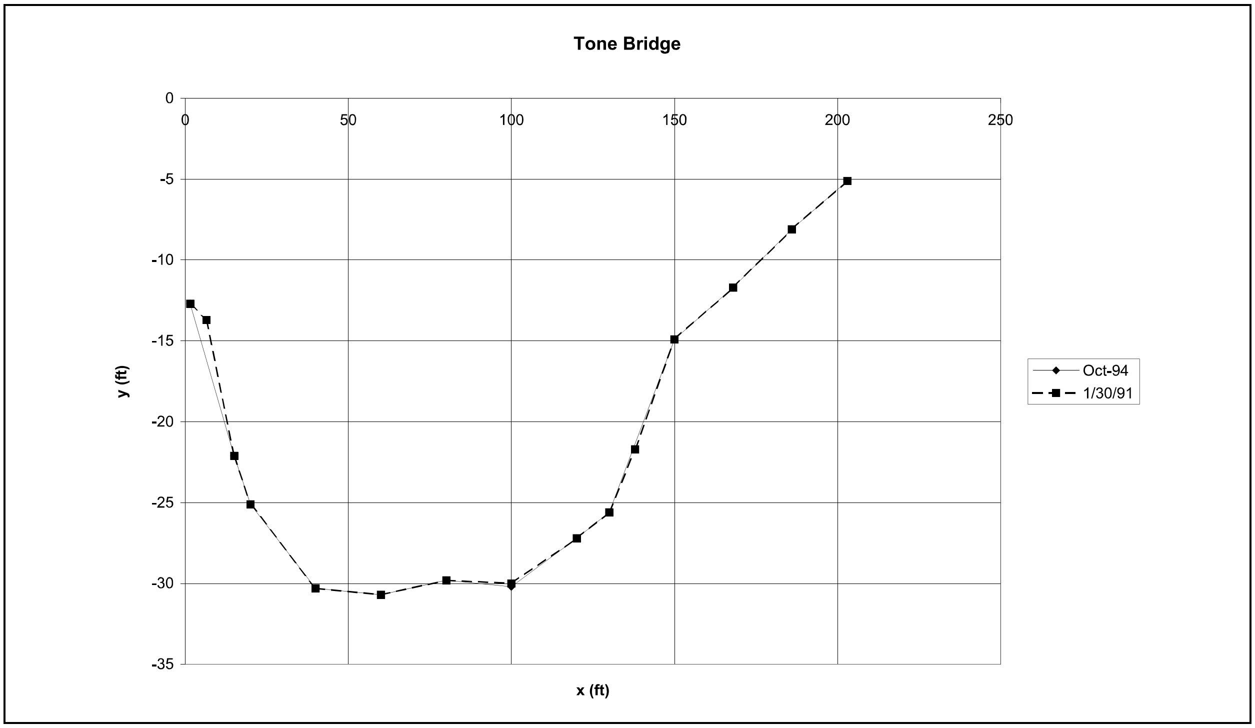


Figure A-6-7. Tone Bridge

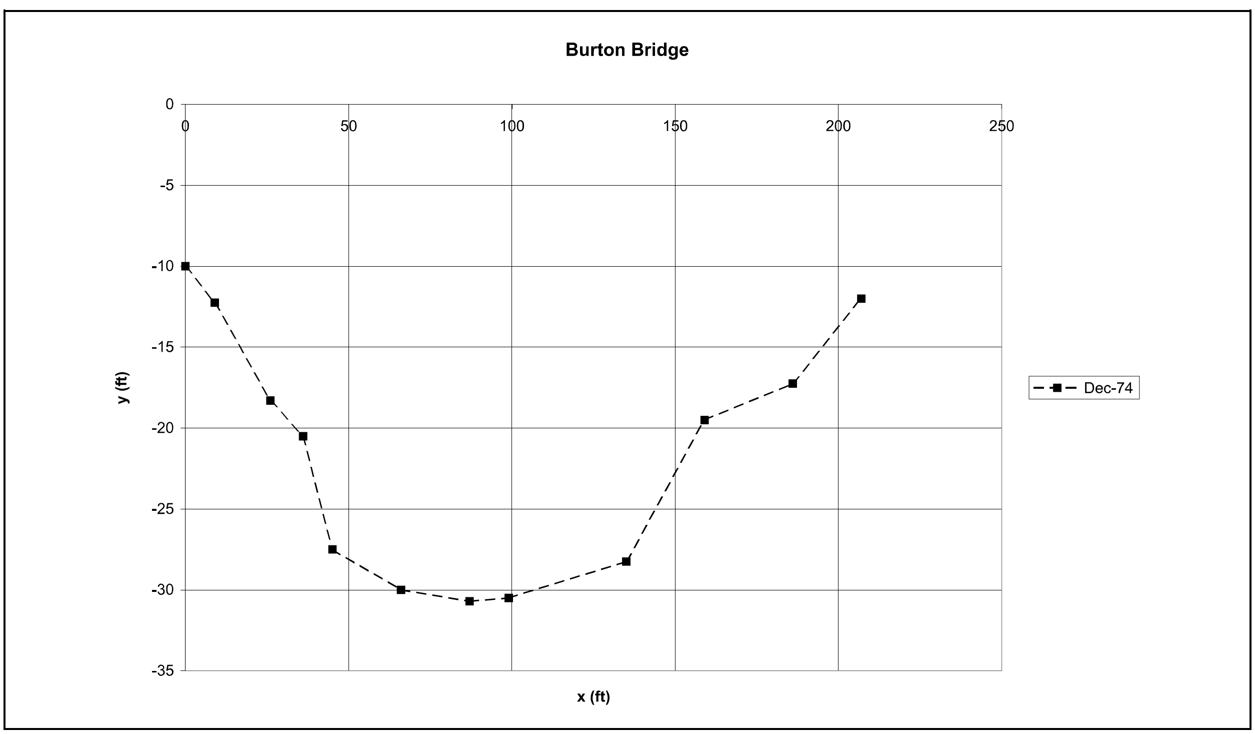


Figure A-6-8. Burton Bridge

A.6.3 Lowland Valley River Sinuosity

■ Objectives

River sinuosity refers to the ratio of channel length to straight-line valley distance (Leopold et al, 1964). Sinuosity can be used to classify river channels based on planform morphology and as an indicator of channel stability. The objective of this assessment was to document changes in lowland river channel sinuosity and evaluate the stability of the river reaches over time.

■ Methods

Current and historic editions of quadrangle maps of the Tillamook lowland valleys were used to document river channel length at three points in time: 1939, 1955 and 1985. These dates reflect the date of the aerial photography flown to create the maps, not the date of map publication. The use of quadrangle maps was assumed to be adequate for this level of investigation, since the maps were derived from aerial photography. More detailed investigations could use larger scale (i.e., closer) aerial photographs.

Figure A-6-9 shows the lengths of the mainstem rivers evaluated for sinuosity. The Miami River was evaluated up to River Mile 5; the Kilchis River, up to River Mile 7; the Wilson River, up to River Mile 7; the Trask River, up to River Mile 8; and the Tillamook River, up to River Mile 10. With the exception of the Miami River, the rivers traverse the wide, unconfined lowland valley near the South end of the bay. This condition presents some difficulty for an assumption on valley direction for each river. For this assessment, sinuosity was estimated as the ratio of length of river channel between river mile marks on the map to a straight line distance between the river mile marks, except where narrow valleys were encountered, such as along the Miami River where a curved valley distance was approximated (Figure A-6-10). River lengths between river mile marks were not consistently one mile in length, so the river distances between river mile marks were measured twice for each mile segment and averaged for a more accurate estimate of actual river length. Figures A-6-11 through A-6-15 show comparisons of river sinuosity by river mile for the five mainstem river reaches. These figures are plotted with consistent vertical and horizontal scales, to allow direct visual comparisons between the rivers.

■ Discussion

Rivers having a sinuosity of 1.5 or greater are considered meandering rivers and those less than 1.5 are straight or sinuous rivers (Leopold et al, 1964). A visual examination of the sinuosity plots indicates that the Trask River exhibits the lowest magnitude and variability in sinuosity over time. The Kilchis and Tillamook Rivers exhibit the highest magnitude and variability in sinuosity over time. Discrete reaches of the Kilchis, Wilson and Trask Rivers exhibit sinuosities greater than 1.5 and these reaches generally correspond to reaches with significant historic planform adjustments. The highest sinuosity values generally coincide with locations where the river is not confined by a valley wall on either side. These reaches with high sinuosity, and high relative change in sinuosity, should be managed with more consideration given to accommodating probable future channel adjustments.

