

III. Flooding Fundamentals in Wahkiakum County

Flooding is a natural process resulting from a combination of factors at a given watershed level scale. In the case of Wahkiakum County, the “watershed scale” involves not only the major basins within the County (characterized below), but also the influences from the Columbia River Estuary, a product of both freshwater and ocean conditions. In general, a flooding event depends on the **intensity, duration, and timing** (see definitions below) that a volume of water drains through a watershed. These will vary depending largely on the interactions between the watershed’s **climate, topography, vegetation, and soils** from the watershed’s ridgetop to its outflow point at the valley bottom. Any natural or artificial modifications to these variables logically change the behavior of flooding for Wahkiakums' watersheds.

Below is a characterization of the fundamental factors important to understanding flooding in Wahkiakum County. Incorporating previously collected information for the watersheds of Wahkiakum County enforces the application of these principles. This information provides a context for understanding the nature of flooding events in the major basins of the County. It also intended to be a source of information for future flood hazard mitigation project planning.

A. Definitions:

Floodplain-

The floodplain is loosely defined as the land area on the sides of the river that become inundated with water during a flood. The extent of the floodplain area is disputable due to the unpredictable nature of flood events. The Federal Emergency Management Agency (FEMA) and floodplain managers define floodplains according to probabilities that a flood of a given magnitude is likely to occur, otherwise known as the **Recurrence Interval**. In this context the floodplain is expressed in terms such as “100 year floodplain” or “10 year floodplain” usually based on historic discharge data. Because little flow data exists for the watersheds of Wahkiakum County, floodplains are mapped very coarsely. The map below shows existing floodplains completed through FEMA studies according to the 100-year flood event. They are divided into the following zones in order to calculate relative risk for flood insurance purposes. Both Zone A and Zone AE are considered Special Flood Hazard Insurance Areas (SFHA) which are areas inundated by 100 year Floods.

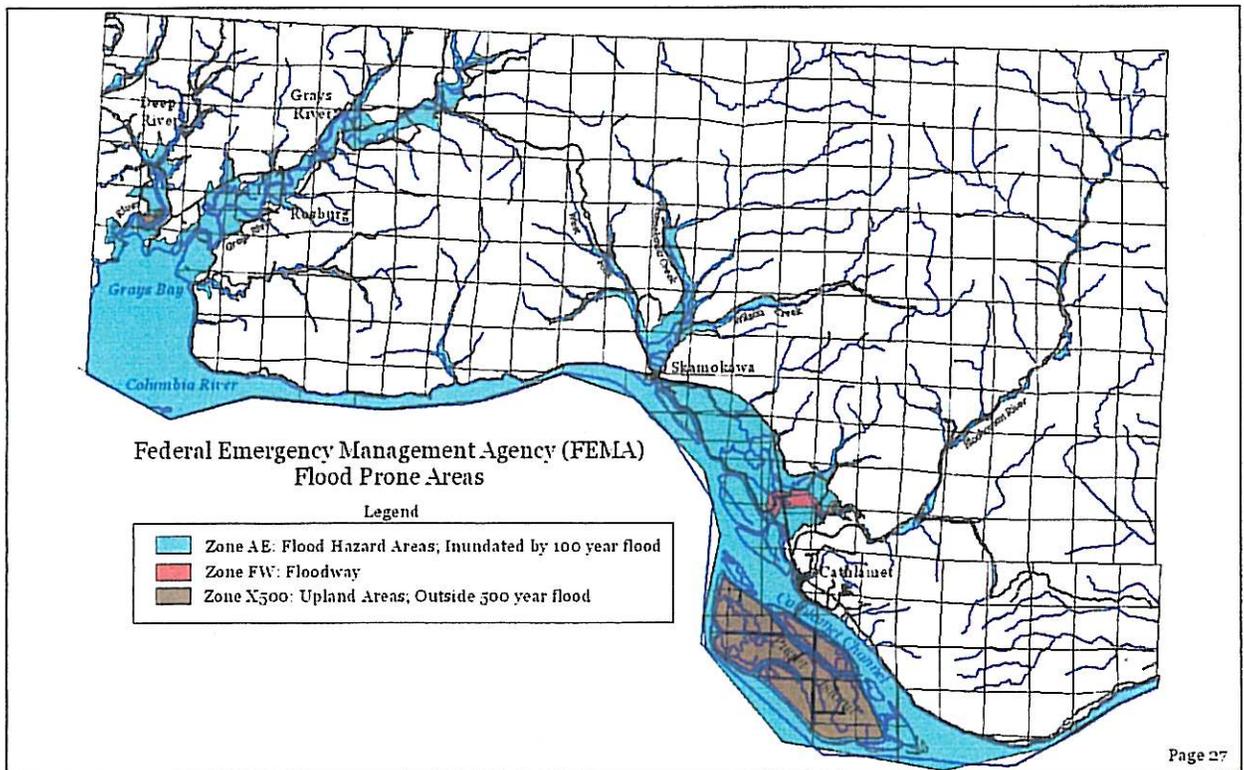
A Zone- Corresponds to the 100 year-floodplains that are determined in the Flood Insurance Study by approximate methods. No base flood elevations or depths are shown within this zone.