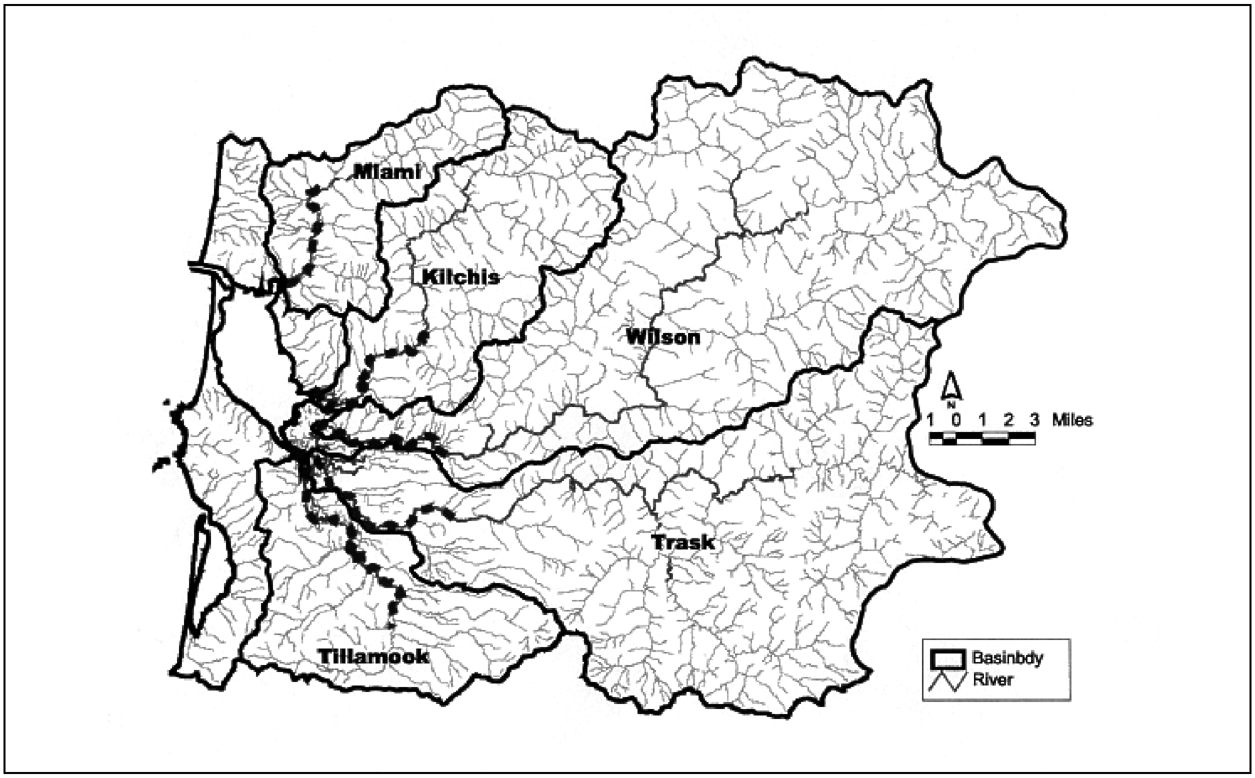


Figure A-6-9. Reach Lengths of Mainstem Rivers Evaluated for Sinuosity

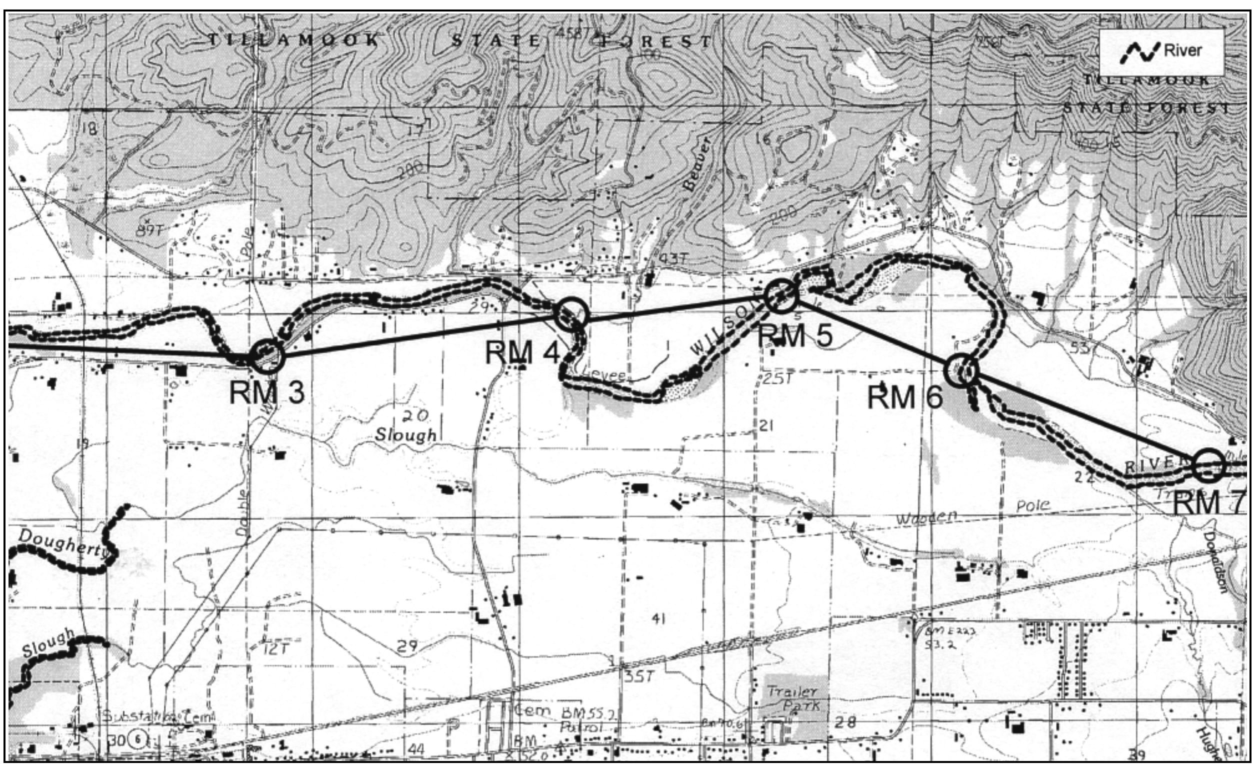


Figure A-6-10. Example of Lowland Sinuosity Estimates

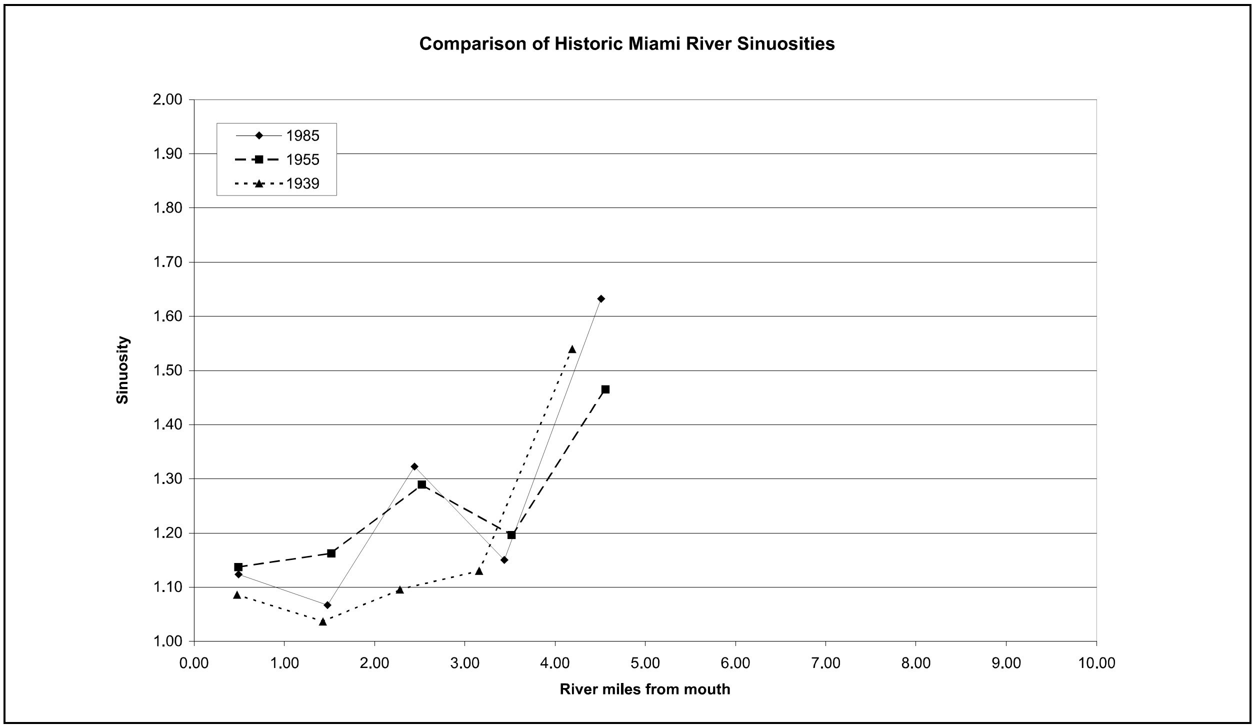


Figure A-6-11. Comparison of Historic Miami River Sinuosities

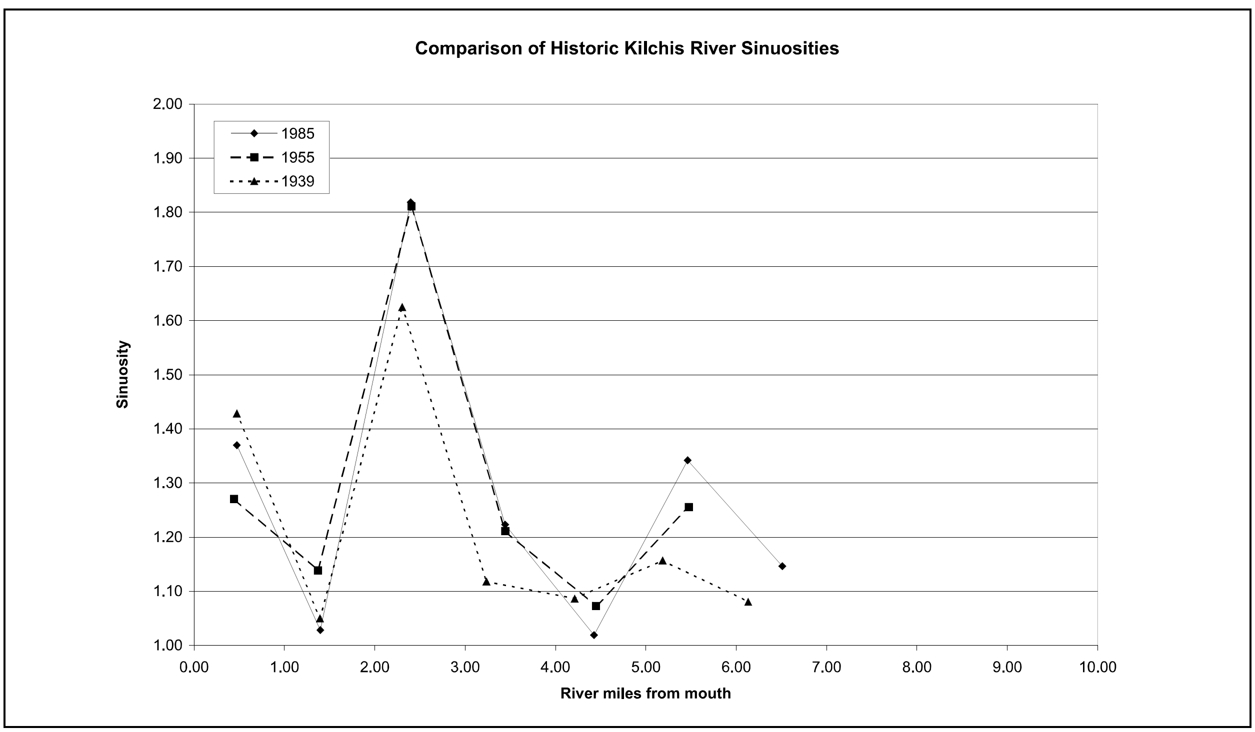


Figure A-6-12. Comparison of Historic Kilchis River Sinuosities

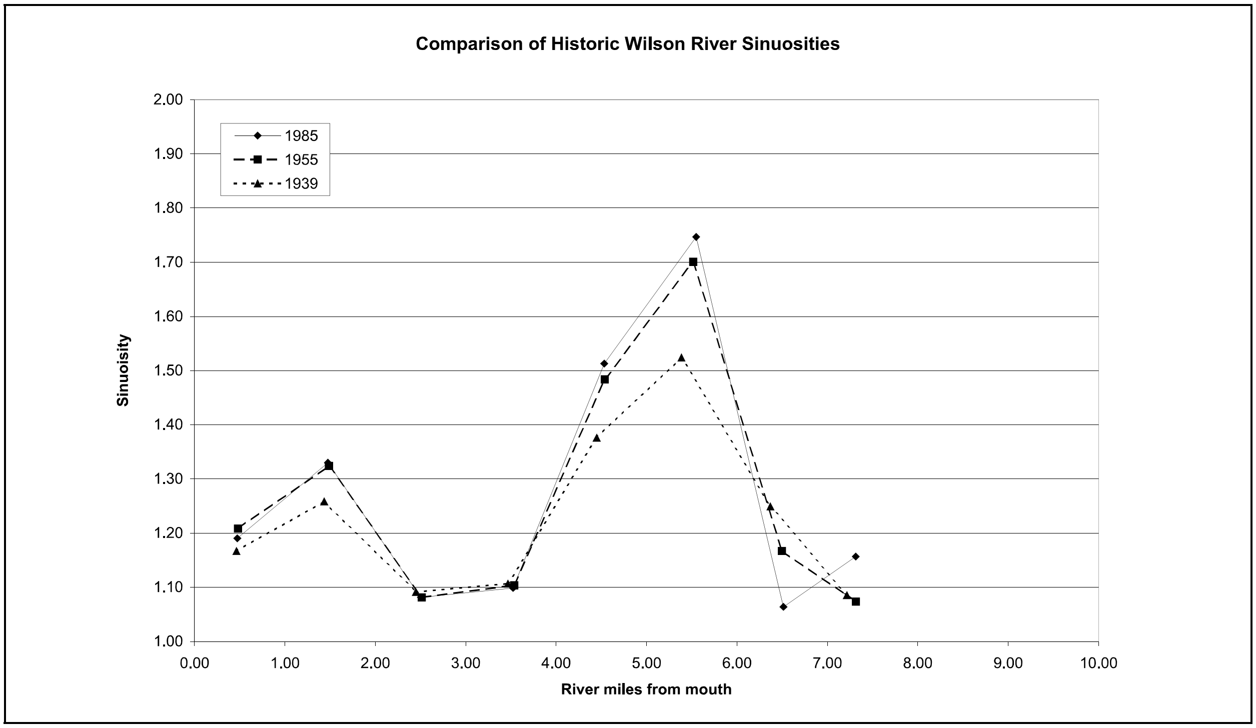


Figure A-6-13. Comparison of Historic Wilson River Sinuosities

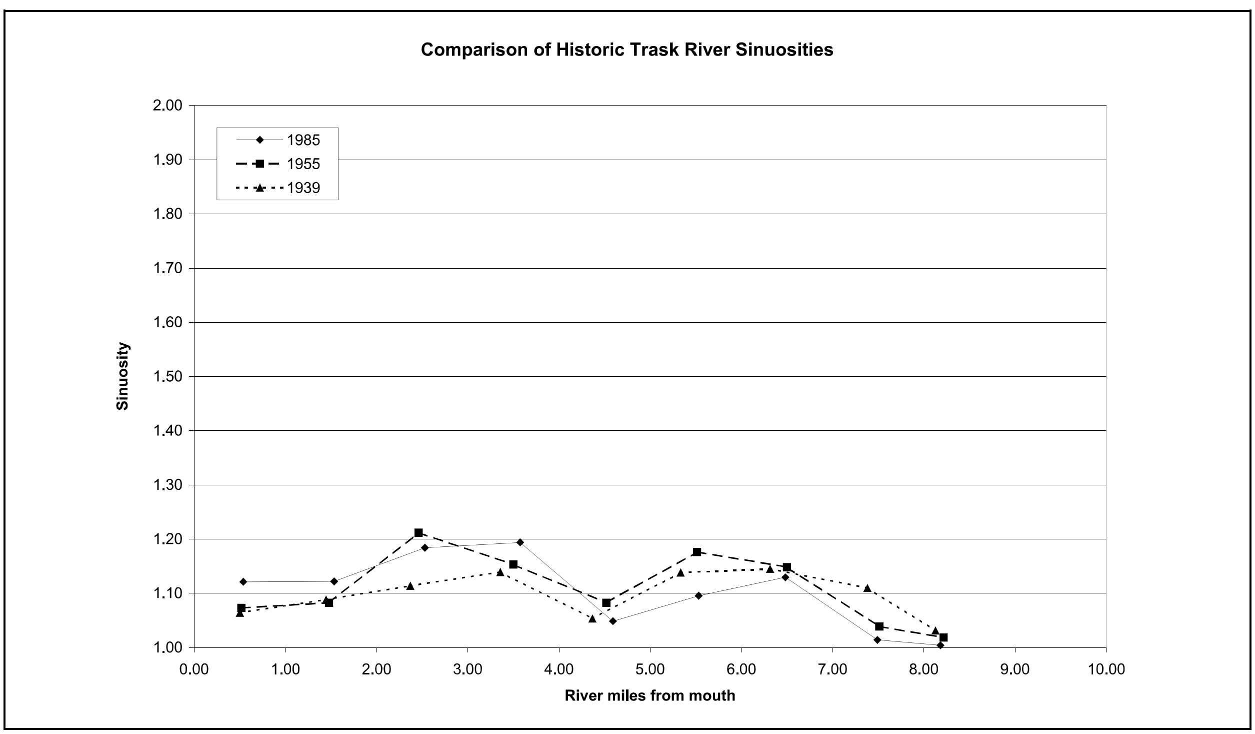


Figure A-6-14. Comparison of Historic Trask River Sinuosities

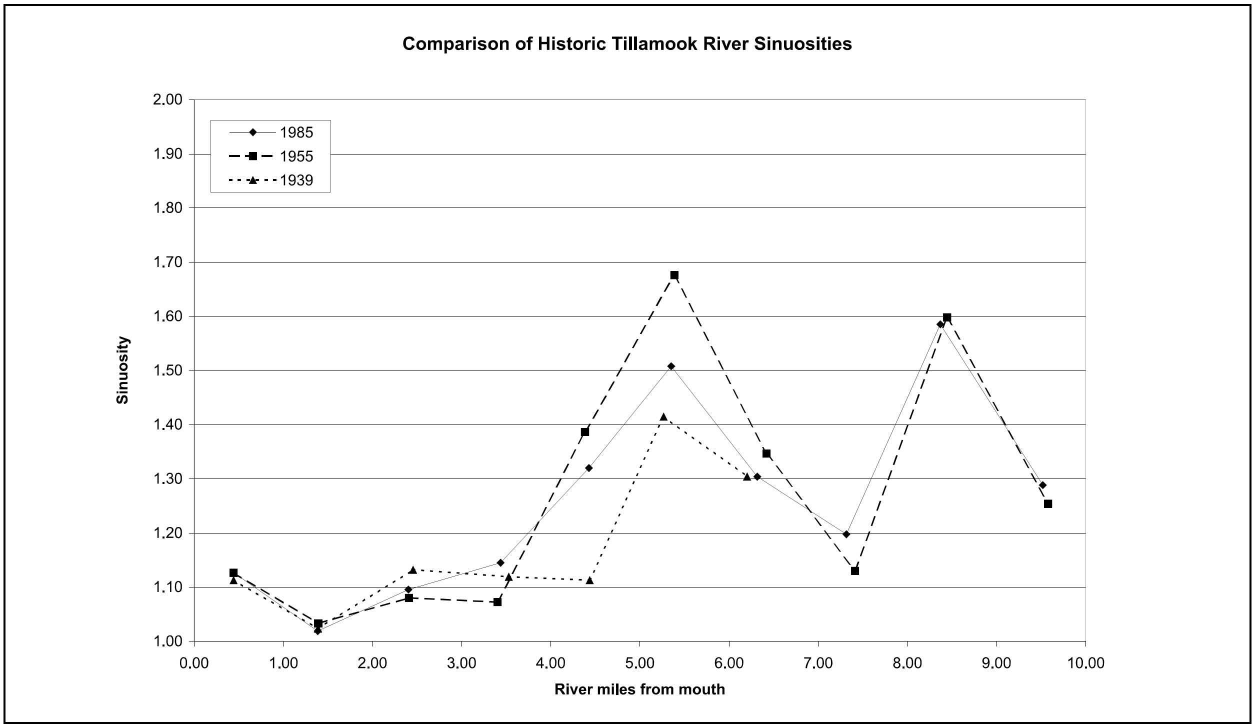


Figure A-6-15. Comparison of Historic Tillamook River Sinuosities

A.6.4 Lowland Riverbank Stability and Erosion Assessment

▪ Objectives

The erosion of riverbanks is a natural process that contributes to the progression of river meandering across a lowland valley. The erosion process can be accentuated by disturbances to the bank and by flooding. The stability of riverbanks is an issue where property ownership and land use interests seek long-term use of the land. These interests are often protected by physically covering the riverbank with rock, or by other methods. These protection efforts are typically done on an individual property-by-property basis. Although bank protection may provide a level of protection to the property of interest, it may have unintended consequences and impacts upstream or downstream along the river system. The objective of this assessment was to evaluate the stability of the natural river banks along the lowland river reaches to provide a comprehensive look at the relative stability of river banks for the entire lowland system.

▪ Methods

A general indication of riverbank stability was established by adopting methods described in the Stream Restoration Handbook (Federal Interagency Stream Restoration Working Group, 1998). The soil survey for Tillamook was reviewed to identify the soil series along the banks of the lowland rivers. Soil interpretation records were obtained from the NRCS for these soils (Jasper, 1999). The soils records provide soils data for several depth classes. The surface depth class was generally not used in the assessment, in favor of soils associated with deeper classes that would be more susceptible to erosion from river flows. The soils series were grouped into soil types under the Unified Soil Classification System. The soils records provided data on moist bulk density in units of grams per cubic centimeter (gcc), which were converted to pounds per cubic foot (pcf) for a moist bulk unit weight [g]. The shear strength of the soils was estimated, assuming minimum values of cohesion and internal friction (U.S. Bureau of Reclamation, 1987). The Unified soil types were used to estimate minimum cohesion values [c] in pounds per square foot (psf). Referencing average engineering properties of compacted soils, a minimum friction angle [f] for each soil type was estimated, assuming unsaturated soil conditions.

A stability number [N_s] was calculated for each soil type and for a range of bank angles [I] from 40 to 90 degrees using the relationship Ns = (4 sin I cos f)/(1-cos(I-f)). A critical bank height [H_c] was then calculated as a function of the geometry of the river bank, the soil properties and soil moisture conditions (Figure A-6-16), where $H_c = N_s$ (c/g). Critical bank heights were estimated assuming "worst case" conditions, involving saturated banks and a rapid decline in river stage where the shear strength goes to zero, and unsaturated conditions. Accordingly, the process was repeated using a friction angle of zero to estimated stability under saturated soil conditions.

The resulting bank stability charts (Figures A-6-17 through A-6-20) show relationships between the critical bank height and the bank angle for the major lowland soil series. The upper line on the charts refers to critical bank heights for unsaturated conditions. Bank angles and heights above this line may present "unstable" conditions. The lower line represents critical bank heights for saturated conditions. Bank geometry conditions below this line may present "stable" conditions. Bank geometry conditions between the two lines may present "at risk" conditions for bank stability.

▪ Discussion

A saturated 45 degree bank angle was assumed typical of riverbank slopes during flood conditions in the lowlands and was used to perform a comparison of the relative stability of the lowland riverbanks. The riverbanks with soils having H_c values rated as unstable or at risk were designated as unstable and plotted on a map. Figure A-6-21 provides a sample of the resulting unstable riverbanks for the Wilson and Trask Rivers.

The unstable riverbank reaches generally coincide with the upper reaches of the lowland rivers. These reaches have experienced significant meandering, as observed from the river channel planform change assessment. These reaches of the rivers should be managed by setting back infrastructure and allowing meandering and bank erosion to occur.

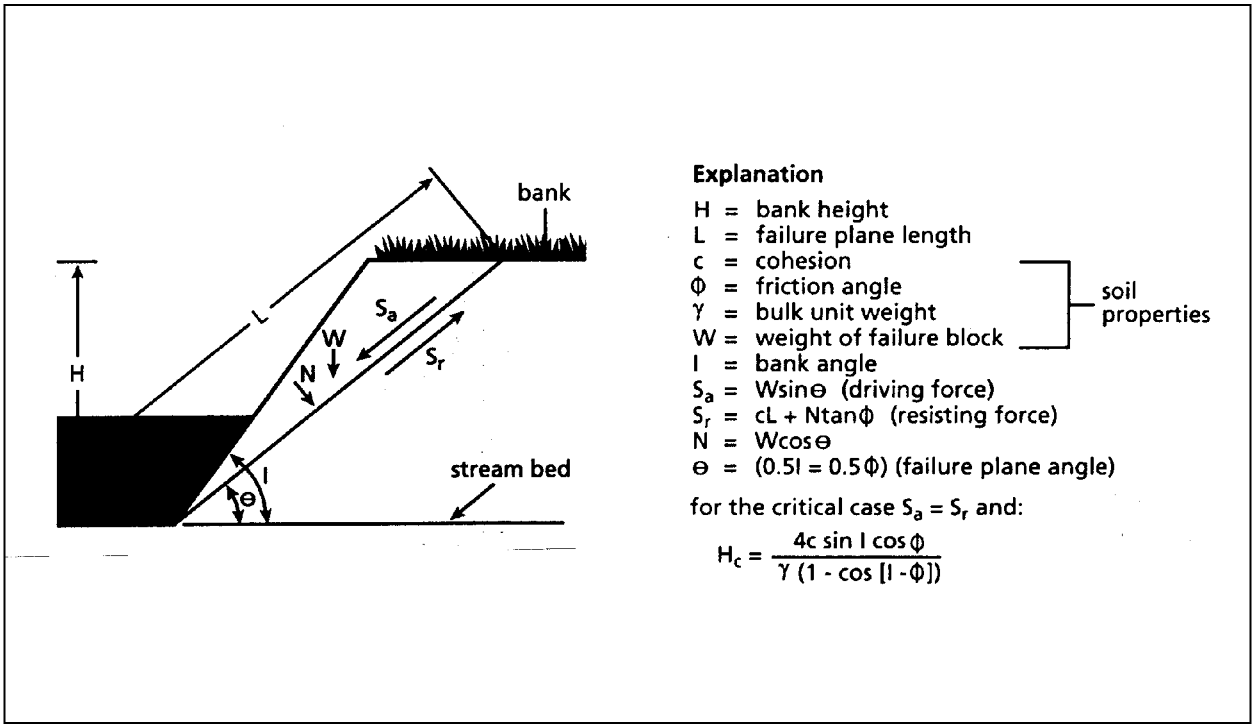


Figure A-6-16. Forces Acting on a Channel Bank Assuming there is Zero Pore-Water Pressure
Bank stability analyses relate strength of bank materials to bank height and angles, and to moisture conditions.

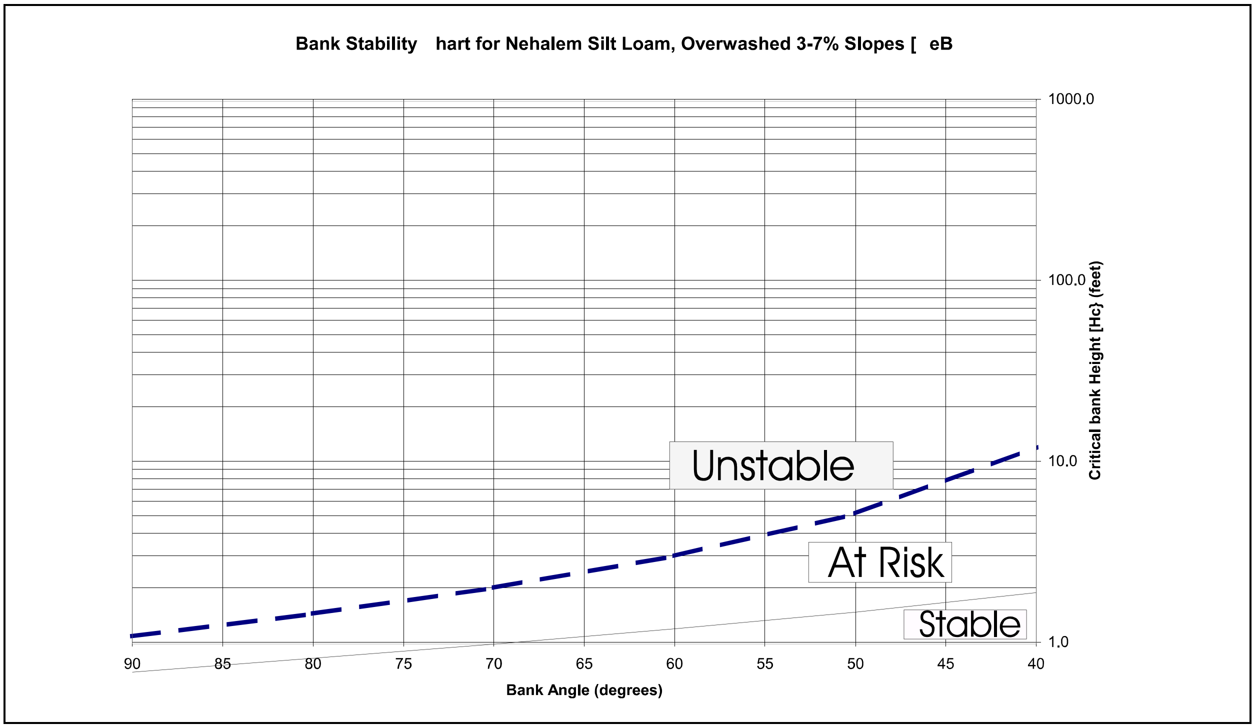


Figure A-6-17. Bank Stability Chart for Nehalem Silt Loam, Overwashed 3-7% Slopes [NeB]

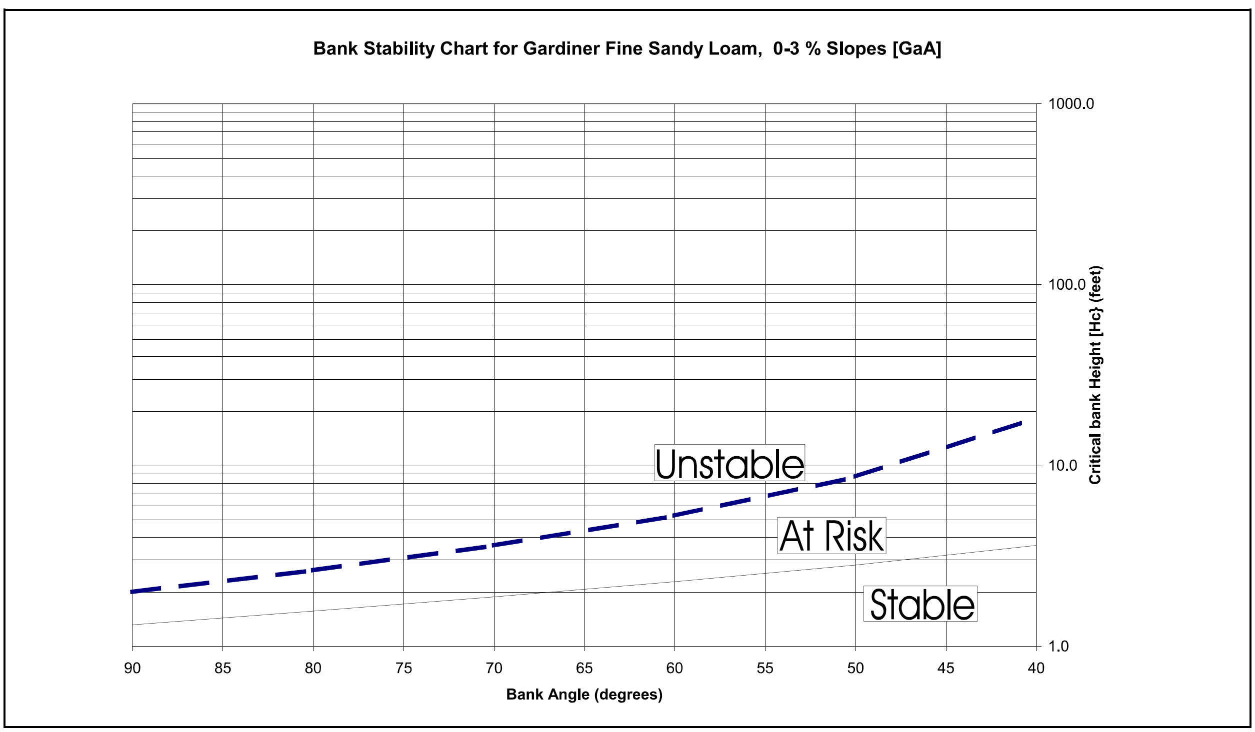


Figure A-6-18. Bank Stability Chart for Gardiner Fine Sandy Loam, 0-3% Slopes [GaA]

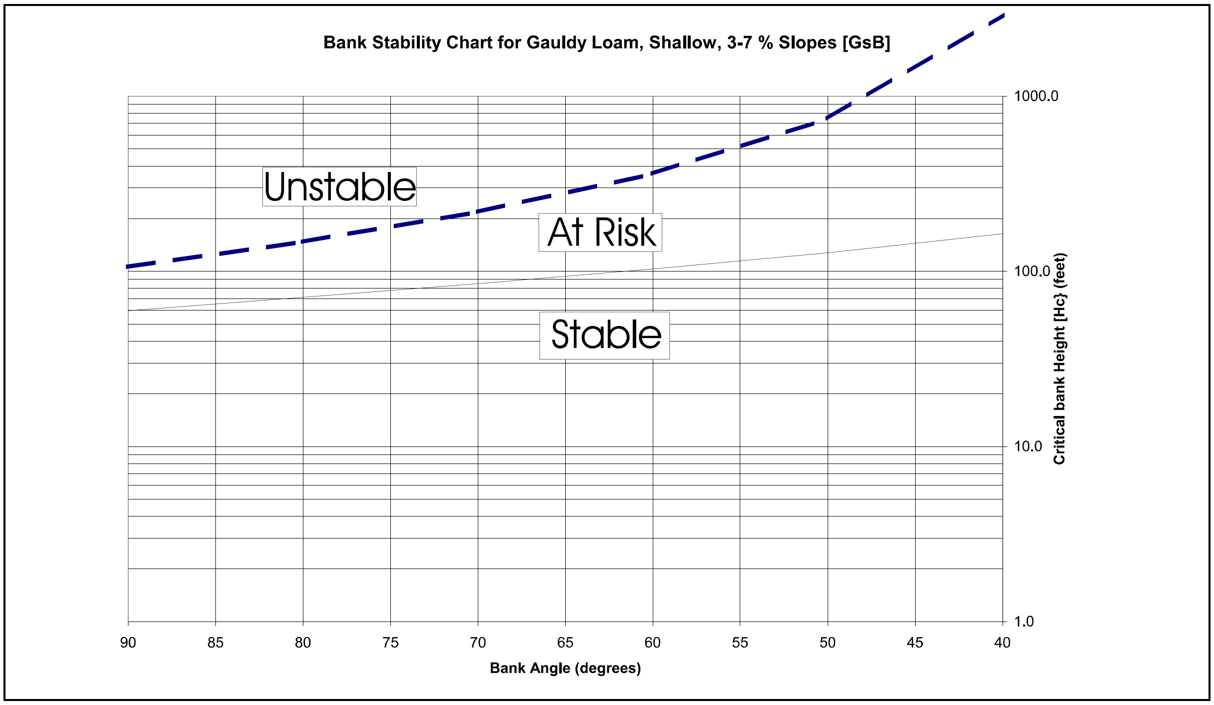


Figure A-6-19. Bank Stability Chart for Gaudy Loam, Shallow, 3-7% [GsB]

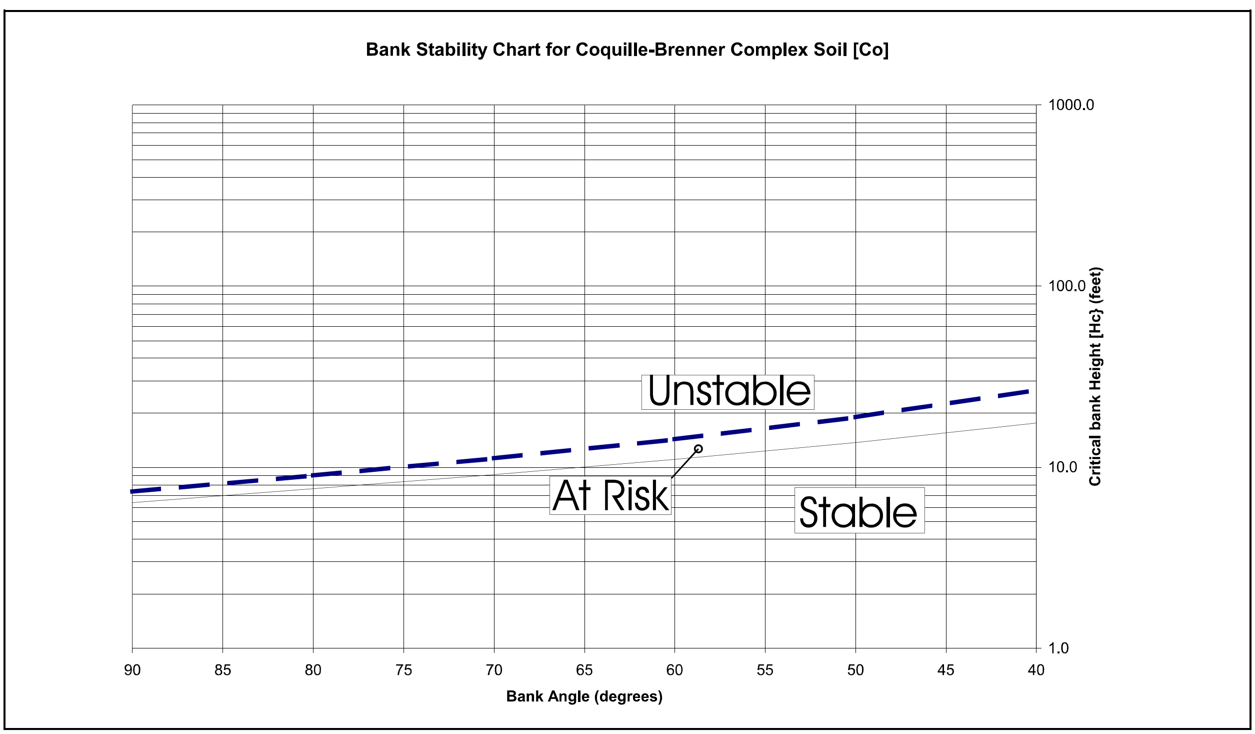


Figure A-6-20. Bank Stability Chart for Coquille-Brenner Complex Soil [Co]

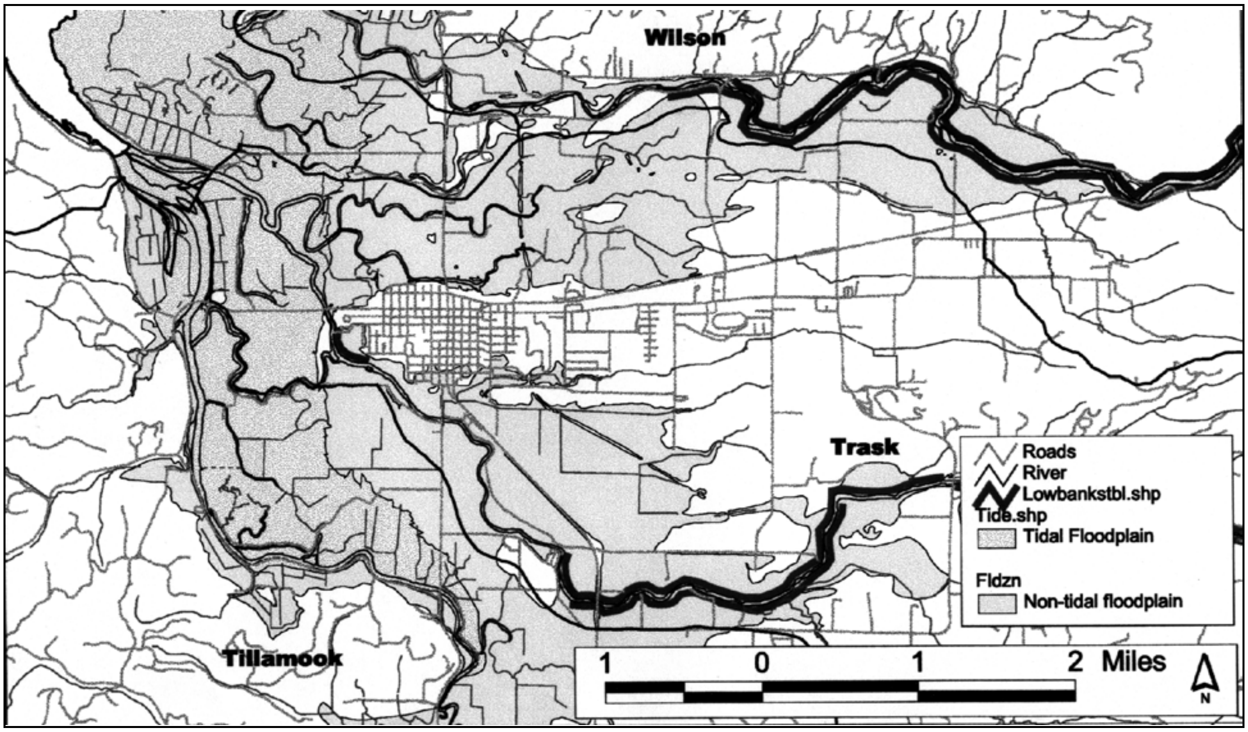


Figure A-6-21. Unstable Riverbanks in the Tillamook Lowlands

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A.7 Salmon Habitat and Distribution

A.7.1 Salmonids in the Tillamook Bay Basin

▪ Objectives

The objective of this assessment was to develop an understanding of the life cycle characteristics of salmonid species native in the Tillamook Basin, their habitat requirements and population dynamics.

▪ Methods

Six different species or races of Pacific salmon are native to Tillamook Bay and its watershed (Kostow et al. 1995). These include chum salmon, coho, spring and fall chinook, winter steelhead, and cutthroat trout. Because the life histories and habitat preferences of these species differ, their temporal and spatial distributions within the basin also vary (Figures A-7-1 and A-7-2). Information on the history of these species within the basin, including catch statistics, spawner counts and hatchery programs, have been compiled by Moore et al. (1995), Coulton et al. (1996), and TBNEP (1998a).

Brief summaries of patterns of salmon use of the Tillamook Bay basin, particularly the lowlands and estuary, were developed, to identify the importance of these areas to each species inhabiting the basin. The information was synthesized from sources listed above and from additional literature on these fish. Relationships between spatial distributions the salmon species within the basin were assessed using GIS data available from the TBNEP. Pertinent GIS layers included CHUM, COHO, CHINFALL, CHINSPRG, STEELHEAD, and TILAHIST.

▪ Discussion

Chum Salmon. In north-coastal Oregon, chum salmon are rarely found very far inland (OSGC, 1961), preferring to spawn in the lower reaches of mainstem rivers or in small floodplain streams tributary to the lower rivers (TBNEP, 1998b). Chum are also known to spawn in the upper intertidal reaches of rivers, streams, and sloughs. They have the shortest period of freshwater residency of any salmon found in Oregon and move quickly to estuarine rearing areas after emergence. These areas include tidal creeks and sloughs that allow chum fry access to key feeding areas in estuarine marshes. Studies in other estuaries have shown that juvenile chum salmon spend up to about a month in estuarine environments before moving toward the open ocean (Simenstad and Salo, 1982). Of the salmon in Tillamook Bay, chum are those most closely associated with the lowlands, which account for about 65% of their current geographic distribution upstream of the estuary (Figure A-7-3).

Coho Salmon. With their preference for slow-flowing habitats, off-channel areas, and the cover provided by woody debris, coho may be found in low to moderate gradient streams within all but the smallest Tillamook Bay watersheds (Figure A-7-4). Juveniles of the species frequently spend at least a portion of their one-year stay in freshwater in side-channels, beaver ponds, lowland sloughs or varied floodplain habitats. Under natural conditions, coho use of aquatic habitats in the Tillamook Bay lowlands would have been both extensive and intensive. In fact, the productivity of sub-populations of coho that spawn in upper portions of the basin may have been substantially enhanced by their ability to overwinter as juveniles in off-channel habitats in the Tillamook Bay lowlands. At present, lowland channels are thought to account for about 25% of the geographic distribution of coho within the stream network draining into the bay.

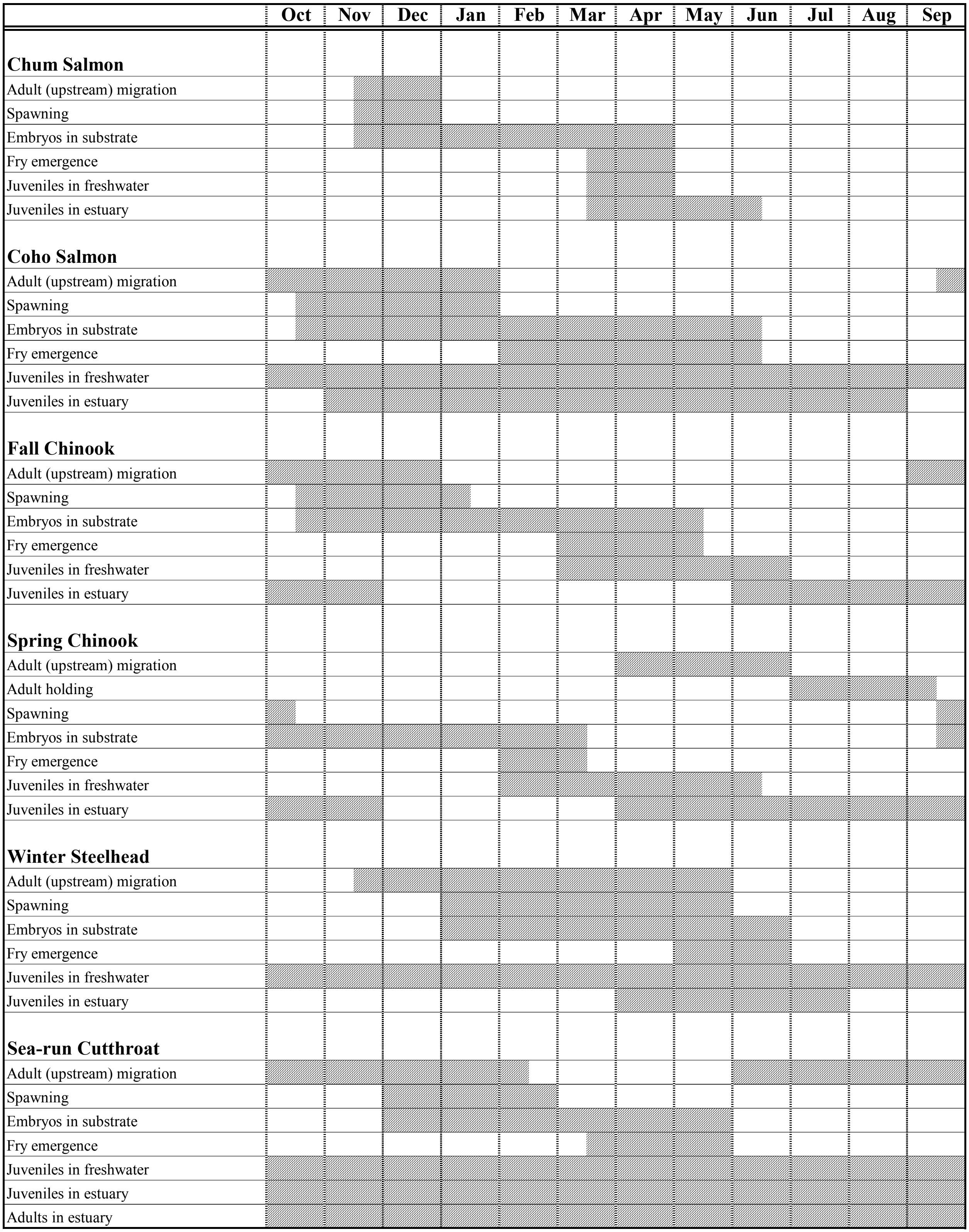


Figure A-7-1. Seasonal Patterns in the Life Cycles of Tillamook Bay's Anadromous Salmonids

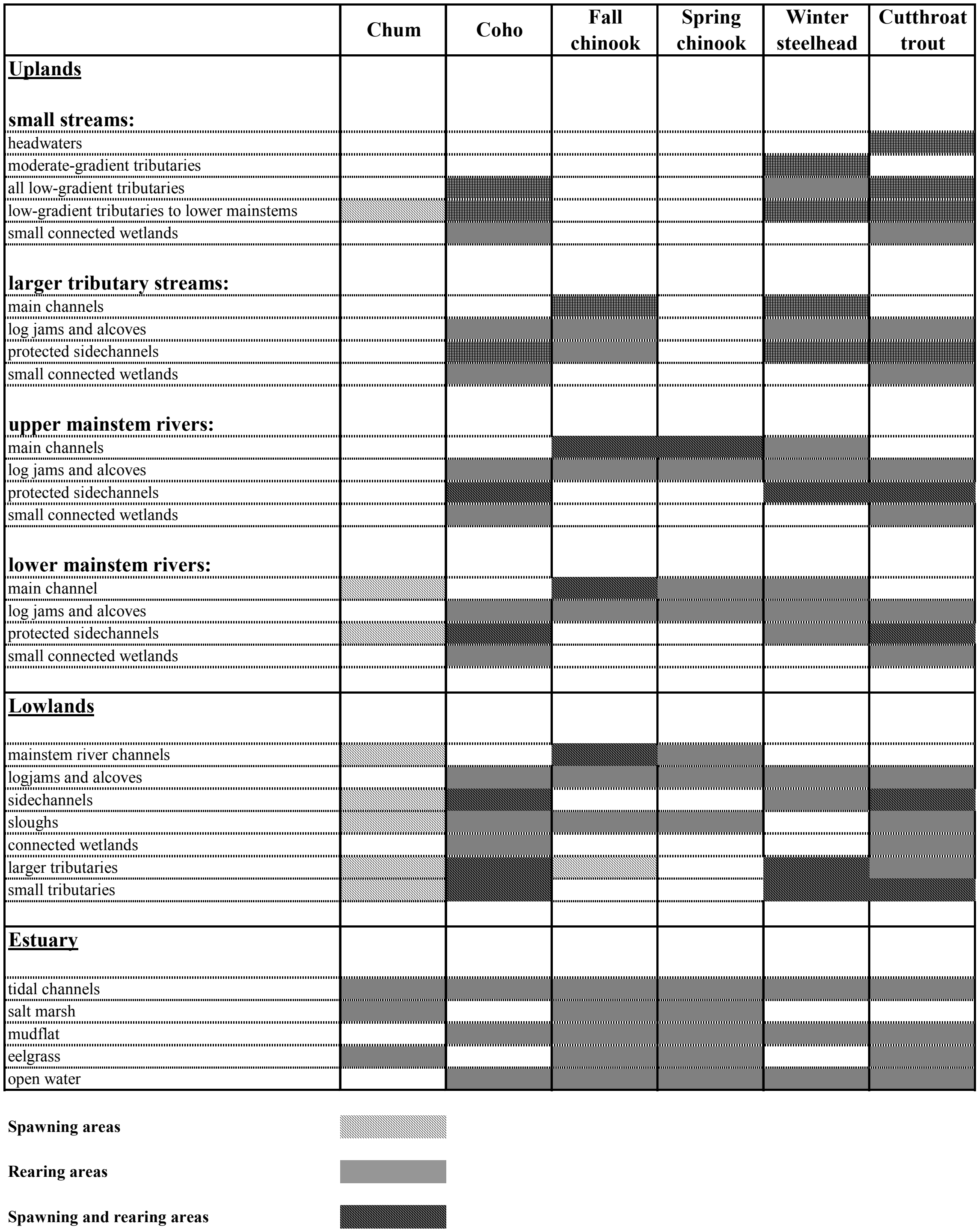


Figure A-7-2. Historic Spawning and Rearing Areas for Salmon and Trout in Tillamook Bay's Uplands, Lowlands, and Estuary

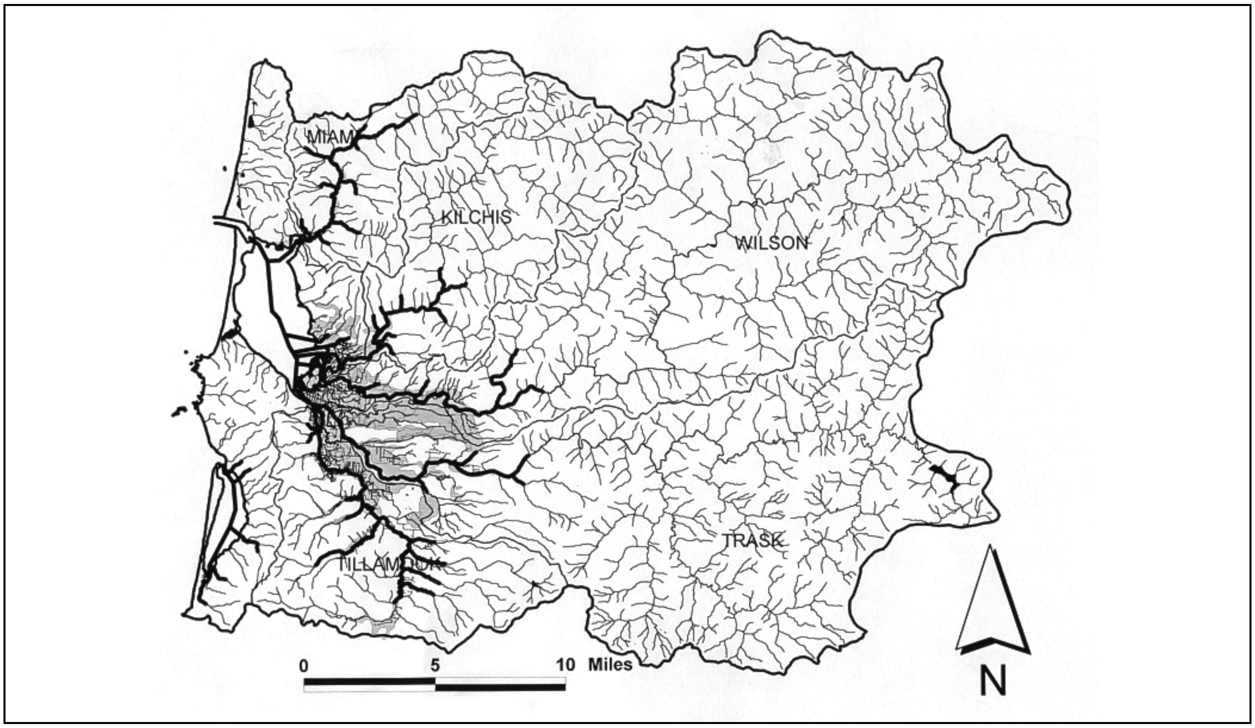


Figure A-7-3. Chum Salmon

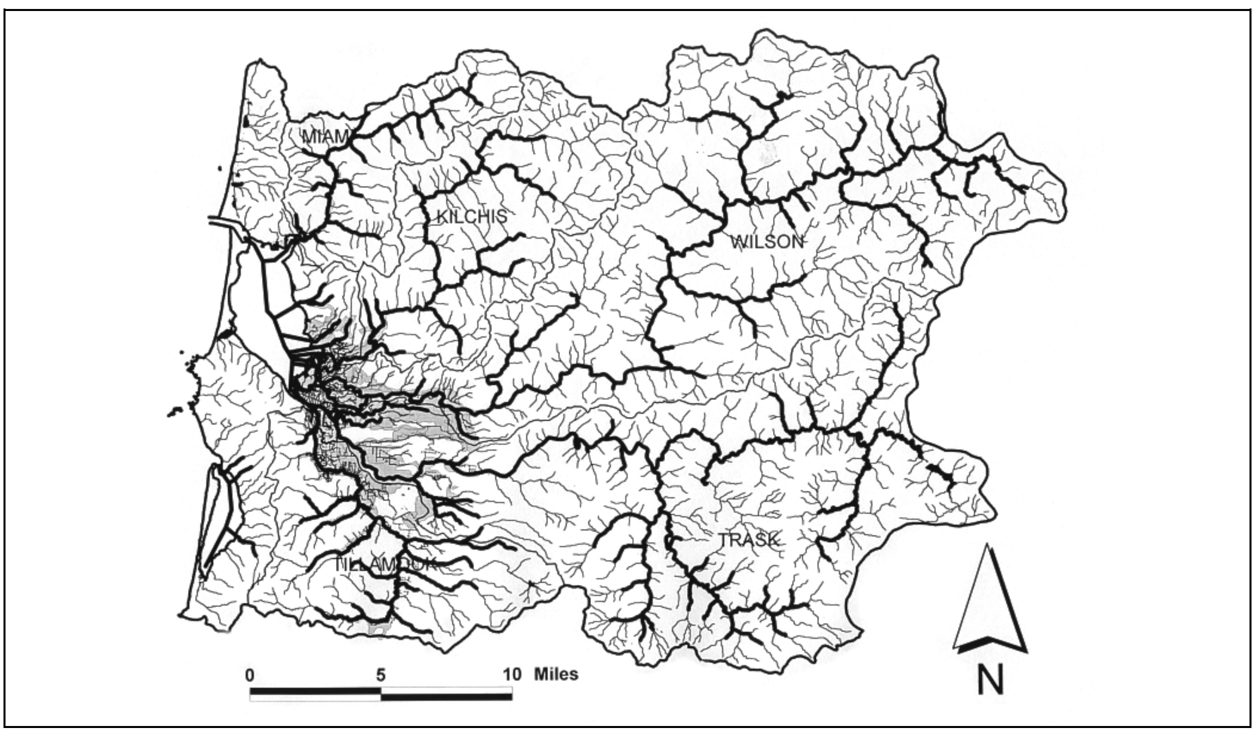


Figure A-7-4. Coho Salmon

Spring Chinook. Spring chinook are native to the Trask, Wilson, and Kilchis river systems (Nicholas and Hankin 1988), but their distributions within these watersheds are generally restricted to mainstem channels and a couple of the largest tributaries (Figure A-7-5). Lowland channels account for approximately 35% of the distribution of this species within the basin. Adult spring chinook migrate up the three rivers toward their upland spawning areas during the spring or early summer, hold during summer in pools that will be inaccessible to fall chinook until water levels rise after late fall rains, and spawn near their holding pools during the early fall. After emerging from the gravel during mid- to late winter, most juvenile spring chinook spend up to several months rearing in freshwater followed by up to six additional months in the estuary. Nicholas and Hankin (1988) note that all of the tidal reaches of Tillamook Bay have the potential to provide important estuarine rearing habitat for juvenile chinook.

Fall Chinook. Fall chinook are native to all five major rivers in the Tillamook Bay basin and differ from spring chinook in that they have a later upstream run (fall), a later spawning period, a wider selection of spawning sites due to differing streamflow conditions, and a later period of fry emergence (late winter or early spring). About 30% of the freshwater channels now used by these fish are found in the basin's lowlands (Figure A-7-6). Historic dependence on these streams may have been greater if the geographic range of fall chinook has expanded in response to the simplification and widening of upland channels. Along with spring chinook, this race of salmon is thought to spend a period of time rearing in the estuary second only to sea-run cutthroat trout. Sub-yearling fish are found throughout the bay at certain times of the year.

Winter Steelhead. Winter steelhead are widely distributed throughout the Tillamook Bay basin and would have been similarly distributed prior to development (Figure A-7-7). Lowland channels appear to account for about 20% of their freshwater distribution within the basin, a smaller percentage than for all of the other salmonids except cutthroat trout. Winter steelhead migrate upstream toward freshwater spawning areas from late fall through early spring, spawn in a diversity of stream channels during winter and spring, and emerge from spawning gravels as fry in late spring. Juveniles spend from one to three years rearing in freshwater, generally preferring tributary streams and areas with complex cover, before making a springtime migration to the estuary as smolts. These smolts move quickly through the estuary and out to sea.

Sea-Run Cutthroat Trout. Cutthroat trout are the most widely distributed salmonids in the Tillamook Bay basin. They exhibit both migratory and non-migratory life histories, and are typically the only salmonids found in the basin's steep headwater streams. Mature sea-run cutthroat trout migrate upstream toward freshwater spawning areas during summer and fall, then spawn in small first- and second-order streams in winter. Sea-run cutthroat fry emerge from spawning gravels in late winter or spring, then rear in small freshwater streams for two to four years before making a springtime migration toward the ocean as smolts. Under historical conditions, substantial numbers of these fish would have reared in small streams within the Tillamook Bay lowlands. Both juveniles and adults of the species commonly rear for extended periods in estuaries.