AE Zone- Corresponds to the 100-year floodplains that determined in the Flood Insurance Study by detailed methods. Whole-foot base flood elevations derived from the detailed hydraulic analyses are shown at selected intervals within this zone.

X 500 Zone-(Shaded 'Gray' on FIRM maps) Corresponds to areas within the 500-year floodplain, areas of 100-year flooding where average depths are less than 1 foot, areas of 100-year flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees. No base flood elevations or depths are shown within this zone.

X Zone-(Unshaded 'White' on FIRM maps) Areas determined to be outside 500-year floodplain

Figure 3.1: FEMA Defined Floodplains



Source: Wahkiakum County

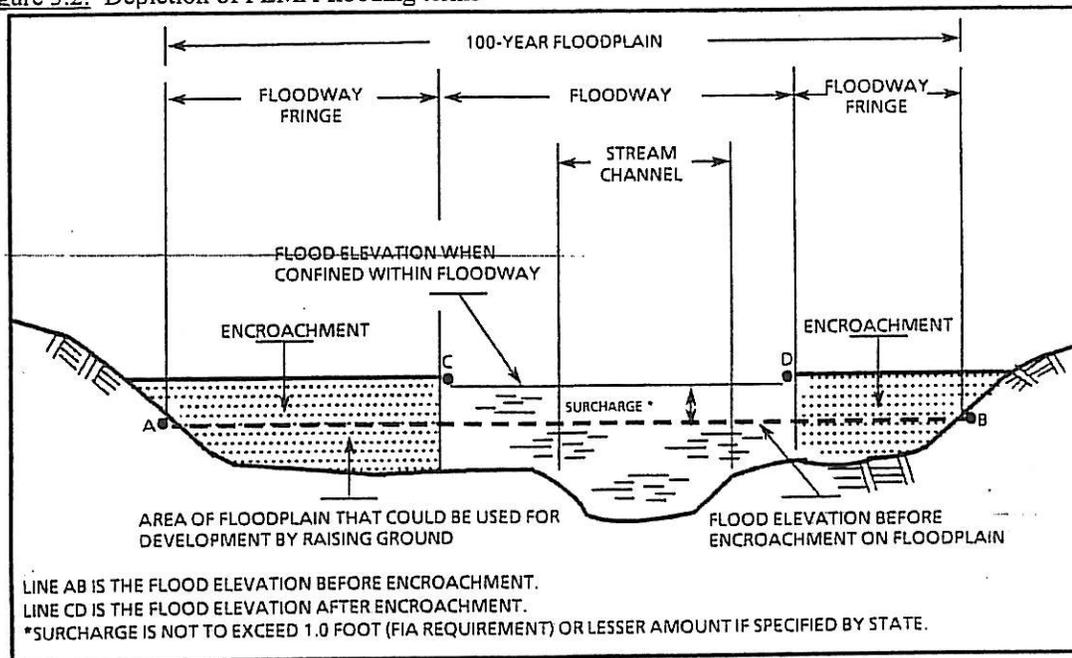
Floodway-

The floodway (red zone in figure 3.1) is one of two main sections (see **Flood Fringe** below) that make up the floodplain. Floodways are defined for regulatory purposes. Unlike floodplains, floodways do not reflect a recognizable geologic feature. Under the National Flood Insurance Program (NFIP), floodways are defined as the “channel of a river or stream, and the over bank areas adjacent to the channel.” The floodway carries the bulk of the floodwater downstream and is usually the area where water and forces are the greatest. NFIP regulations require that the floodway be kept open and free from development or other structures, so that flood flows are not obstructed or diverted onto other properties. The NFIP defines a floodway as the channel of a river or other watercourse and adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than one foot. Floodways are not mapped for all rivers and streams but are generally mapped in developed areas. For Wahkiakum County, the floodway is mapped only for portions of the Elochoman River resulting from a FEMA flood study. This study determined base flood elevations in the area near the Town of Cathlamet.