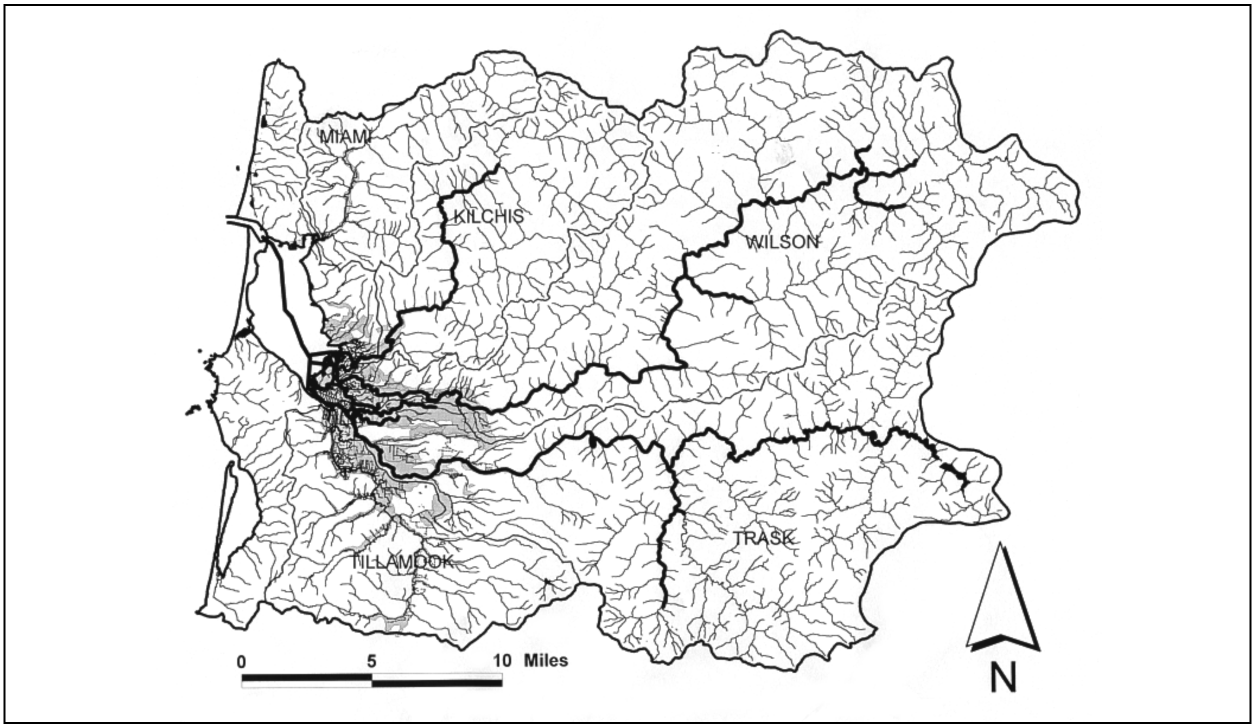


Figure A-7-5. Spring Chinook

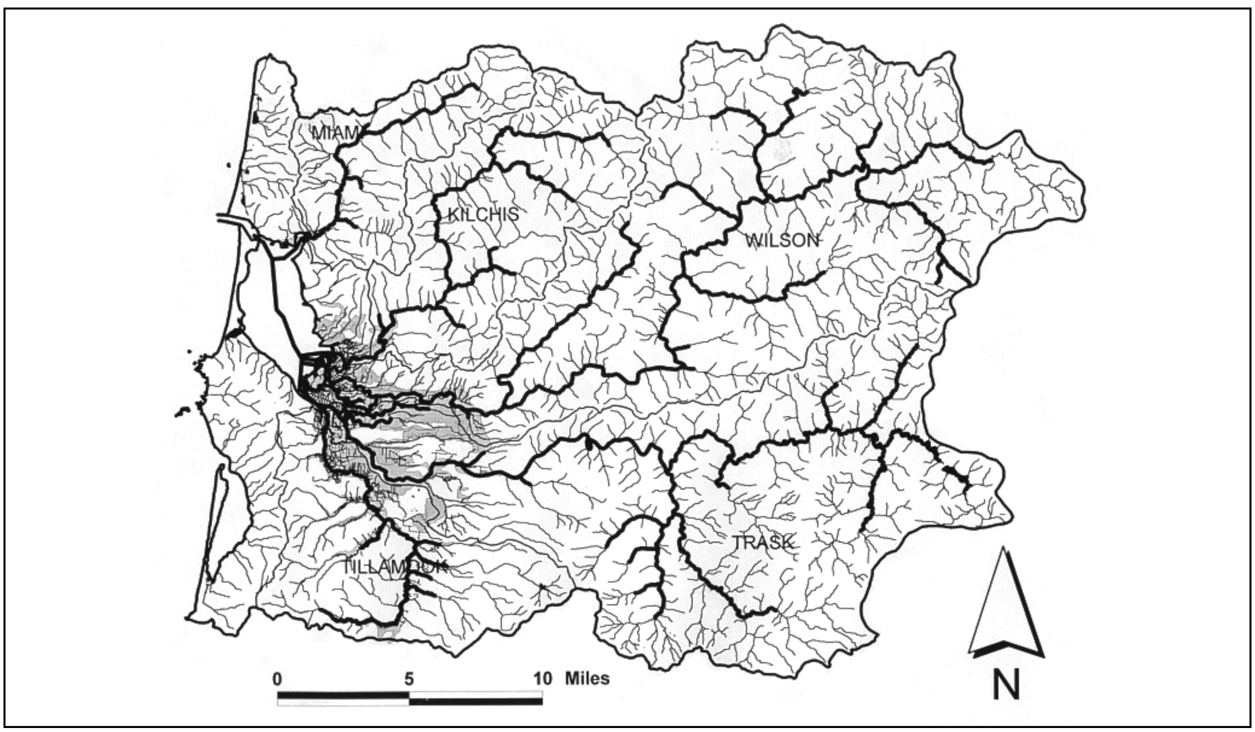


Figure A-7-6. Fall Chinook

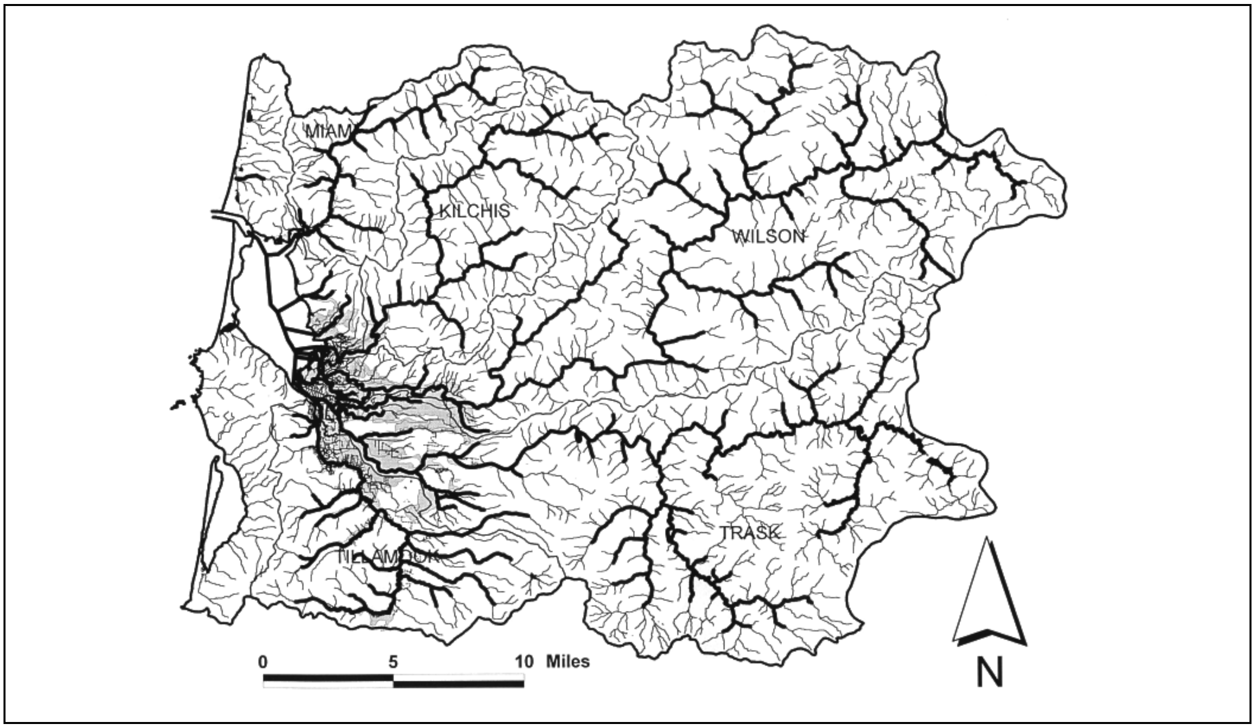


Figure A-7-7. Winter Steelhead

A.7.2 Historic Salmon Abundance

▪ Objectives

The objective of this assessment was to develop an understanding of the historic salmon production on the Oregon Coast and how production in the Tillamook Bay Basin compared to other coastal basins.

▪ Methods

We examined data that Cobb (1930) summarized on the annual pack of salmon at canneries that operated at the turn of the century on Tillamook Bay and within other coastal Oregon basins, then supplemented these data with information on historic gill net catches reported by Cleaver (1951) and Smith (1956). We then examined recent assessments of these data by Lichatowich and Nicholas (1991) and Huntington and Frissell (1997), and drew general conclusions about turn of the century salmon production in Tillamook Bay and how it compared to other coastal basins. Data on the historic abundance of salmon were scaled to drainage basin area, to provide a common basis upon which to compare historic salmon productivity among basins.

▪ Discussion

Historic peaks in annual cannery packs of salmon suggest that at the turn of the century the Tillamook Bay basin was the most productive salmon producer in the Oregon Coast Range (Figure A-7-8). Not only was the area highly productive for salmon, but it differed from other coastal river basins within the Coast Range in that the most abundant species was chum and not coho salmon. This historical dominance of chum salmon has been overlooked in most retrospective assessments of the Tillamook Bay ecosystem. Lichatowich and Nicholas (1991) suggest that at the turn of the century the Tillamook Bay basin produced coho salmon at a rate (about 310 adults/mi^2/yr) equal to or higher than most other basins in the Oregon Coast Range. Huntington and Frissell (1997) estimated that the basin's capacity to produce chum salmon (apparently more than 610 adults/mi^2/yr, double the number of coho) was far greater than that of other river basins in coastal Oregon. Aquatic habitats within the basin have also been quite productive for other anadromous salmonids. Available data suggest that the basin was at or near the upper end of the range of Oregon's coastal basins in productivity for chinook salmon and for winter steelhead, although both of these species were less abundant than chum and coho.

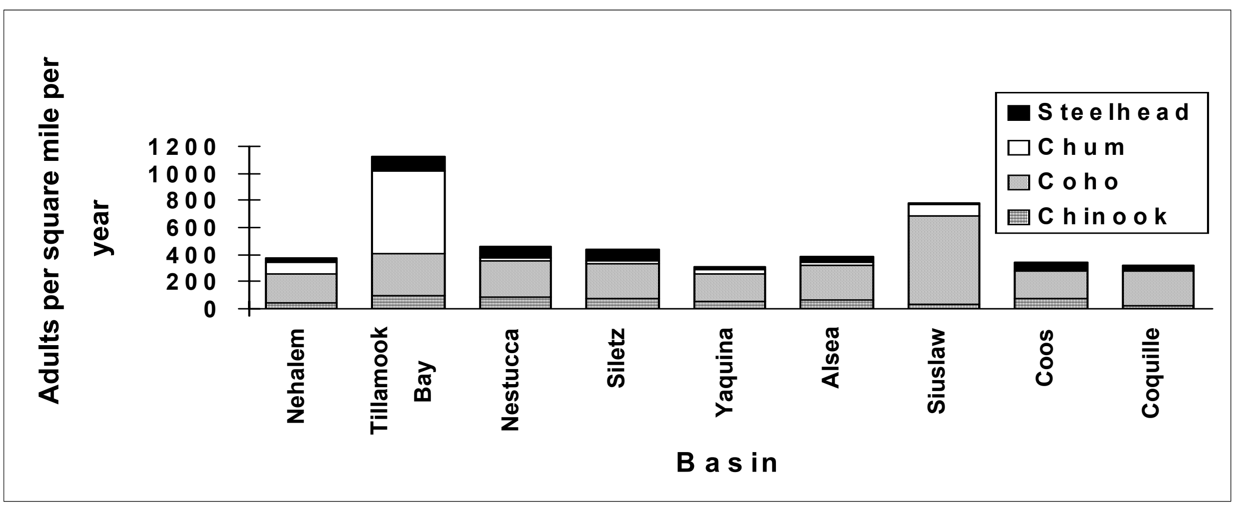


Figure A-7-8. Catch-Based estimates of Historic (c. 1900) Pacific Salmon Production in Nine Coastal Oregon River Basins. Adapted from Huntington and Frissell 1997.

A.7.3 Changes in Salmon Abundance

■ Objectives

The objective of this assessment was to document what is known about the recent and historic changes in salmon abundance.

The status of wild salmon populations within a basin is often considered an indicator of environmental health. Salmon declines in coastal Oregon and elsewhere in the Pacific Northwest have had many causes, including degradation and loss of freshwater and estuarine habitats, over-harvesting, and losses of genetic integrity due to the effects of hatchery practices and introductions of non-local stocks (Nehlsen et al., 1991; Kostow et al., 1995; OCSRI, 1997). These factors have often acted in concert, but the loss, degradation, and fragmentation of habitat have been those most frequently recognized as responsible for the declines (Nehlsen et al., 1991). Natural cycles in oceanic productivity also affect the abundance of Oregon's salmon (Bottom et al., 1986; Nickelson, 1986; Pearcy, 1992). These cycles complicate salmon management (Lichatowich, 1996), and make declining productivity of freshwater and estuarine habitats particularly troublesome for salmon during periods of low oceanic productivity (Lawson, 1995).

■ Methods

Recent status reviews of Tillamook Bay's multiple species of salmon were referenced. Then, available catch, escapement, harvest rate, and other records were used to reconstruct historic trends in abundance of the basin's wild chum and coho salmon. The reconstruction of abundance trends for these two species extended from 1923, the year the State of Oregon began keeping consistent records of the numbers of salmon caught by commercial fisheries, to the present. The focus is on chum and coho because of the quantitative dominance of these salmon in the historic ecosystem.

■ Discussion

The Current Status of Tillamook Bay Salmon. The status of various species of Tillamook Bay salmon has been reviewed by Nehlsen *et al.* (1991), Nickelson *et al.* (1992), ODFW (1995), Huntington *et al.* (1996), Huntington and Frissell (1997), multiple investigators from the National Marine Fisheries Service, and Ellis (1998). A general synthesis of these reviews, based largely on the assessment of Ellis (1998), is given in Table A-7-1. Natural production of all species of salmon in the Tillamook Bay basin except fall chinook has declined during this century, with chum and coho salmon exhibiting the greatest reductions in numbers.

A full explanation of why Tillamook Bay's fall chinook are doing well is unavailable, but historic catch statistics suggest they became consistently more abundant than the basin's spring chinook after the mid-1930s. Gharrett and Hodges (1950) reported that they were doing better than most other fall chinook stocks on the Oregon Coast as far back as the late 1940s. Huntington and Frissell (1997) suggested that factors contributing to the currently robust status of the basin's fall chinook may include: colonization of tributaries inaccessible to them before stream channels became simplified; use of habitats least vulnerable to land use impacts or left vacant by declining salmon species; factors of ocean feeding locations, harvest patterns, and partial recovery of the Tillamook Burn.

TABLE A-7-1. Current Status of Wild Anadromous Salmonids in the Tillamook Bay Basin, Oregon

Species/race	Status	Recent population trends[1]
Chum salmon	**severely depressed (two or more orders of magnitude less than historic abundance)**	**declining**
Coho salmon	**severely depressed (two or more orders of magnitude less than historic abundance)**	**declining**
Fall chinook	**healthy (recent abundance has been similar to historic levels, suggesting robust populations)**	**stable or increasing**
Spring chinook	**depressed from historic levels, heavily influenced by hatcherty fish**	**possibly declining**
Winter steelhead	**depressed (perhaps one order of magnitude less than historic abundance), heavily influenced by hatchery fish**	**declining**
Sea-run chutthroat trout	**depressed**	**possibly declining**

Patterns of Decline for Tillamook Bay Chum and Coho Salmon. The reconstruction of post-1923 declines in the abundance of Tillamook Bay chum and coho salmon are given in Figure A-7-8, with changes in stock sizes and spawning escapements shown separately. Abundance of chum salmon appears to have been erratic but relatively high from the mid-1920s until the mid-1940s, when it began experiencing a steep decline from which it has not recovered. Oakley (1966) noted that similar, perhaps less precipitous declines were observed across large areas of the Pacific Northwest at about this same time, and suggested that a climate shift or oceanic factor was largely responsible. Deleterious lowland and watershed conditions that were widespread in the region but particularly severe in the Tillamook Bay basin have also played a role, affecting important spawning and early rearing areas. Chum abundance in the basin rose slightly after all commercial salmon fishing within Tillamook Bay ended in 1961, but began a second period of decline in the late 1970s that continues today. Despite their low abundance by historical standards, chum salmon are more abundant in the Tillamook Bay basin than elsewhere in Oregon. The basin represents the best opportunity for assuring the species' continued presence in the state.

Wild Tillamook Bay coho appear to have declined more slowly than the basin's chum salmon, although by the early 1940s their total numbers (i.e., stock size) had already fallen to less than half those estimated for the turn of the century (<130 adults/mi^2/yr versus about 310 adults/mi2/yr). The basin's production of wild coho declined in an erratic fashion between the late 1930s and late 1950s, then increased during the 1960s and early 1970s in response to highly favorable ocean conditions. Our estimates of this increased wild production (as seen in Figure A-7-8) are inflated to an unknown degree by increases in natural spawning by stray hatchery fish. Much like the chum, coho have declined since the mid-1970s and are now no more than about 1% as abundant as they are estimated to have been at the turn of the century. ODFW (1995) and Nickelson and Lawson (1997) identified Tillamook Bay's coho populations as being among the most severely 'at-risk' of the many ESA-listed populations on the Oregon Coast. Declining habitat quality, periodic downturns in oceanic productivity, and harvest rates that have at times been extraordinarily high for coho salmon, have combined to severely depress the numbers of adult chum and coho salmon reaching spawning grounds within the Tillamook Bay basin since the late 1950s. Research by Cederholm *et al.* (1999) on the role of salmon in cycling marine nutrients back to watersheds suggests that low spawning escapements such as these may themselves have had deleterious effects on the basin's aquatic ecosystems.

Appendix 1. Estimated adult abundance for naturally produced Tillamook Bay coho salmon, 1923-1998.

Year(s)	(A) Peak count of spawners (#/mile)	(B) Mean AUC spawners (#/mile)	(C) SRS estimate of total spawners	(D) Number of "natural" spawners Method 1	(E) Method 2	(F) Combined	(G) Adult returns from hatchery releases	(H) TB sport harvest rate	(I) TB coho sport catch	(J) Percent of TB adults "natural"	(K) TB sport catch "natural" coho	(L) TB comm. catch (pounds)	(M) TB comm. catch (# adults)	(N) TB comm. harvest rate	(O) Nat. TB coho before harvest	(P) Ocean harvest rate	(Q) Adult coho in ocean	(R) Adults per unit area of TB Basin (#/sq mi)	adults to bay	adults to spawn	Basin area (sq. mi.)
1923	---	---	---	---	68256	68256	527	0.007	454	0.992	451	**530450**	42436	0.38	110818	0.062	118153	203	190	117	582
1924	---	---	---	---	89940	89940	0	0.009	794	1.000	794	**695140**	55611	0.38	146345	0.083	159552	274	251	155	582
1925	---	---	---	---	63888	63888	516	0.011	712	0.992	706	**498870**	39910	0.38	104183	0.103	116207	200	179	110	582
1926	---	---	---	---	42664	42664	2227	0.013	597	0.950	567	**348490**	27879	0.38	69727	0.119	79171	136	120	73	582
1927	---	---	---	---	53229	53229	1003	0.015	843	0.982	827	**370700**	29656	0.35	83164	0.147	97486	168	143	91	582
1928	---	---	---	---	55432	55432	943	0.017	1004	0.983	987	**386200**	30896	0.35	86798	0.147	101809	175	149	95	582
1929	---	---	---	---	79492	79492	2349	0.020	1643	0.971	1596	**561910**	44953	0.35	124750	0.159	148367	255	214	137	582
1930	---	---	---	---	77085	77085	1217	0.022	1750	0.984	1723	**538820**	43106	0.35	121244	0.176	147122	253	208	132	582
1931	---	---	---	---	50050	50050	1262	0.024	1265	0.975	1234	**353880**	28310	0.35	78898	0.182	96457	166	136	86	582
1932	---	---	---	---	42003	42003	0	0.026	1132	1.000	1132	**290330**	23226	0.35	66361	0.219	84930	146	114	72	582
1933	---	---	---	---	38888	38888	1727	0.028	1188	0.957	1138	**245900**	19672	0.32	58861	0.219	75356	129	101	67	582
1934	---	---	---	---	94187	94187	511	0.031	2991	0.995	2974	**574640**	45971	0.32	142885	0.223	183955	316	246	162	582
1935	---	---	---	---	105204	105204	1096	0.033	3605	0.990	3568	**739740**	59179	0.35	167341	0.272	229914	395	288	181	582
1936	---	---	---	---	52257	52257	301	0.035	1905	0.994	1895	**366580**	29326	0.35	83310	0.227	107725	185	143	90	582
1937	---	---	---	---	67667	67667	1473	0.037	2669	0.979	2612	**483330**	38666	0.35	108121	0.266	147308	253	186	116	582
1938	---	---	---	---	71434	71434	1074	0.039	2971	0.985	2927	**508030**	40642	0.35	114402	0.256	153799	264	197	123	582
1939	---	---	---	---	69637	69637	297	0.042	3031	0.996	3019	**491110**	39289	0.35	111777	0.284	156188	268	192	120	582
1940	---	---	---	---	34214	34214	1536	0.044	1635	0.957	1565	**251630**	20130	0.35	55044	0.334	82675	142	95	59	582
1941	---	---	---	---	24529	24529	1377	0.046	1247	0.947	1181	**182760**	14621	0.35	39553	0.366	62409	107	68	42	582
1942	---	---	---	---	22937	22937	851	0.048	1202	0.964	1159	**168200**	13456	0.35	37070	0.314	54009	93	64	39	582
1943	---	---	---	---	12079	12079	1269	0.050	707	0.905	640	**94600**	7568	0.35	19567	0.299	27921	48	34	21	582
1944	---	---	---	---	39217	39217	1099	0.052	2233	0.973	2172	**286390**	22911	0.35	63676	0.294	90145	155	109	67	582
1945	---	---	---	---	48149	48149	329	0.055	2803	0.993	2784	**345160**	27613	0.35	78359	0.278	108529	186	135	83	582
1946	---	---	---	---	20927	20927	1222	0.057	1335	0.945	1261	**158060**	12645	0.35	34135	0.338	51587	89	59	36	582
1947	---	---	---	---	31630	31630	2637	0.059	**2150**	0.923	1985	**195090**	15607	0.30	48021	0.375	76819	132	83	54	582
1948	---	---	---	---	31133	31133	1808	0.046	**1600**	0.945	1512	**185040**	14803	0.30	46636	0.366	73599	126	80	53	582
1949	---	---	---	---	27406	27406	736	0.047	**1400**	0.974	1363	**158260**	12661	0.30	41099	0.397	68192	117	71	47	582
1950	**8.2**	---	---	7528	14272	10761	786	0.049	769	0.932	716	**84790**	6783	0.30	21071	0.394	34772	60	36	18	582
1951	**23.3**	---	---	21389	20530	20564	2296	0.050	1195	0.900	1075	**141300**	11304	**0.32**	31777	0.461	58951	101	55	35	582
1952	**13.1**	---	---	12026	33534	22557	698	0.051	1836	0.970	1781	**193220**	15458	0.30	49980	0.547	110310	190	86	39	582
1953	**15.9**	---	---	14596	12981	13518	645	0.052	749	0.954	715	**73390**	5871	**0.29**	19324	0.740	74333	128	33	23	582
1954	**2.6**	---	---	2387	14846	8572	423	0.053	859	0.953	819	**86400**	6912	0.30	21957	0.713	76499	131	38	15	582
1955	**6.1**	---	---	5600	13054	9223	606	0.054	786	0.938	738	**77390**	6191	0.30	19365	0.691	62710	108	33	16	582
1956	**5.9**	---	---	5416	20334	12775	267	0.056	1213	0.980	1188	**116860**	9349	0.30	30525	0.743	118877	204	52	22	582
1957	**3.1**	---	---	2846	---	2846	129	0.057	179	0.957	82	**9540**	763	---	3658	0.786	17071	29	6	5	582
1958	**2.8**	---	---	2570	---	2570	1347	0.058	241	0.656	76	**12900**	1032	---	3324	0.820	18507	32	6	4	582
1959	**9.0**	---	---	8262	---	8262	144	0.059	528	0.983	259	**9900**	792	---	9299	0.724	33749	58	16	14	582
1960	**8.0**	---	---	7344	---	7344	1725	0.060	582	0.810	436	**4410**	353	---	8065	0.698	26698	46	14	13	582
1961	**20.6**	---	---	18911	---	18911	1433	0.061	1333	0.930	983	**11910**	953	---	20779	0.720	74294	128	36	32	582
1962	**23.1**	---	---	21206	---	21206	4084	0.063	1691	0.839	1134	**0**	**0**	---	22340	0.670	67678	116	38	36	582
1963	**19.2**	---	---	17626	---	17626	6044	0.064	1614	0.745	723	**0**	**0**	---	18349	0.796	89880	154	32	30	582
1964	**32.2**	---	---	29560	---	29560	13406	0.065	2987	0.688	1041	**0**	**0**	---	30600	0.696	100684	173	53	51	582
1965	**11.9**	---	---	10924	---	10924	9077	0.066	1418	0.546	715	**0**	**0**	---	11639	0.706	39553	68	20	19	582
1966	**16.0**	---	---	14688	---	14688	6527	0.067	1532	0.692	402	**0**	**0**	---	15090	0.636	41459	71	26	25	582
1967	**31.8**	---	---	29192	---	29192	16556	0.069	3366	0.638	1866	**0**	**0**	---	31058	0.731	115445	198	53	50	582
1968	**18.6**	---	---	17075	---	17075	8095	0.070	**1886**	0.678	1279	**0**	**0**	---	18354	0.770	79898	137	32	29	582
1969	**7.5**	---	---	6885	---	6885	9223	0.129	**2384**	0.427	1019	**0**	**0**	---	7904	0.698	26146	45	14	12	582
1970	**26.5**	---	---	24327	---	24327	11969	0.050	**1921**	0.670	1288	**0**	**0**	---	25615	0.639	71021	122	44	42	582
1971	**25.5**	---	---	23409	---	23409	10895	0.055	**1994**	0.682	1361	**0**	**0**	---	24770	0.812	131888	227	43	40	582
1972	**10.0**	---	---	9180	---	9180	8291	0.051	**940**	0.525	494	**0**	**0**	---	9674	0.832	57700	99	17	16	582
1973	**30.6**	---	---	28091	---	28091	8304	0.042	**1580**	0.772	1219	**0**	**0**	---	29310	0.810	154031	265	50	48	582
1974	**29.2**	---	---	26806	---	26806	9990	0.041	**1569**	0.729	1143	**0**	**0**	---	27949	0.825	160036	275	48	46	582
1975	**15.9**	---	---	14596	---	14596	1433	0.048	**809**	0.911	737	**0**	**0**	---	15333	0.801	77073	132	26	25	582
1976	**10.3**	---	---	9455	---	9455	24071	0.060	**2138**	0.282	603	**0**	**0**	---	10058	0.892	93219	160	17	16	582
1977	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---			
1978	**10.0**	---	---	9180	---	9180	2617	0.047	**579**	0.778	451	**0**	**0**	---	9631	0.812	51224	88	17	16	582
1979	**9.7**	---	---	8905	---	8905	3930	0.024	**312**	0.694	216	**0**	**0**	---	9121	0.778	41016	70	16	15	582
1980	**5.9**	---	---	5416	---	5416	6399	0.044	**541**	0.458	248	**0**	**0**	---	5664	0.715	19878	34	10	9	582
1981	**17.7**	**24.9**	---	7420	---	7420	2177	0.049	**494**	0.773	382	**0**	**0**	---	7802	0.806	40240	69	13	13	582
1982	**16.7**	**29.0**	---	8642	---	8642	2987	0.133	**1789**	0.743	1330	**0**	**0**	---	9972	0.615	25868	44	17	15	582
1983	**2.3**	**3.9**	---	1162	---	1162	2832	0.052	**221**	0.291	64	**0**	**0**	---	1227	0.795	5979	10	2	2	582
1984	**16.7**	**24.5**	---	7301	---	7301	10315	0.128	**2597**	0.414	1076	**0**	**0**	---	8377	0.310	12147	21	14	13	582
1985	**16.7**	**28.0**	---	8344	---	8344	**4539**	0.095	**1357**	0.394	534	**0**	**0**	---	8878	0.429	15545	27	15	14	582
1986	**14.7**	**22.7**	---	6765	---	6765	**6187**	0.240	**4092**	0.276	1128	**0**	**0**	---	7893	0.327	11728	20	14	12	582
1987	**6.1**	**7.1**	---	2116	---	2116	**1245**	0.182	**749**	0.450	337	**0**	**0**	---	2453	0.592	6006	10	4	4	582
1988	**8.1**	**9.1**	---	2712	---	2712	**5321**	0.213	**2169**	0.163	354	**0**	**0**	---	3066	0.554	6877	12	5	5	582
1989	**12.5**	**6.9**	---	2056	---	2056	**10174**	0.127	**1777**	0.065	115	**0**	**0**	---	2171	0.541	4731	8	4	4	582
1990	**1.8**	**1.4**	**265**	265	---	265	**5817**	0.147	**1049**	0.044	46	**0**	**0**	---	311	0.667	933	2	1	0	582
1991	**2.7**	**2.9**	**3000**	3000	---	3000	**5400**	0.509	**8698**	0.357	3106	**0**	**0**	---	6106	0.438	10867	19	10	5	582
1992	**.2**	**1.9**	**261**	261	---	261	**3164**	0.193	**821**	0.076	63	**0**	**0**	---	324	0.517	670	1	1	0	582
1993	**.2**	**1.5**	**860**	860	---	860	---	---	---	---	---	**0**	**0**	---	860	0.423	1490	3	1	1	582
1994	**6.1**	**17.5**	**652**	652	---	652	---	---	---	---	---	**0**	**0**	---	652	0.023	667	1	1	1	582
1995	**2.5**	**10.9**	**289**	289	---	289	---	---	---	---	---	**0**	**0**	---	289	0.228	374	1	0	0	582
1996	**.9**	**3.1**	**661**	661	---	661	---	---	---	---	---	**0**	**0**	---	661	0.140	769	1	1	1	582
1997	**1.3**	**1.7**	**388**	388	---	388	---	---	---	---	---	**0**	**0**	---	388	0.125	443	1	1	1	582
1998	**2.2**	**1.3**	**312**	312	---	312	---	---	---	---	---	**0**	**0**	---	312	0.065	334	1	1	1	582

(A): Mean peak count (adults/mile)for Cedar Cr. and Devils Lk. Fk. Index areas (StreamNet 1999). **(B):** Mean AUC spawners (adults/mile) for Cedar Cr. and Devil's Lk. Fk. Index areas (StreamNet 1999). **(C):** SRS estimates for total spawning escapement in the Tillamook Bay Basin (PFMC 1999). **(D):** Method 1 estimates were based on the best-available quantitative index of spawning escapements, estimated as 918xA (mean 1990-98 ratio of C/A) for 1950-1980, 298xB (mean 1990-98 ratio of C/B) for 1981-89, and C for 1990-98. **(E):** Method 2 calculated Natural Spawners = (M/N)-N-I-G. **(F):** Escapements estimated by Method 1 (1923-49), as the average of Methods 1 and 2 (1950-56), and by Method 2 (1957-98). **(G):** For 1923-60, all juvenile hatchery fish released were converted to smolt equivalents and then to adults assuming half the SAR rate seen for 1961-93, adjusted for interceptions (0.0466/2); For 1961-1984, estimated by converting all releases to smolt equivalents and assuming the same SAR experienced by fish at Trask Hatchery (adjusted for interceptions). For 1985-92, known hatchery returns were used in calculation. **(H):** Calculated from values in the table, except that values for 1923-47 assumed zero sport harvest in 1920 and a steady increase in harvest from 1920 to 1948, and values for 1950-67 were assumed to steadily increase from a know value for 1949 to a known value for 1968. **(I):** Data are shown in bold; estimated values were calculated as F-(F/(1-H)). **(J):** Calculated as G/(G+H). **(K):** K = I x J. **(L):** ODFW, Tillamook, OR. **(M):** M = L/12.5. **(N):** Harvest rates from two OSGC studies or as the mean of the two OSGC studies times fishing days in a given year/fishing days in the years of the studies. **(O):** O = M/N. **(P):** For each year during 1923-51, rates were calculated as the average of two values: (1) linearly interpolated estimates assuming zero harvest in 1920 and an 0.547 rate in 1952 and (2) estimates derrived by assuming a 40% coast-wide gillnet harvest rate and known values for Oregon coastal troll landings plus total coastal gillnet landings. For 1952-91, estimates from Lawson (1992), adjusted for gillnet catches in early years, were used. For 1992-98, PFMC (1999) values adjusted to SRS

Appendix 1. Estimated adult abundance for naturally produced Tillamook Bay coho salmon, 1923-1998.

Year(s)	(A) Peak count of spawners (#/mile)	(B) Mean AUC spawners (#/mile)	(C) SRS estimate of total spawners	(D) Number of "natural" spawners Method 1	(E) Method 2	(F) Combined	(G) Adult returns from hatchery releases	(H) TB sport harvest rate	(I) TB coho sport catch	(J) Percent of TB adults "natural"	(K) TB sport catch "natural" coho	(L) TB comm. catch (pounds)	(M) TB comm. catch (# adults)	(N) TB comm. harvest rate	(O) Nat. TB coho before harvest	(P) Ocean harvest rate	(Q) Adult coho in ocean	(R) Adults per unit area of TB Basin (#/sq mi)	adults to bay	adults to spawn	Basin area (sq. mi.)

escapements were used **(Q):** Q = O/(1-P). **(R):** R = Q/582.

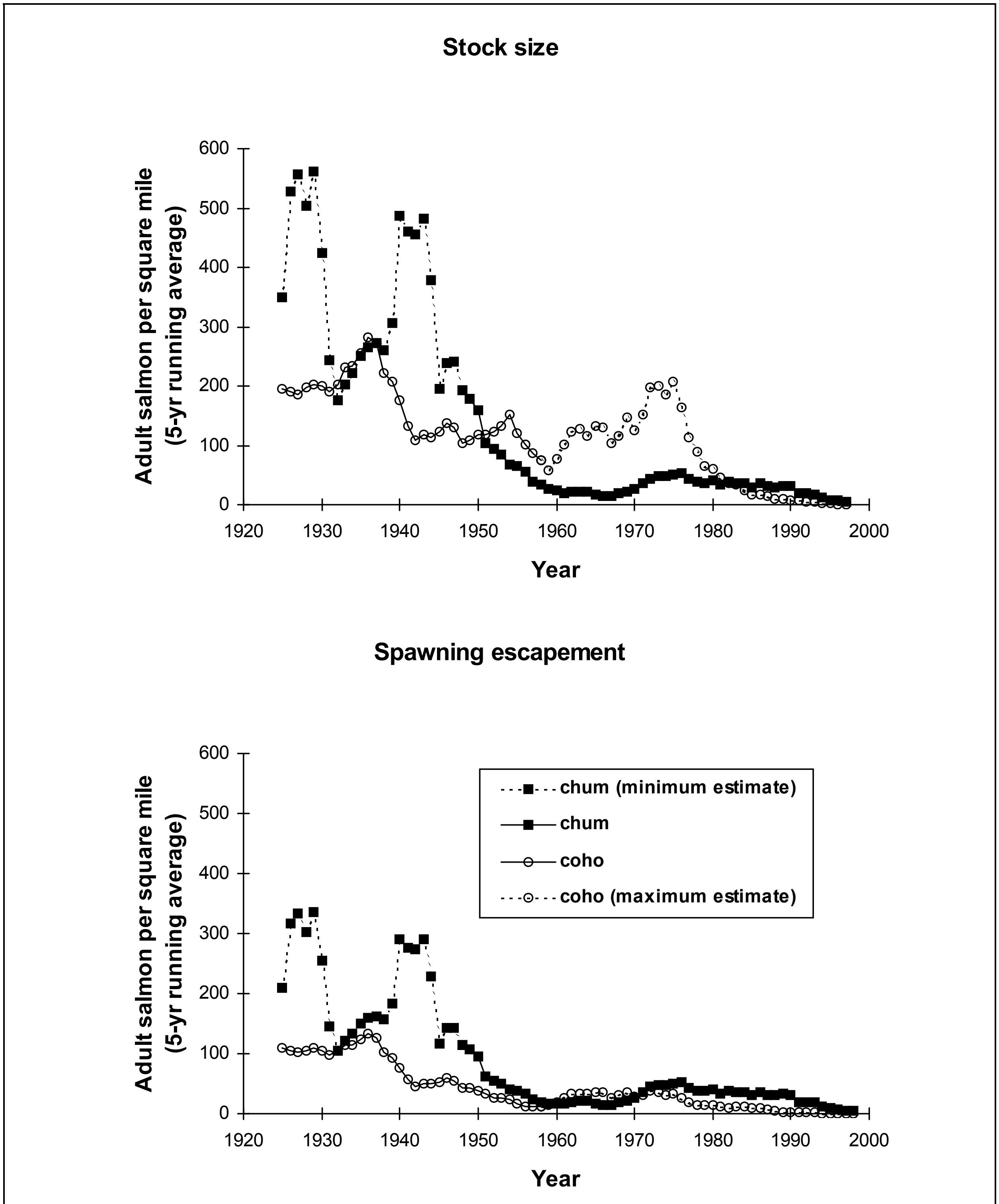


Figure A-7-9. Estimated Declines in Stock Sizes (top) and Spawing Escapements (bottom) for Wild Tillamook Bay Chum and Coho Salmon, 1923-1999. (See Appendix 1 on the following page for more information.)

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

A.8 Human Land Use and Flood Risk

Human land use is directly linked to flood risk and salmon habitat degradation. The economic benefits derived from human land uses are often the primary obstacles to making changes in the policies and practices of floodplain management. This section includes assessments of land ownership and use, stream crossings and diversions, water quality, dikes and levees, and flood damage claims and permits.

A.8.1 Forest Land Ownership

■ Objectives

This assessment maps the general land ownership patterns in the Tillamook Bay Basin. The objective of this assessment was to develop an understanding for the spatial extent and diversity of land ownership. The success of river system management can often be more readily accomplished when landowners are identified and involved early in the planning process.

■ Methods

In order to understand the current upland forest land management conditions, we generalized the ownership categories defined in the TBNEP GIS land ownership coverage. The categories mapped in Figure A-8-1 represent federal, state, county, and private industrial ownership. The private category includes land in agriculture, rural residential, and urban uses as well as private non-industrial forest.

■ Discussion

Each of these land use categories, with the exception of private, is linked to a forest management plan or policy. Federally managed land in the Tillamook Bay Basin represents a small portion of the uplands. The land is managed by either the BLM, the Forest Service, or the US Fish and Wildlife Service. The Northwest Forest Plan affects the use of federally managed public forest land and includes a 300-foot buffer along streams from the ordinary high water line or the upper edge of adjacent wetlands.

State and private industrial lands represent the bulk of the forested uplands in the Basin. The Tillamook State Forest, by far the largest land management area, is the result of the transfer of land to the State following the Tillamook Burns. Both private industrial and state managed land are governed by the Oregon Forest Practices Act (1995) which prescribes an average buffer width of 70 feet along streams, measured from the ordinary high water line or the upper edge of adjacent wetlands. Harvest rotations generally vary between state and private industrial land. State land is on a 100-year rotation while private industrial land is on a 60-year rotation.

The success of an IRMS for the Tillamook Bay lowlands will be based to a large degree on management decisions in the forested uplands. The rate of movement of water, sediment and organic materials from the uplands to lowlands will be dictated by land use actions. The entire basin should be managed in an integrated manner.

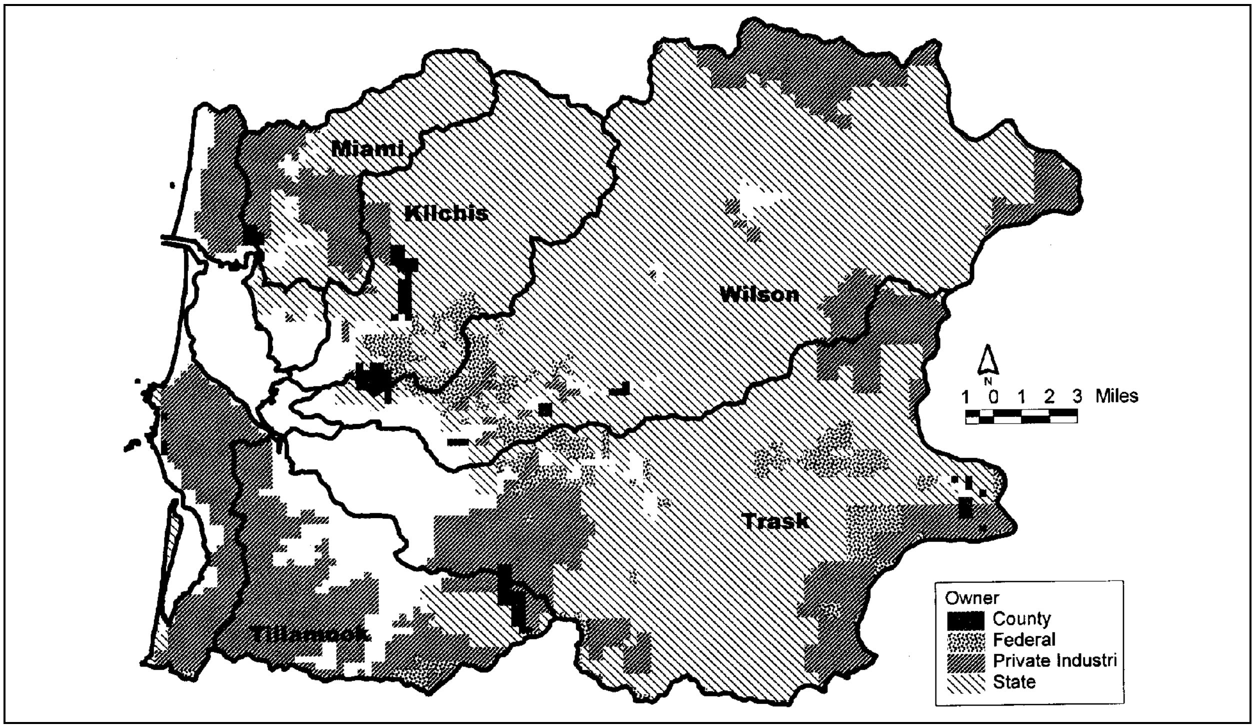


Figure A-8-1. General Ownership of Upland Forest

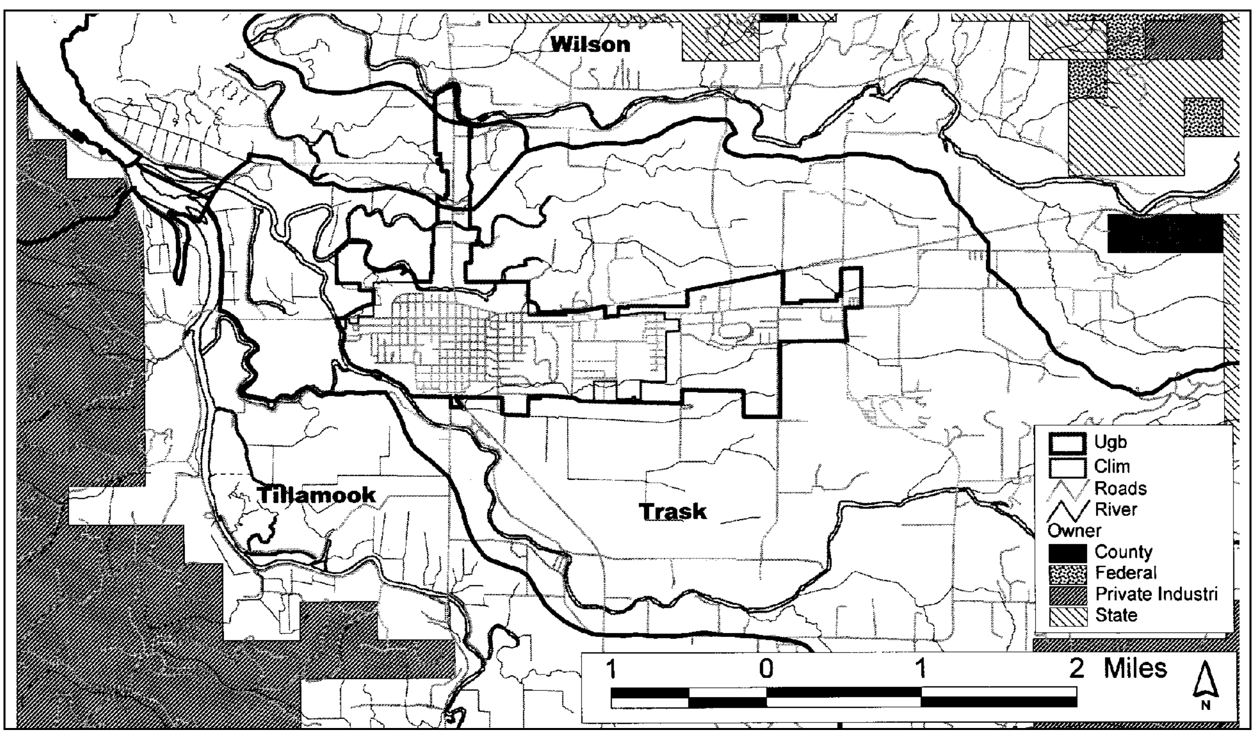


Figure A-8-2. General Ownership of Lowland Forest

A.8.2 Floodplain Land Use and Development

■ Objectives

The extent and type of flood hazards are a reflection of the characteristics of land use occurring within floodplain lands. The objective of the floodplain land use assessment was to characterize the types of human land uses occurring within the regulatory 100-year floodplain in the Tillamook Bay lowland valley areas. Land uses within the floodplain can be linked to flood damage claims and permits and to the policies and programs affecting floodplain development and flood risk mitigation. Understanding the distribution and quantity of land in various uses helps to define management strategies and to identify and prioritize courses of action.

■ Methods

Current Tillamook Bay lowland land use GIS data was obtained from the TBNEP. These data were sorted into the following general land use categories: agriculture, farm buildings, rural residential, rural industrial, and urban. The coverage was then clipped to the extent of the FEMA Q3 100-year floodplain. A detail of the floodplain around Tillamook is mapped in Figure A-8-3. The coverage provides a summary of the acreage of different land use types within the 100-year floodplain of the Tillamook Bay. The resulting land use acreages are presented in a pie chart (Figure A-8-4).

■ Discussion

As expected, agriculture is the predominant land use type within the lowland valley areas. Agriculture in the basin is primarily associated with Tillamook's dairy industry, so most of the agricultural land is used as pasture. Flood risk in this area is primarily livestock health and loss of access to grazing land. Strategies that facilitate post-flood drainage will provide great benefits in this area. This land use includes farm buildings, which represent the smallest land use acreage in the 100-year floodplain. Some of these areas correspond to confined animal feeding operations (CAFOs). These may pose a serious threat to human health and aquatic habitat when exposed to flood water.

There is some rural residential development in the basin. It is clustered along the roads and rivers and may indicate increased damage claim amounts following flood events. Rural industrial use in the basin is primarily gravel extraction and is also clustered along the rivers. Management of these uses should be considered and prioritized based on the intensity of the industrial use versus that of other land uses that cover a greater area of the floodplain.

Urban land use is the second most extensive use in the 100-year floodplain. A large portion of this use is along Highway 101 north of the city of Tillamook. Though the acreage in agricultural use within the 100-year floodplain is twice that of the acreage in urban use, the value per acre of urban land is substantially higher than that of pasture land. This is especially true in Oregon where land use planning confines urban development to urban growth areas. There is, therefore, an increased likelihood of higher damage claims in the urban areas, so efforts to reduce flood risk in urban areas will have a greater overall effect on reducing the total amount spent on damages. Conversely, the relatively small area and short length of stream channels inside urban areas may limit the benefit to salmon created through floodplain management efforts in urban settings. The longer contiguous reaches of river on agricultural lands presents greater opportunities from an aquatic habitat perspective.

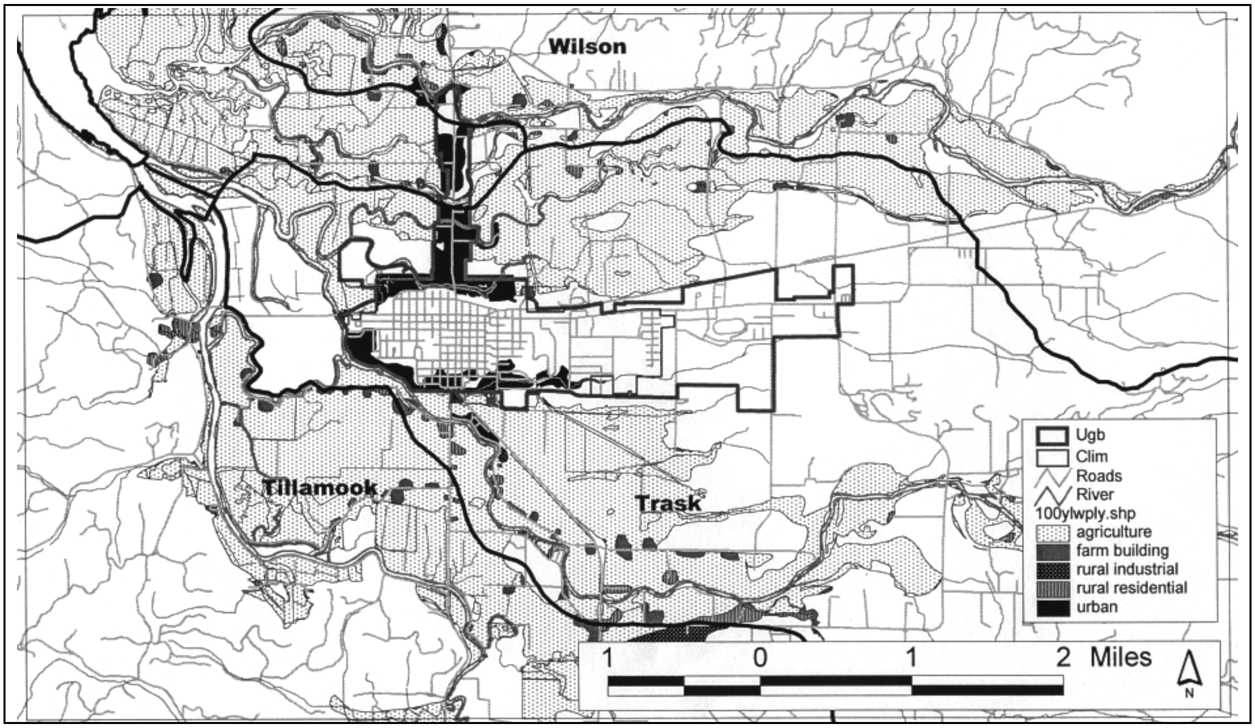


Figure A-8-3. Generalized Land Use within the FEMA 100-Year Floodplain

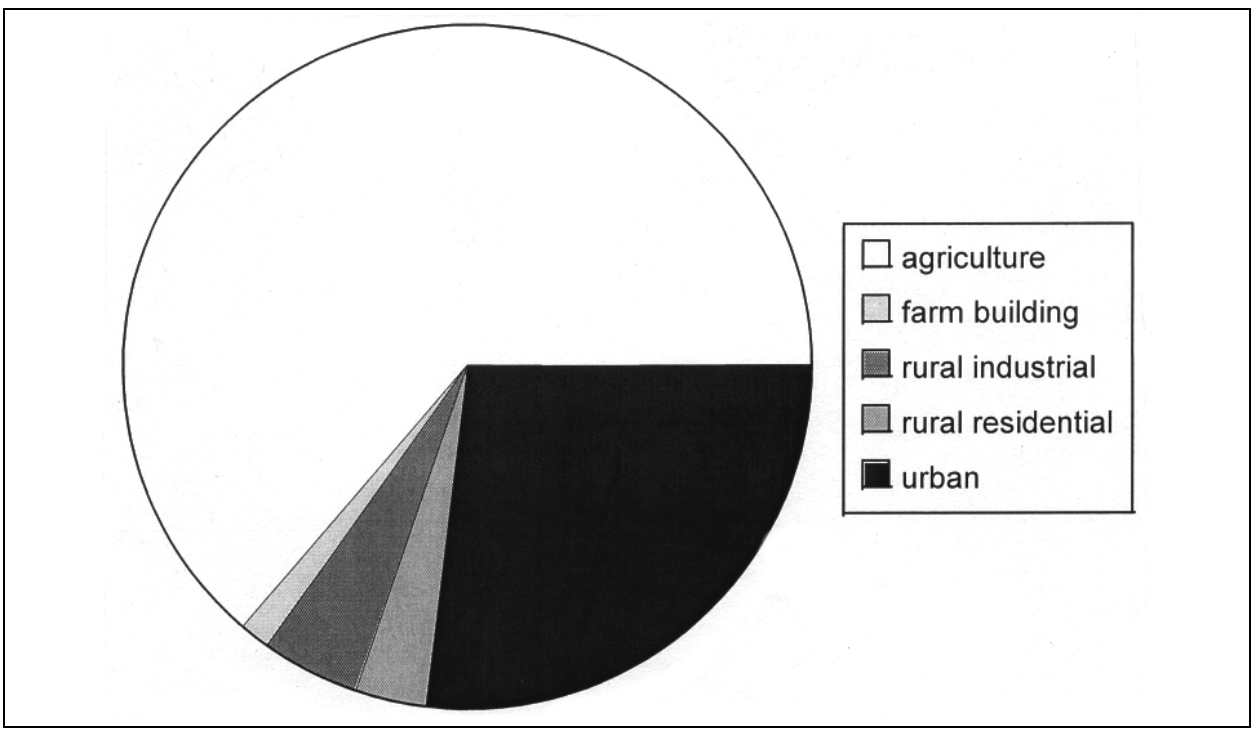


Figure A-8-4. FEMA 100-Year Floodplain Land Use

A.8.3 Stream Crossings

▪ Objectives

The linear characteristics of roads and railroads often result in stream crossings. Traditionally, the most economical method employed for conveying streamflow through a crossing was with the use of a culvert and an earth fill embankment. This technique often restricts the cross-sectional area of a stream and causes changes in flow velocity, leading to unnatural erosion and deposition patterns in the stream, locally and upstream and/or downstream. In many cases, a pool and drop will form downstream of the culvert because of these conditions, creating a barrier to salmon passage, or flow will be concentrated in the culvert and water velocities will be too high for salmon to swim against. Culverts also perform poorly in flood events and can be washed out at high flows, causing localized landslides, especially in steeper sloped upland areas. The objective of this assessment was to identify the location and distribution of stream crossings in the Tillamook Basin and lowlands and evaluate their importance in a river management strategy.

▪ Methods

A GIS coverage of culvert locations in the Tillamook Basin was obtained from the TBNEP (Figure A-8-5). The coverage was created by TBNEP for ODFW and maps all culverts in the Tillamook Basin that are assumed fish barriers. Additional culverts are known to exist within the basin uplands and are associated with state and private forestry roads. These data are being prepared by the Oregon Department of Forestry (ODF); however, they were not yet available during the course of this investigation. The basin mapping is enlarged to show culverts and tide gates in the Tillamook lowlands (Figure A-8-6).

▪ Discussion

Since culverts are primarily associated with roadways, the heaviest concentration of stream crossings is in the lowlands and the low elevation uplands (Figure A-8-5). The Trask, Tillamook and Miami River subbasins have culverts distributed throughout their areas. The Kilchis subbasin has relatively fewer culverts in headwater areas, as does the middle portion of the Wilson subbasin. Salmon recovery efforts may be most viable in portions of the basin where these upland interventions in the river system are few, because natural processes may be relatively intact and salmon passage may be available for a wider range of seasonal streamflows. Where single ownership of large land parcels (and associated culverts) exists in upland sub-watersheds coordinated efforts to improve stream crossings may be more feasible than if multiple land owners are involved.

The dispersed locations of culverts and tide gates in the lowlands (Figure A-8-6) represents a patchwork of flood control structures that modifies and complicates the natural flow of the tides and streamflows in the lowlands. Unforeseen circumstances, such as debris blockages after flood events, may create localized maintenance problems and lead to unintended consequences in the operation of the gates. Tide gated diversion structures or backwaters may also strand and kill fish that enter and cannot get out, and die as the side channels dry out (or get washed into fields). A system-wide effort to retrofit or remove these structures could reduce regional flood risk and restore large contiguous areas of habitat, but may be hindered by multiple ownership of the structures.

Culverts and tide gates are some of the more intrusive elements in a river system because they directly and significantly alter sediment and water flow patterns, leading to morphological changes and fish passage barriers. Since the physical effects of a culvert may impact large reaches of a river and upstream fish distributions, modification or removal of these structures should be prioritized to restore natural processes and fish access to restored river reaches.

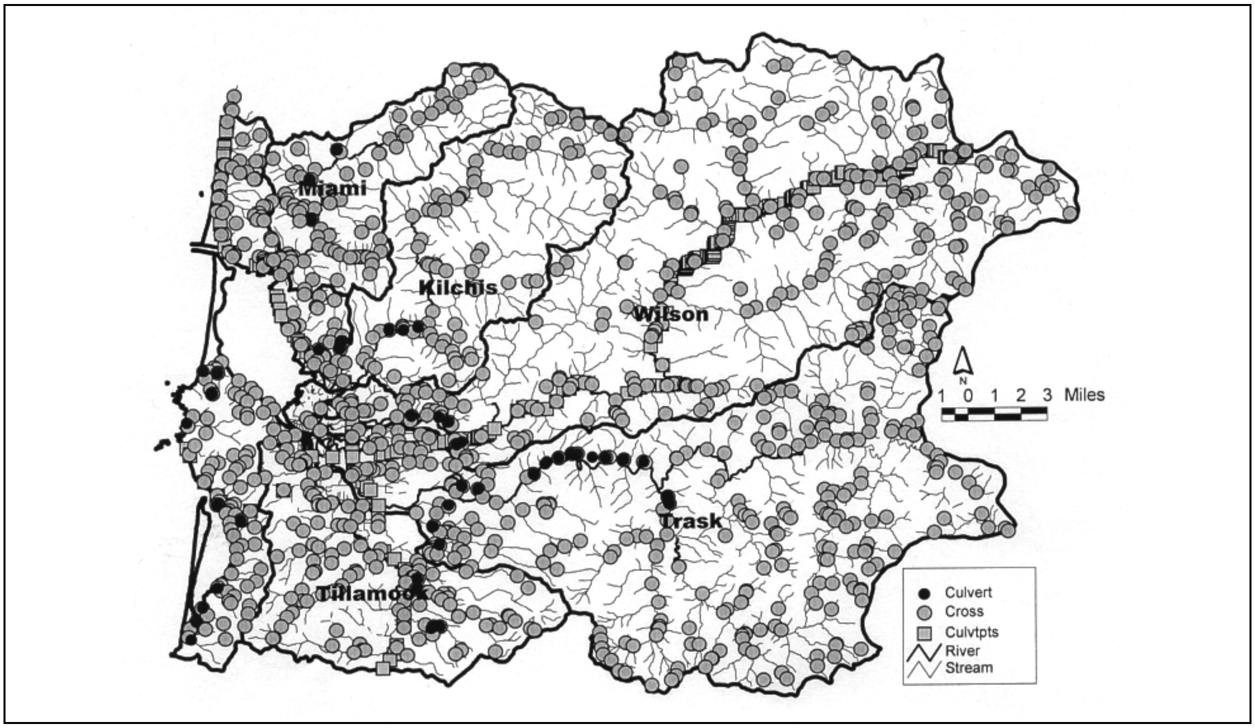


Figure A-8-5. Basin Stream and River Crossings by Source

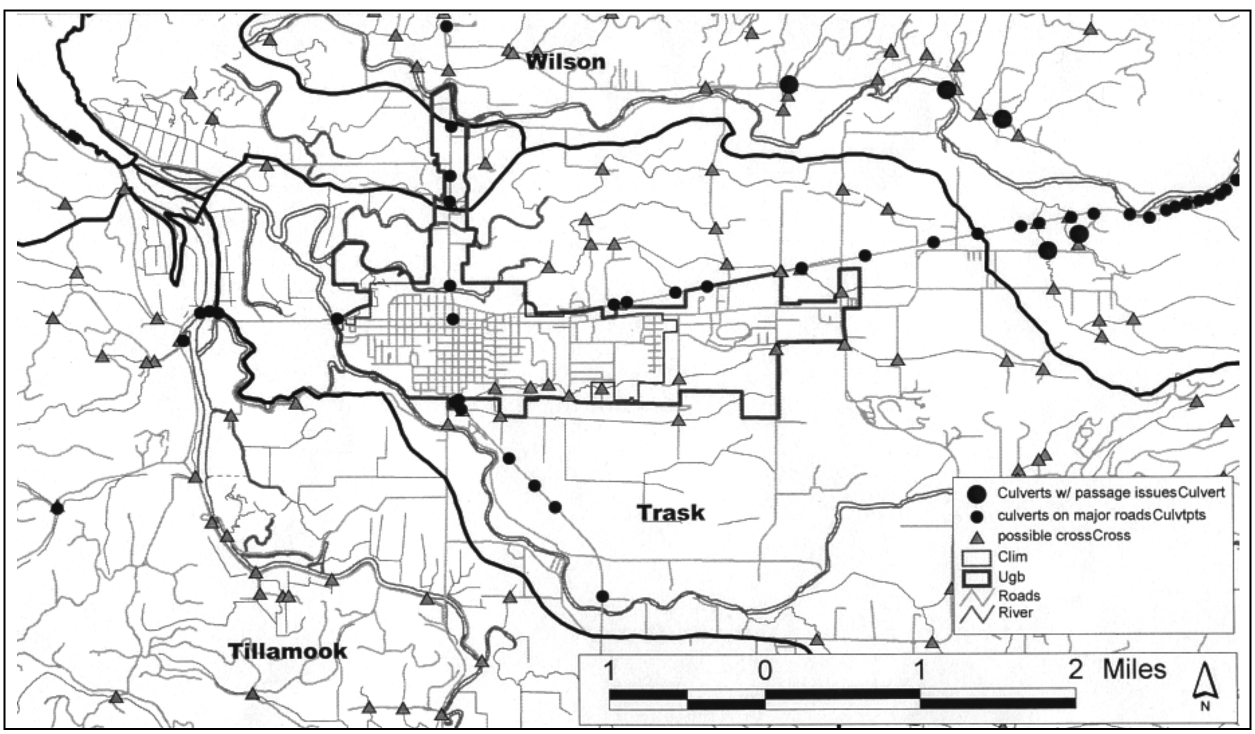


Figure A-8-6. Tillamook Lowland Valley Stream and River Crossings

A.8.4 Water Diversions and Water Rights

■ Objectives

The highly variable nature of streamflow makes water use a complicated resource issue, especially in light of salmon recovery efforts that require certain seasonal streamflow rates to sustain populations. The diversion of water from a river system may alter salmon habitat conditions and/or food sources such that the survival of the fish through dry summer months is threatened. The physical impacts of water diversions, such as seasonal water table lowering, instream impoundments, riverbank clearing, and the suction of water, may further affect habitat and free movement of salmon and other wildlife. The objective of this assessment was to identify the location and distribution of water diversions in the Tillamook Basin and evaluate their importance in a river management strategy.

■ Methods

Watershed maps were obtained from the Oregon Water Resources Department (OWRD) web site at [http//www.wrd.state.or.us/cgi-bin/findstream.pl]. These maps show points of surface water and groundwater diversion, and land parcels serviced by water rights. Data were available as screen output GIF files and in optional map formats including ArcInfo Arcplot Metafiles. Water rights map data are being digitized by OWRD for the state of Oregon, and a majority of the state has been completed as of the time of this work. Water diversion data were compiled for the Tillamook Basin (Figure A-8-7). The basin mapping is enlarged to show water diversion in the Tillamook lowlands (Figure A-6-8). The lowland map designates diversions by lake, reservoir, spring, stream, sump, or well sources.

■ Discussion

Water diversions are located primarily in the lowlands and along the mainstem river reaches (Figure A-8-7). In the uplands, diversions appear to be concentrated in the lower elevations where stream channel slopes are flatter. A variety of water diversions are scattered throughout the lowlands. Steam diversions are numerous along the upper reaches of the Trask and Wilson Rivers, but the lower reaches, in the vicinity of tidal influence, are free from diversions because of the seasonal occurrence of brackish and saline surface and ground waters. Wells are present in several locations along the Trask and Tillamook Rivers. The effect of well pumping on seasonal water table elevations and floodplain restoration efforts should be investigated.

The OWRD maps show individual land parcels serviced by water rights in the lowlands. This spatial designation of parcels can provide a good indication of the extent of land actively or potentially irrigated for agriculture. These parcels may represent areas with a higher infrastructure investment and should be factored into any lowland management strategies.

Restoration and flood management actions should be developed with respect for existing water rights and points of water diversion. Protection or acquisition of diversions and land parcels serviced by water rights should be explored to guide the designation of river reaches for comprehensive management capabilities. Excessive flow diversion may reduce water levels to a threshold condition where water temperature impacts habitat. Diversions may also change the salinity structure of the estuarine reaches of the river system and allow increased inland intrusion of saline waters.

The spatial data available from OWRD is not currently available in GIS form. The utility of these data could be significantly improved if the data were compatible with GIS-based mapping software.

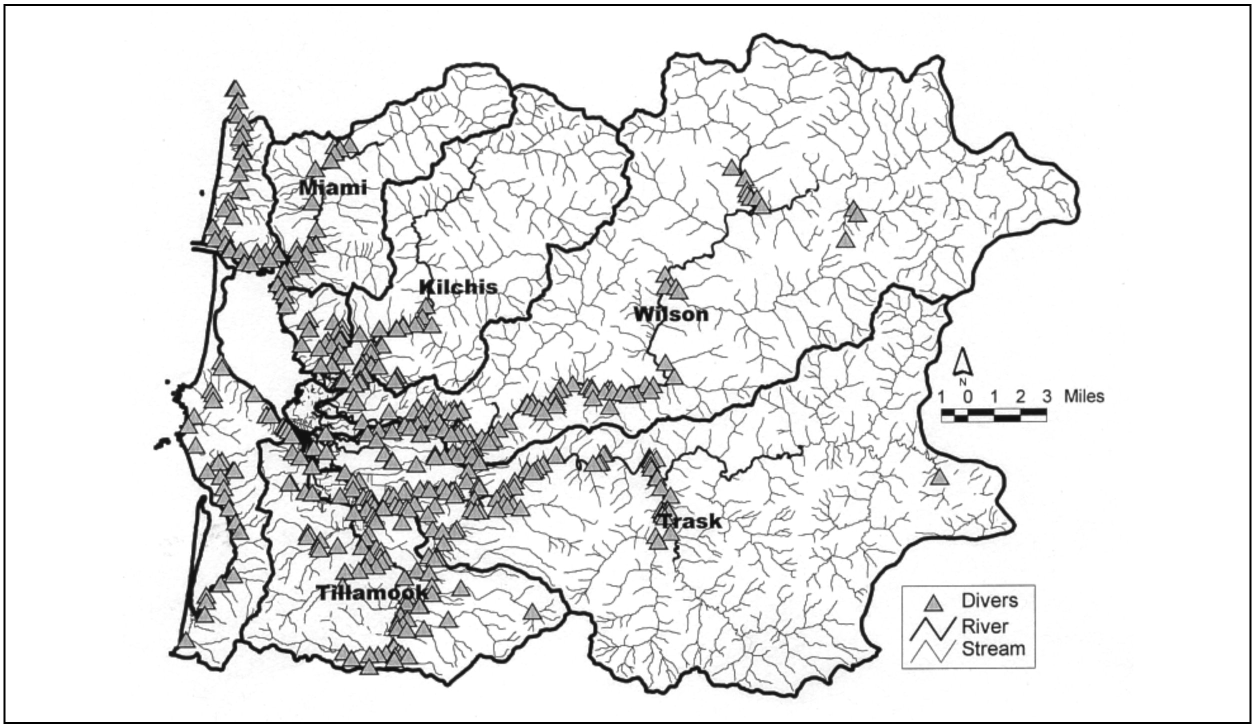


Figure A-8-7. Tillamook Basin Water Diversions

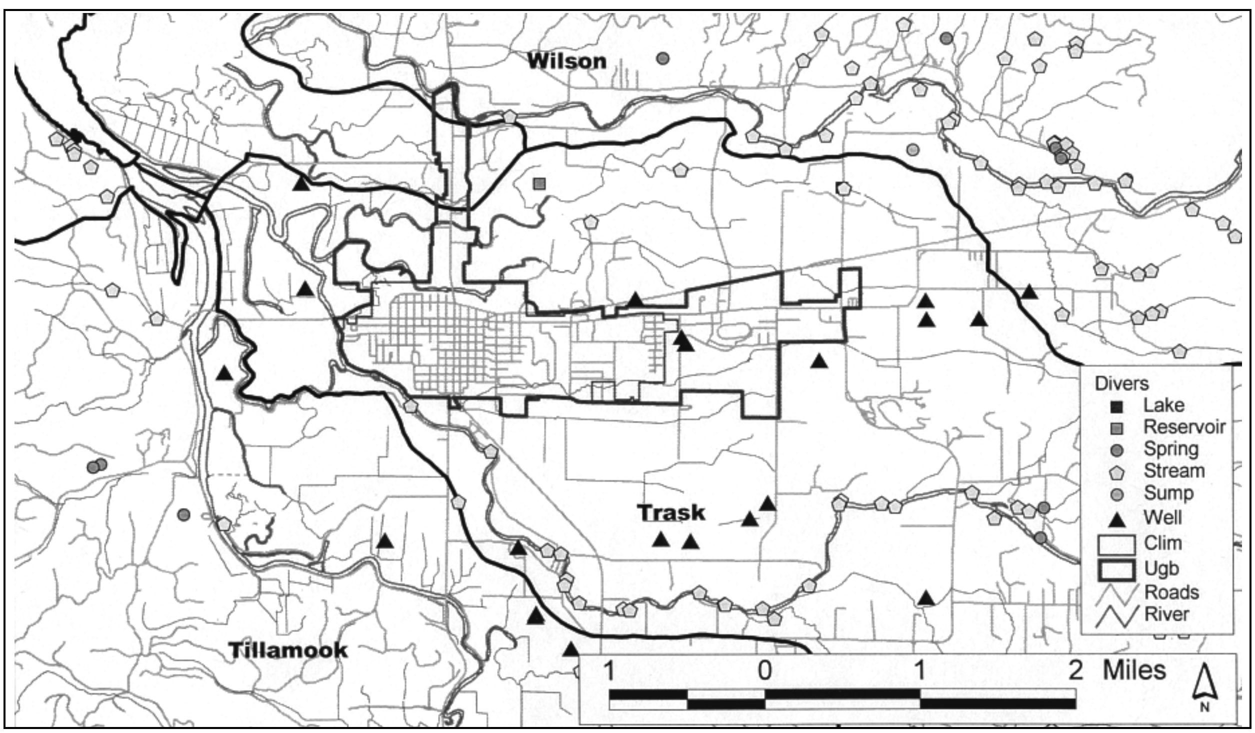


Figure A-8-8. Tillamook Lowland Water Diversions by Type

A.8.5 Water Quality

■ Objectives

Water quality or quantity problems are usually greatest in the lowland areas of a drainage basin because these areas tend to accumulate problems from upstream sources, have highly altered landscapes, and are often intensely used for a variety of human purposes. Within the Tillamook Bay basin, key water quality concerns include fine sediments, bacterial pollution, and high summer water temperatures. Fine sediments are a concern largely because of elevated erosion rates in upland forests and bank erosion problems in the lowlands. Bacterial pollution has been partially addressed through management improvements by lowland dairies, but continues to be a problem because of relatively recent increases in cattle numbers within the lowlands and because free livestock access to many near-stream areas. The object of this assessment was to define the spatial extent, relative intensity, and effects of key land uses on water quality.

■ Methods

Available GIS data layers from the TBNEP were used to map the Tillamook Bay drainage network, including streams and sloughs identified on Oregon's 1998 303(d) list as having impaired water quality (STRDEQ), the locations of water diversions (TILLPOD), known sources of bacterial or other pollutants (CAFO, OUTFALL), and the lowland areas (Figure A-8-9). This assessment was then supplemented with an analysis of the intensity of water use within each of Tillamook Bay's five major subbasins. Intensity of use was calculated by dividing the volume of water rights allocated to consumptive use (in cubic feet per second) by subbasin area. Water rights information was obtained from the Oregon Department of Water Resources website [http://www.wrd.state.or.us].

■ Discussion

Most of the documented water quality problems in the Tillamook Bay basin are spatially associated with lowland areas, confined animal feeding operations, and municipal or other sites with pollution discharge (NPDES) permits (Figure A-8-9). Water diversions are most abundant in or near the lowlands, but are not strongly associated with stream segments of impaired water quality.

Consumptive uses associated with surface water diversions ranged from a low of 0.07 cfs /mi^2 in the Wilson subbasin to highs of 0.94 cfs/mi^2 in the Tillamook subbasin and 0.69 cfs/mi^2 in the Trask subbasin (Figure A-8-10). The high intensity of water use in the Tillamook and Trask subbasins is likely a factor influencing water temperatures in lowland streams, and may be affecting patterns of bacterial contamination there and within the Tillamook Bay estuary. For example, analyses by TBNEP (1998a) have shown the Tillamook and Trask rivers to differ from the less diverted Wilson River in that they contribute much more bacteria to the bay in winter than in summer, while the Wilson's autumn contributions are only moderately higher than in summer.

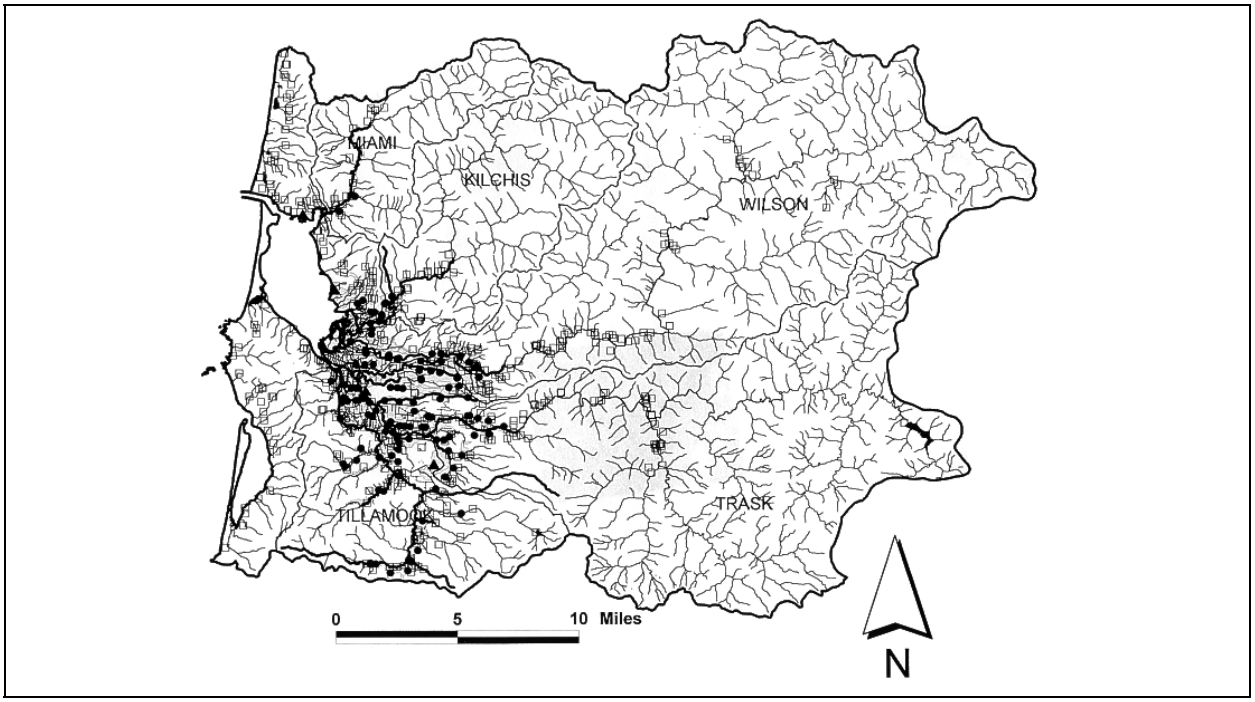


Figure A-8-9. Spatial relationships between lowland areas (gray), 303(d) listed stream channels (bold lines), confined animal feeding operations (CAFOs, solid circles), sites with NPDES pollution discharge permits (solid triangles), and points of surface water diversion (open squares) in Tillamook Bay Basin.

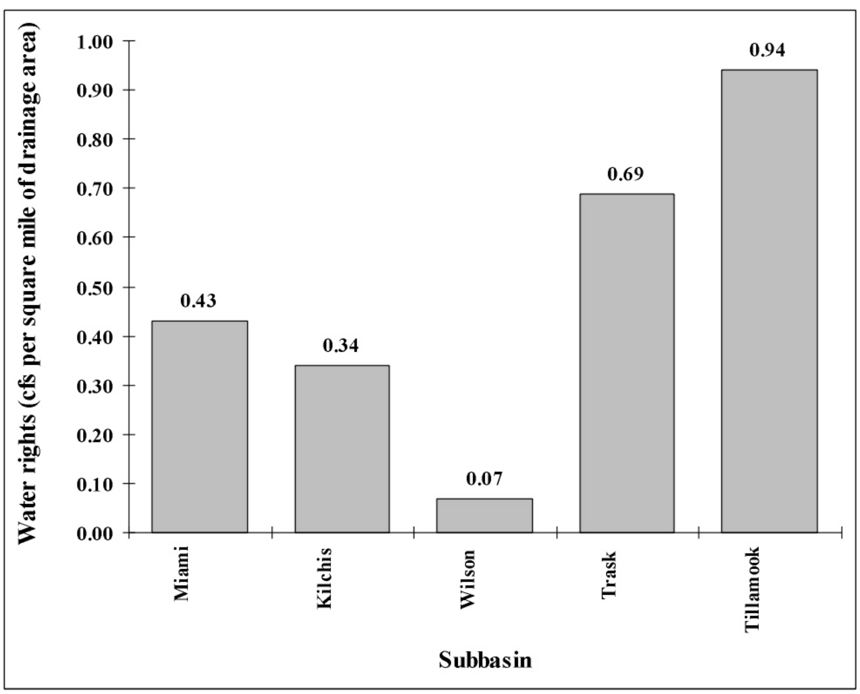


Figure A-8-10. Intensity of Water Use (total water rights [cfs] per square mile of drainage area) for Five Subbasins within the Tillamook Bay Basin, Oregon.

A.8.6 Dikes and Levees

■ Objectives

The construction of dikes and levees is associated with a number of impacts affecting both aquatic habitat and flood risk. The objective of this assessment was to better understand the impacts of levees and dikes in the Tillamook Bay Basin estuary. Levee locations, when combined with information on native vegetation and channel planform, will help to develop and prioritize management strategies for the lowland estuary area.

■ Methods

Two sets of available dike and levee GIS data for the Tillamook Bay Basin were obtained. One was created by the TBNEP and the other by the Corps. The Corps' data includes a subset of the levees mapped by TBNEP, but they are mapped with greater accuracy. A new levee coverage, LEVEEMO, was created by augmenting these coverages with information from USGS topo quads. This data coverage includes the levees from the Corps coverage and the levees and roads mapped on USGS topo quads (Figure A-8-11). Roads were included because they are often built on elevated roadways and, though not labeled as levees on maps, often have the same effects on the movement of water. This new levee coverage was mapped along with historic vegetation and current wetland vegetation (Figure A-8-12) to illustrate the relationship between levees and changes in vegetative cover.

■ Discussion

Many of the dikes and levees in the Tillamook Bay Basin are located below the MHHW elevation in the estuary. Levees are often used in conjunction with drainage tiles to improve agricultural productivity in tidally influenced areas by protecting land from salt water. Separated from tidal action and exposed to land drainage and grazing, native plant communities were replaced, over time, by non-native communities. Interestingly, some of the vegetation has reverted to its historic community structure. This has likely occurred in areas where the levees were not maintained the reintroduction of salt water inundation was allowed.

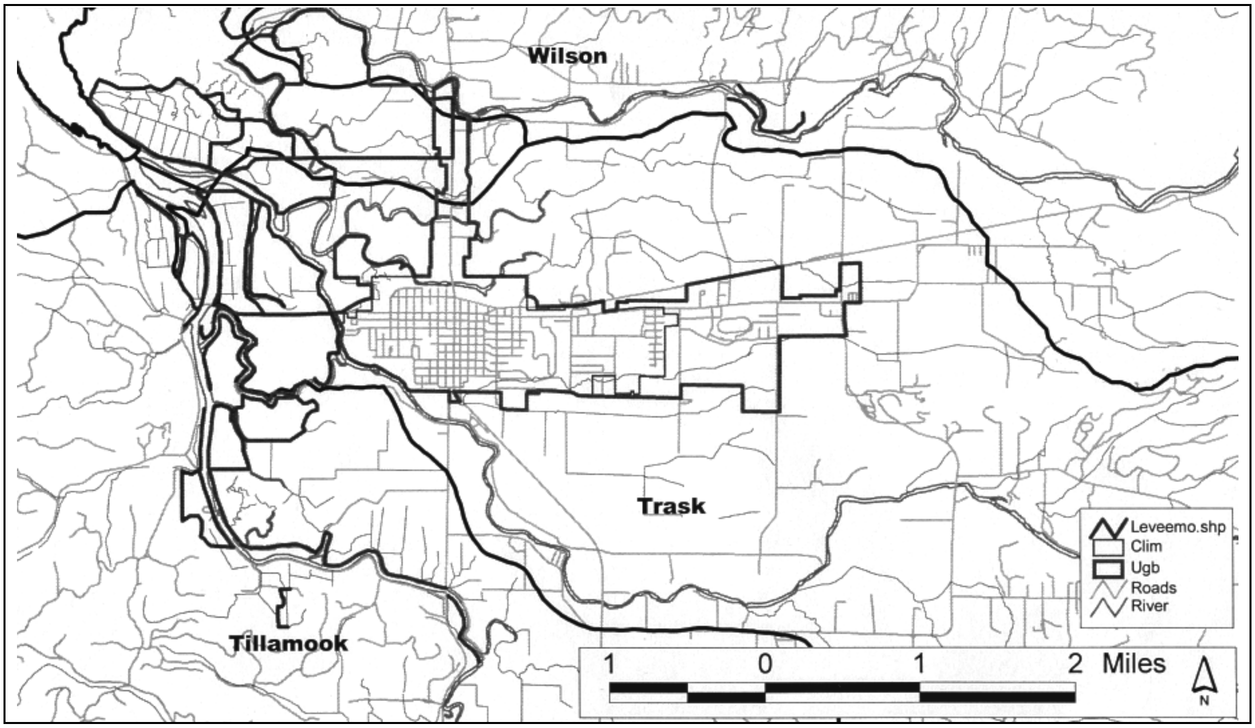


Figure A-8-11. Lowland Valley Levees and Dikes

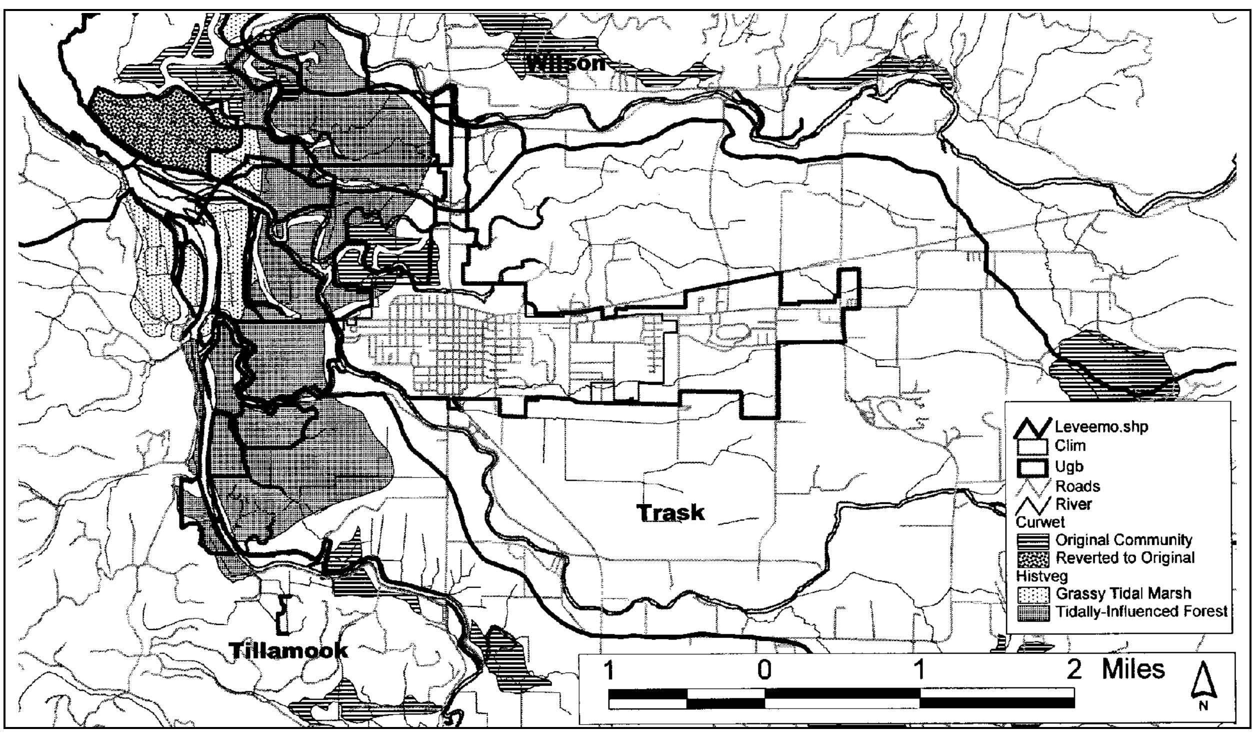


Figure A-8-12. Levees and Dikes Mapped with Historic and Current Tidal Plant Communities

A.8.7 Post-Flood Permit and Damage Claims

▪ Objectives

Increasing development in flood-prone areas, combined with repetitive flood events, have resulted in an increasing number of flood damages and permit requests for waterway work following floods. These post-flood actions often hinder habitat restoration efforts or increase flood risks to neighboring properties. The objective of this assessment was to understand the characteristics of flood damage claims and permit requests in Tillamook County, to determine how permit actions are approved, tracked and archived and to assess how well the permit database information reflects the actual permitting of post flood actions. Based on the findings of this assessment, recommendations are made for streamlining the permit system and improving the accuracy and usefulness of permit data.

▪ Methods

Tillamook County flood damage estimates, damages claims and flood insurance data were evaluated from a comprehensive report on flood problems in the county (Levesque, 1980) and from interviews with FEMA Region X staff (Eberlein, 1997). Historic flood damage data were compiled and compared on a common basis using 1996 dollars (Table A-8-1). Damage estimates were converted to 1996 dollars by multiplying earlier dollar amounts by a ratio of the respective MEANS Historical Cost Indexes (MEANS, 1997). Flood insurance policies and coverage amounts for 1980 (Levesque, 1980) were compared to those for 1997 (Eberlein, 1997) by local jurisdiction (Table A-8-2). Claims amounts since 1978 were also itemized by local jurisdiction.

Post-flood permits were evaluated from agency databases including: the U.S. Fish & Wildlife Service (USFWS), the Federal Emergency Management Agency (FEMA), the Corps of Engineers (COE), the Natural Resource Conservation Service (NRCS), and the Oregon Division of State Lands (DSL). Data were obtained directly from permit and database staff through interviews. Permit application forms and data entry practices were compared among the agency databases, and the accuracy of the entries was assessed. The computer hardware and software used for the databases was identified, and the portability of data among agency databases and to PC-based computing systems was assessed. The accuracy and usefulness of the data for quantitative analysis using GIS was evaluated by plotting raw agency data and observing resulting permit locations on maps.

▪ Discussion

A comparison of 1996 flood damages to historic flood damages indicates the 1996 event was significantly the most damaging event in the history of the county (Table A-8-1). Flood insurance policies have more than tripled in Tillamook County between 1980 and 1997, and insurance coverage has increased by nine times to $122 million (Table A-8-2). The increase in flood insurance policies may be an indication of increasing development in flood hazard areas.

Several agency permit databases exist because of the variation in the jurisdictions of the agencies. For instance, the FEMA database lists actions not in waters of the United States and thus not permitted and recorded by COE or DSL. A compilation of 1996 permit and claim locations in the Tillamook Bay Basin is shown in Figure A-8-13 for FEMA actions and COE and NRCS permits. Data for this year was loosely assumed to reflect permits and claims related to the February 1996 flood event. Numerous post-flood permits were applied for in Tillamook County. In the Tillamook Bay Basin, these projects tended to be concentrated along the margins of the bay and in the

Table A-8-1. Comparison of Tillamook County Historic Flood Damages in 1996 Dollars

Flood Year [1]	Flood Damages [1]	Historic Cost Index [2]	Flood Damages (1996 $)[3]
1964-65	$1,632,000	21.2	$8,337,057
1972	$3,303,000	34.8	$10,279,164
1974	$310,000	41.4	$810,942
1977	$4,213,000	49.5	$9,217,533
1996	$53,000,000	108.3	$53,000,000

[1] From Levesque, 1980

[2] From MEANS, 1997

[3] Example 1996 $ = 1974 $ x (1996 index/1974 index

Table A-8-2. Comparison of Tillamook County Flood Insurance Coverages Between 1980 and 1997 and Claims Since 1978

Area	No of Policies (in 1980)	Insurance Coverage (1980$)	No of Policies (in 1997)	Insurance Coverage (1997$)	Claims Since 1978 (1997 $)
Tillamook County	235	$9,393,700	766	$80,470,600	$1,416,161
City of Tillamook	15	$451,500	91	$10,623,100	$1,451,185
City of Bay City	6	$176,600	8	$722,100	$0
City of Garibaldi	0	$0	2	$693,000	$0
City of Manzanita	15	$572,500	47	$7,889,000	$1,954
City of Nehalem	11	$556,600	27	$3,184,300	$190,881
City of Rockaway	50	$1,960,100	155	$17,281,700	$48,777
City of Wheeler	3	$44,900	3	$685,300	$0
TOTALS	**335**	**$13,155,900**	**1099**	**$121,549,100**	**$3,108,958**

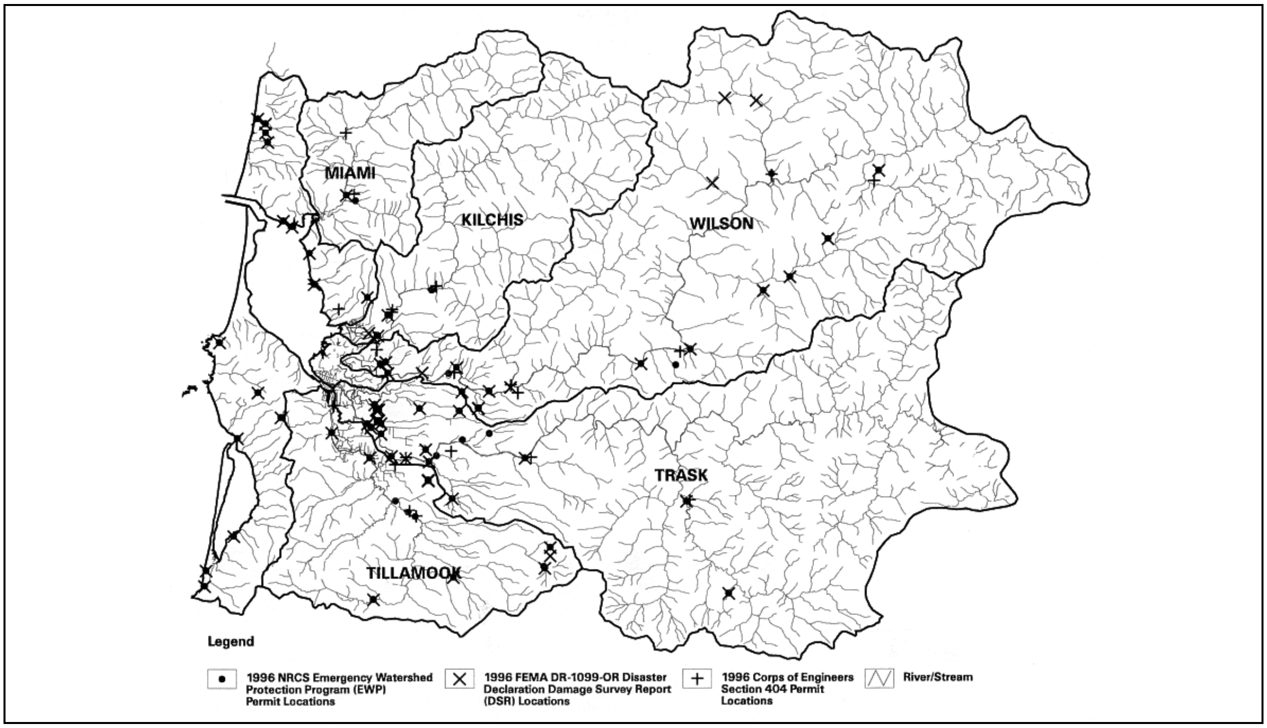


Figure A-8-13. 1996 Permits and Flood Damage Claims

City of Tillamook and the Wilson River floodplain. Efforts should be made to coordinate or consolidate databases to enable consistency and efficiency in the permit process. The complexity of evaluating cumulative impacts is one of the major reasons why coordination of databases is needed, between agencies which regulate waterway impacts, agencies which evaluate water quality, and agencies responsible for fish and wildlife resources.

Different agencies use different database hardware and software. For instance, USFWS uses Paradox while DSL has used Wang. An agency which does not have Wang cannot access the DSL database unless DSL converts the requested information into a different format, such as an EXCEL spreadsheet. The COE RAMS database is not transferrable to file at all, and can only be used on screen or in print-outs. The NRCS uses a form of spreadsheet which USFWS programs have not been able to import. In many instances, federal agency computing systems were established many years ago, and large databases are still being managed on old mainframe systems, as opposed to PC-based systems that are compatible with microcomputer applications and GIS systems.

In instances where there is a compatible database structure, it is difficult to exchange data because of differing database content. For instance, NRCS does not provide applicant names in public copies of the database, and does not include COE or DSL permit numbers. Therefore, it is difficult to match these records. Some of the databases lack detailed information about actions. The COE database contains latitude and longitude for each action, but not the size of the action. The DSL database records the size of the action, but not its latitude and longitude. It is understood that DSL gave up the lat/long system with consideration of private property rights. A standardized method should be followed by all agencies to record similar data, especially in a format that can be transferred to microcomputers and GIS.

Databases for quantitative analysis should have separate fields for each type of information and should have clear and consistent naming conventions. For instance: River, County, Latitude, and Longitude should be separate fields, rather than having one field for Location. This way, information which is needed for the purpose can be easily isolated, and extraneous information ignored. When information is not thoroughly divided into specific fields, querying also becomes difficult and less useful. Again, a consistent format or one central database would eliminate repetition of data entries and the inability to cross reference data among agencies.

Discrepancies also exist between actual actions and their recorded descriptions. For instance, an applicant is likely to use a different amount of riprap than what was requested in the permit application and permitted. The DSL database has fields for both permitted and completed amounts of fill and removal, but there is virtually no data entered in the 'completed' field. The regulatory program should be expanded to require documentation of the resulting 'as-built' condition, possibly through the use of economic incentives for the permit applicant.

From the databases, it is difficult to study the repetitive damages from flooding. Some databases, such as that of DSL, go back several decades but contain limited information on repeated actions. For instance, it is not evident how many times the same gravel removal permit had been renewed. Other databases only contain records since 1991 (COE) or 1996 (NRCS) because of programmatic changes. Permit databases should be structured in a manner that allows an assessment of repetitive actions and the cumulative impacts of these actions.

A number of problems in the existing databases can impede efforts to create a GIS map which emphasizes the biological significance of actions. DSL's use of section, township, and range results in permit actions being plotted at the center of a section, and not necessarily even appearing associated with any stream. Even with latitude and longitude data, many actions appear to overlap. Another location method used is river miles. These data could be helpful to correlate flood response actions with fish habitat. However, plotting river miles requires that they be measured from the mouth of every stream, and every stream has a River Mile 0, for example. This is in contrast to a more precise measurement such as latitude, which signifies a specific point on the globe. Preparing data for GIS or other forms of analysis is extremely time-consuming and complicated, perhaps needlessly so. A close working connection should exist between field staff, database staff, GIS staff, and project managers so that products can be evaluated at every step of the process and work can proceed efficiently.

The nationwide permit process, under which almost all bank stabilization projects are authorized by the COE, is meant to speed the construction of projects which have minimal environmental impacts, individually and cumulatively. In Tillamook County, 97 percent of the Nationwide Permits issued between 1988 and 1996, during the designated flood disasters of 1990 and 1996, were approved. Whether cumulative impacts are minimal is especially difficult to evaluate for river projects because habitat and habitat impacts are not quantified in acreage as wetland losses are. Under the nationwide permit process, not all post-flood actions which occur receive permits. Rural areas are especially likely to have large waterway impacts that go unnoticed by regulatory agencies. The nationwide permit process should be reviewed to assess the criteria for permit approval, the implications of the process on cumulative effects, and the opportunities for using data from the process to evaluate cumulative effects.

A.8.8 Public Policy Assessment

■ Objectives

The intent of the public policy component of the Tillamook Integrated River Management Strategy (IRMS) is to develop the context in which to implement the three underlying objectives:

- restoration of floodplain functionality
- reduction of flood impacts
- improvement of aquatic and terrestrial habitat

The scope of the public policy assessment was originally intended to review all plans and government-administered activities which impact the three main objectives. The focus was fairly clear as to the limited number of polices which potentially impacted these objectives. However, soon after the review of the target policies and programs began, it became clear that the specific items as mentioned were not the crux of the key issues. For example, the Goal 7 update process is not only significantly behind schedule, but its scope is also being modified. Another example is the Oregon Plan, which relies heavily on current permitting and review processes.

Thus, after a preliminary review of key policies, it was determined that the first step must be an inventory of policies currently in effect for the study area. The term 'public policy' was broadly defined to include a wide range of activities to accomplish such tasks as:

- problem identification (hazard analysis, water quality degradation, etc.)
- data analysis (GIS based inventories, etc.)
- development of planning goals (CZM project, NEP, etc.)
- adoption of plans (county plans, Oregon Plan, etc.)
- adoption of regulations and permits (404, 402, building permits, etc.)

After defining the scope to cover all of the above types of "policies" it became clear that the array of policies and permits in the generalized area encompassed by the IRMS is vast. Most, however, do not explicitly address the floodplain, and do not necessarily explicitly address the IRMS goals. Nonetheless, each policy has important impacts on the areas of concern of the three original objectives. Conversely, tools which are in effect have not been structured to implement the key objectives, e.g. NEPA. Finally, major efforts in effect for our study area are only indirectly impacting the actual public policies, e.g. NEP, but such projects do not explicitly promote implementation because they have no legally binding status.

■ Methods

Since the public policy assessment was intended to clarify the complex federal, state and local policy environment, an initial effort was made to inventory the 54 programs impacting the IRMS. The inventory was prepared in spreadsheet format (Table A-8-3) in order that entries could be accessed and sorted into seven categories:

1. **Level.** Programs promulgated at federal, state, and local levels were identified.
2. **Responsible Agency.** The specific agency within the federal, state or local levels were identified.
3. **Spatial (geographic scope)**. The spatial scope of the each policy was defined (surface waters, flood plain etc.). In many cases the spatial context of the policy has not been explicitly defined, i.e. the polices were aspatial as written; however as they become implemented they impact a specific spatial area, e.g. Tillamook basin.
4. **Purpose.** Underlying intent of the program.
5. **Program Authority**. Policies adopted by law have legal/implementation authority, while plans tend to be advisory where

implementation is discretionary. In general, laws and regulations are promulgated at the federal level. They are, however, administered at the state level, and are in many cases implemented at the local level.

6. **Trigger Activity**. In many cases an action results in the requirement for compliance with specific programs or regulations, i.e. they will trigger the need for a permit. An emphasis of this inventory has been on the legal context of requirements.

7. **Key Issues.** Key issues were defined in relation to concerns of the IRMS primary objectives. The issues and the number of policies reviewed in each category are listed below:

(4) Access/NEPA
(11) Flood Hazard Reduction
(2) Floodplain Management
(14) Water quality
(8) Watershed Planning
(10) Habitat
(1) Land use planning
(1) Terrain analysis
(2) Water availability

▪ Discussion

Review of the accompanying inventory leads to a number of conclusions.

1. **Policy is highly fragmented.** Broad investigative actions are initiated at the federal level. Authority for review is at the state level; while administration of permit granting and decision making is at the local level. Although 54 separate policy items were reviewed, the inventory is dramatically incomplete and does not give a holistic view of the planning status for the area.

2. **Policies are generally advisory, while permit requirements are legal tools and are only tangentially related to polices.** The most comprehensive planning programs do not have the status of law e.g. NEP, CZM. Conversely, existing permit authorities are currently being used to achieve objectives significantly different than the underlying intent of the permitting authority.

3. **Disconnect exists between plans and regulations.** There appears to be a continuity gap between plans and regulations. The most prevalent forms of permits pertain to fill and dredging. The intent of the these permits does not correspond to any of the three objectives, yet they have the most significant impact on the geographic/spatial area (integrated river system) under study.

GIS data sets being developed by various planning efforts do not necessarily support planning or regulatory need which would facilitate the three policy objectives.

Future efforts should be made to complete this document by reviewing the existing implementation profiles (including 404 and other permits) in light of both their original intent and current planning goals e.g. Essential Fish Habitat goals. The underlying objective should be to ascertain whether the existing permit structure needs to be modified in light of current concerns. Related efforts should look at flood control efforts such as diking practices and removal-fill agreements in light of current ESA and related issues.

Table A-8-3. Inventory of Public Policies Influencing Resource Management in Oregon and Tillamook

IMPLEMENTING AGENCY	LEVEL	GEOGRAPHIC SCOPE	PURPOSE	PROGRAM / AUTHORITY	TRIGGER ACTIVITY	KEY ISSUES
Oregon Coastal Salmon Restoration Initiative, aka The Oregon Plan (for Salmon and Watersheds)	Consortium	Upper Tillamook Watershed	State response to salmon restoration issue. Oregon State authority under Constitutio Article V, Sections 1 & 13	Endangered Species Act as enforced by National Marine Fisheries Service (NMFS) Authority		Watershed
Tillamook Bay National Estuary Project (TBNEP)	Consortium	Bay	NEP est. in 1987 by amendments of the Clean Water Act to identify, restore and protect estuaries along the coasts of the US ; Local NEPS develop partnerships between gov't agencies that oversee estuarine resources and ppl who depend on the estuaries.	Data Collection : GIS data layers Inventory List (active and archived, ARC/Info export files) available at osu.orst.edu/dept/tbaynep/archive.html & osu.orst.edu/dept/tbaynep/active.html ; Base Programs Analysis available from this office	Directs the Comprehensive Conservation Management Plan: Currer mandate- to address 3 priority problems: critical habitat loss; sedimentation; bacterial contamination. The Mgnt committee is considering adding "Flooding" as a 4th priority problem.	Habitat
Tillamook Coastal Watershed Resource Center	Consortium	Watershed	Collaborative effort of the Tillamook Bay Community College, the Economic Development Center of Tillamook, the Tillamook Bay NEP, and the Soil and Water Conservation District of Tillamook.	State Watershed Council	N/A	Flood hazard
Federal Emergency Management Agency (FEMA)	Federal	Floodplain	Eligibility for flood insurance to communities that adopt approved floodplain management regulations	National Flood Insurance Act (NFIP)	Participation in NFIP requires minimum floodplain management regulations	Flood hazard
Federal Emergency Management Agency (FEMA)	Federal	Floodplain	Funds projects which will result in long term impacts and produce repetitive benefits over time. Must have 404 Hazard Mitigation Plan	Hazard Mitigation Grant Program.	Presidentially declared disaster	Flood hazard
Federal Emergency Management Agency (FEMA)	Federal	Floodplain	Post disaster infrastructure repair	Public Assistance (for public facilities)	Presidentially declared disaster	Flood hazard
U.S. Army Corps of Engineers	Federal	Navigable waters		Section 404 waterway permits. Dredging and filling which may affect water quality.	Work affecting navigable waters, tributary streams, & wetlands (considered special aquatic sites)	Flood hazard
U.S. Army Corps of Engineers	Federal	Navigable waters	Permits administered by DSL ; USFWS & NMFS also review permit applications (advisory function); also requires (State) 401 certifications for mitigation of impacts to fish and wildlife; EPA review for 404(b)(1) compliance with CWA	Section 404 permit (Joint with DSL) ; and Section 401 Water Quality Certification	Work affecting navigable waters (tidal and fresh), tributary streams, & wetlands (considered special aquatic sites)	Flood hazard
U.S. Army Corps of Engineers	Federal	Navigable waters	Preserve navigability of nation's waterways, regulates activities within ordinary high water mark	Rivers and Harbors Act, Section 10 permit (administered through DSL)	All work affecting navigable waters: construction of dock and in-wate structures, placement of pilings.	Water quality, Flood
U.S. Bureau of Land Management	Federal					Habitat
U.S. Department of Fish & Wildlife	Federal	Watershed	Review US COE permits for mitigation of impacts to fish and wildlife (advisory function)	Fish and Wildlife Conservation Act		Habitat
U.S. Department of Fish & Wildlife	Federal	Watershed		Tillamook Bay Flood Systems Analysis		Habitat
U.S. Department of Fish & Wildlife	Federal	Navigable waters	Granting agency ; Advisory role - specific to individual projects	Section 10 & 404 Permits (Joint with DSL); all 404 permits are also subject to Section 401 Water Quality Certification by DEQ	Fill activity in navigable waters	Habitat
U.S. Environmental Protection Agency, Region X	Federal	Surface waters		National Estuary Projects (a section of the Clean Water Act) fall under general oversight of the EPA Office of Water		Habitat
U.S. Environmental Protection Agency, Region X	Federal	Surface waters	Review of NPDES permits and NPDES Storm Water Permit 1200-C	Regulates storm water discharges into surface water bodies under 40 CFR, Sect. 122-124		Water quality
U.S. Environmental Protection Agency, Region X	Federal	Surface waters	Policy making authority in Tillamook; member on Policy Committee for TBNEP			Water quality
U.S. Geological Survey (USGS)	Federal	Shore	Topographic, geological and water resources data collection	Educational; data collection		Terrain
U.S. Geological Survey (USGS)	Federal	Surface waters	TBNEP contracted with the USGS for installation of tidal gauges data collection from Wilson & Trask Rivers.			Water quality
U.S. National Marine Fisheries Service (National Oceanic & Atmospheric Administration) (NMFS)	Federal	Water bodies	Review US COE permits for mitigation of impacts to fish and wildlife	Fish and Wildlife Conservation Act	Administration of certifications and permits delegated to Oregon DEQ	Habitat
U.S. Natural Resource Conservation Service (U.S. Department of Agriculture) (NRCS)	Federal	River basin	Provides planning assistance for development of coordinated water and related land resource programs. Priority: upstream rural community problems w/ wetlands preservation	Cooperative River Basin Program		Watershed planning
U.S. Natural Resource Conservation Service (U.S. Department of Agriculture) (NRCS)	Federal	Stream banks	Technical & data collection assistance to Water district cooperators ; Performs watershed inventories and assessments	Advisory ; Educational		Habitat
U.S. Natural Resource Conservation Service (U.S. Department of Agriculture) (NRCS)	Federal	Watershed	Assists local governments to make repairs which reduce threat from future flood events to private property	Emergency Watershed Program (EWP) Permit		Watershed protection
Tillamook County Community Development Department	Local		Administers NPDES permits	Tillamook County Land Use Ordinance		Water quality
Tillamook County	Local	Project	Municipal authority		Sources which discharge wastewater to a municipal sewer have no permit requirements from DEQ, but may be affected by municipal discharge and pretreatment requirements	Water quality
Tillamook Watershed Council	Local, Voluntary	Watershed	Established by the Governor's Office to improve the condition of watersheds in their local area. Represents a balance of interested and affected persons within the watershed	Advisory function ; Coordinates various involved agencies	N/A	Watershed
Interrain Pacific	Non-profit	Tillamook Bay	Educational, Data Collection, Provide training & GIS tech support, Assist in watershed assessment/monitoring programs.	NEP support	Contracted by EPA to provide GIS data for Tillamook Bay NEP	Watershed

Draft

Table A-8-3. Inventory of Public Policies Influencing Resource Management in Oregon and Tillamook

IMPLEMENTING AGENCY	LEVEL	GEOGRAPHIC SCOPE	PURPOSE	PROGRAM / AUTHORITY	TRIGGER ACTIVITY	KEY ISSUES
Office of Emergency Management (OEM)	State	County	Administers FEMA's mitigation programs, including 404 hazard mitigation programs	State Hazard Mitigation	Declared disaster	Flood hazard
Oregon Department of Consumer & Business Services, Building Codes Division [DCBS]	State	Structure		1996 Oregon Manufactured Dwelling Standard (OMDS), Section 308 requires manufactured dwelling parks to be 12" above the base flood level or 3' above finished grade, whichever is less.	FEMA regulations [44 CFR Chapter 1, Section 60.3(c)(6)(iv)] requires manufactured dwellings substantially damaged from the 1996 Oregon floods be elevated to or above base flood level.	Flood Hazard
Oregon Department of Environmental Quality [DEQ]	State	Project	Structural measures impacting surface water requires water quality certification and/or modification. Sources which discharge to land but also discharge to surface waters part of the year must obtain a NPDES Permit.	Clean Water Act, Section 401 Certification of Water Quality Compliance required prior to any in-water disposal	Clean Water Act Section 401 applies to any activity which may result in a discharge to waters of the state (ex.: land uses such as agriculture, mining, ports, transportation projects, industrial siting/construction and operations)	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Project	Water Quality Program concentrates on protecting the "beneficial uses" of Oregon's water , and preventing pollution through education, training, and regulation	National Pollution Discharge Elimination System (NPDES) Permit, Individual. Issued under the Federal Water Pollution Control Act and OAR 340-45-005 through 340-45-065 ; the EPA may review the permit during the public notice period	Point source discharge of pollutants into surface waters. Construction activities: clearing, grading, excavation which disturb 5 or more acres, and development which disturbs al least 5 acres over a period of time	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Project	Several municipalities are issuing the construction permits for DEQ, processing/application times may differ. Generally it is part of the process required to obtain a building permit	National Pollution Discharge Elimination System (NPDES) Permit, General	Issued to cover categories of minor discharges when an individual permit is not necessary to adequately protect water quality (ex.: fish hatcheries, log ponds, seafood processing, petroleum hydrocarbons cleanup, vehicle wash water)	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Project		Clean Water Act, Section 402 NPDES Storm Water Discharge Permit 1200-C, General	Storm water discharges associated with industrial activity listed by the EPA and which involve storm water which leaves the site through a "point source" and reaches surface waters either directly or through storm drainage	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Large sites	Issued under of ORS 486B.050, OAR 340-14 and OAR 340-71, and in accordance with OAR 340-40	Water Pollution Control Facilities (WPCF) Permit, Individual	Issued for systems which disposes of wastewater with no direct discharge to surface water (ex.: land irrigation systems, evapotranspiration lagoons, industrial seepage pits, on-site disposal systems with 2,500+ gal/day wastewater flows)	Water quality
Oregon Department of Environmental Quality [DEQ]	State	Stream		303d water quality - limited streams and lakes		Water quality
Oregon Department of Forestry	State	Watershed	Technical Assistance, Notification of Operation	Authority under the Forest Practices Act	Required prior to beginning a forestry operation	
Oregon Department of Forestry - Tillamook River Watershed	State	Stream	Water quality monitoring - Tillamook River watershed			Watershed
Oregon Department of Geology & Mineral Industries (DOGMI)	State	Shore	Landslide analysis ; Administration of Tsunami Inundation Zones	Review		Flood hazard
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	Administers National Flood Insurance Program (NFIP)			Flood hazard
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	Works w/ Tillamook County in an advisory capacity to help them remain compliant w/ zoning ordinances & the statewide goals			Flood hazard
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	State Land Use Planning authority ; Preparing administrative guidelines for Goal 7	Administers State Land Use Law		Land use
Oregon Department of Land Conservation & Development	State	Coastal Lands and flood plain	Administers federally approved Coastal Management Program	Administers the National Estuary Project (NEP)		Water quality
Oregon Department of Transportation	State	Roadways	Responsibilities are project-specific. Current project in Tillamook: Wilson River Dougherty Flue on Hwy 101 (N. end of Tillamook)- re: Road widening & impact on wetland ditches	Construction permits		Access
Oregon Department of Transportation	State	Roadways	Technical/design assistance to city and county road projects ; Not participating in TBNEP	Review		Access
Oregon Department of Transportation	State	Roadways	Serves as an instrument of the FHWA when channeling federal funds for city/county projects			Access
Oregon Department of Transportation	State	Roadways	Environmental Research Unit, Wetlands Team	National Environmental Policy Act (NEPA)		Access
Oregon Division of State Lands	State	Water bodies	Authority under the state's Removal-Fill Law. USFWS, NMFS and Oregon DFW also review permit applications (advisory function) ; requires (State) 401 certif. for mitigation of impacts to fish and wildlife; & EPA review for 404(b)(1) compliance with CWA	Fill & Removal permit, aka Removal-Fill Permit, aka Dredge & Fill 401 Certification, aka Section 401 Water Quality Certification (All sect. 404 Permits are also subject to this req.) A Joint DSL/USCOE permit which is next forwarded to DEQ for review	In any wetland - to remove from or place fill into state waters, 50 cubic yards or more of material, i.e. to dredge, fill, or otherwise alter a waterway. Generally, projects that impact wetlands/waters require this permit	Floodplain
Oregon Division of State Lands	State	Channel	In-water structures	Section 10 permit (Joint with DSL)	Work affecting navigable waters: construction of dock and in-water structures, placement of pilings, dredging & filling [Both 10 & 404 permits required for fill activity] which may affect water quality	Floodplain
Oregon Division of State Lands	State	Channel	Erosion Control General Authorization	General Authorization for Wetland Restoration & Enhancement		Habitat

Table A-8-3. Inventory of Public Policies Influencing Resource Management in Oregon and Tillamook

IMPLEMENTING AGENCY	LEVEL	GEOGRAPHIC SCOPE	PURPOSE	PROGRAM / AUTHORITY	TRIGGER ACTIVITY	KEY ISSUES
Oregon Division of State Lands, joint with U.S. Army Corps of Engineers	State	Rivers, Streams, Wetlands	Regulates the discharge of dredged or fill materials. Projects in which the applican wil dredge, fill, or otherwise alter a waterway requires a Joint DSL/USCOE permit (which is next forwarded to DEQ for review).	Clean Water Act, Section 404 Dredge and Fill Permit		Water quality
Oregon Water Resources Department	State	Rivers	Distribution & regulation of water rights; Generally has authority over anything re: water use or quantity.	Permit to Appropriate Surface Water	Appropriation/storage/use of surface water	Water
Oregon Water Resources Department	State	Basin		Permit to Appropriate Ground Water	Appropriation/storage/use of ground water	Water
Oregon Water Resources Department	State	County	Because of the Salmon Plan Initiative, regional area coverage is changing to have the rivers and their related watersheds covered by a single region; Tillamook county is the new site of a regional office formerly based in St. Helens.	Tillamook Office has a contract with the TBNEP to install and collect flow measure data on stream gauges in Miami, Tillamook & Kilchis Rivers		Watershed
Oregon Water Resources Department	State	Rivers		Water Diversion Structure Permit		Watershed
Oregon Department of Fish & Wildlife	State	Riparian Corridor	Formulates general state programs and policies for mgmt & conservation of fish and wildlife resources.	Clean Water Act, Section 402 and 404. Administration of permits delegated to DEQ.	Reviews NPDES, sect. 10 & 404 permits for mitigation for impacts of activities/development; Provides research/technical assistance.	Habitat