Flood Fringe-

The flood fringe refers to the outer portions of the floodplain, beginning at the edge of the floodway and continuing outward. It encompasses the portion of the floodplain that could be completely obstructed without increasing the elevation of the 100-year flood by more than 1 foot at any point. This is the area where development is most likely to occur, and where precautions to protect life and property need to be taken.

Figure 3.2: Depiction of FEMA flooding terms



Source: National Flood Insurance Study, Wahkiakum County (FEMA, 1990)

Development-

For floodplain ordinance purposes, development is broadly defined to mean “any man-made change to improved or unimproved real estate, including but not limited to buildings or other structures, mining, dredging, filling, grading, paving, excavation, or drilling operations or storage of equipment or materials.”

Development in the floodplain can involve some level of risk for all residents along the stream corridor. Activities associated with development in the form of diking and filling can reduce the potential area that a volume of river flow can occupy. This displaces the volume of water downstream thereby increasing the need for flood mitigation elsewhere.

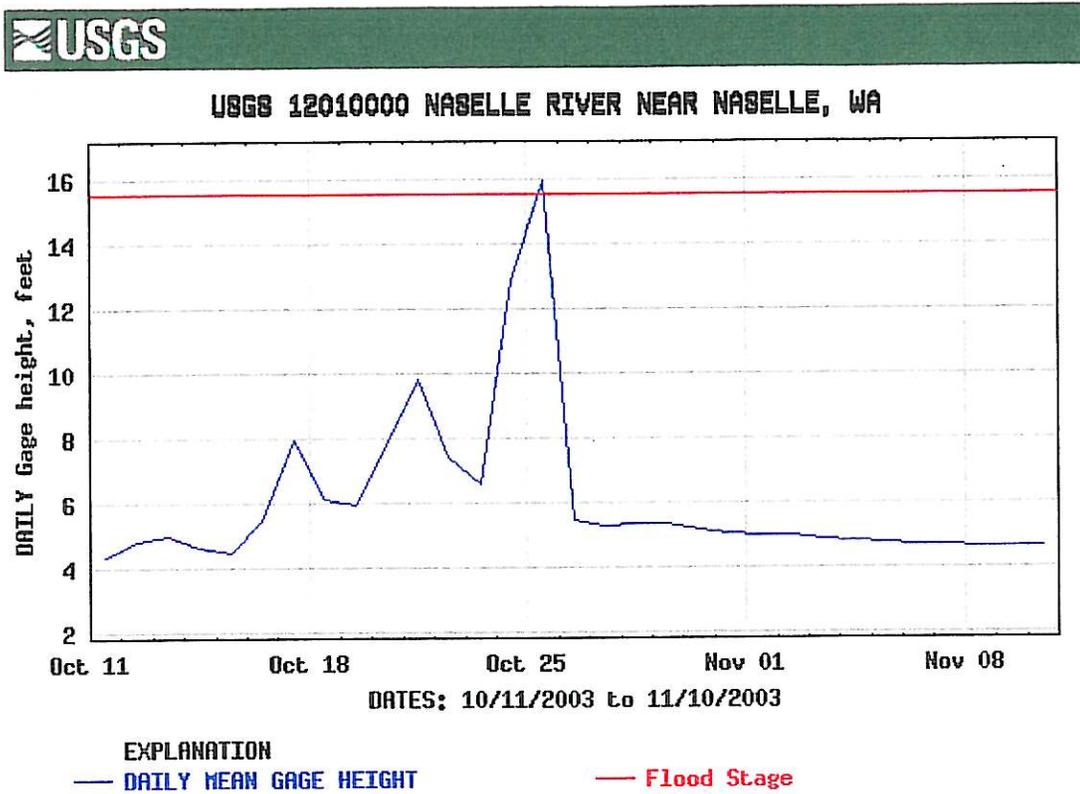
Base Flood Elevation-

The term Base Flood Elevation (BFE) refers to the elevation (normally measured in feet above sea level) in which the base flood is expected to reach. Base flood elevations can be set at levels other than the 100-year flood. Some communities choose to use higher frequency flood events as their base flood elevation for certain activities, using lower frequency events for others. For example, for the purpose of storm water management, a 25-year flood event might serve as the base flood elevation, while the 500-year flood event may serve as base flood elevation for the tie down of mobile homes. The regulations of the NFIP focus on development in the 100-year floodplain. The only place BFE has been determined is in the Town of Cathlamet through the Flood Insurance Study and the entire Columbia River from the Elochoman River to Grays River explained later in this document (Chapter 6).

Hydrograph-

Hydrograph is the most commonly used method for understanding the floodplains interaction with the active river channel. Hydrographs measure the rate of flow and/or level of water at a given point for a period of time otherwise known as **discharge**. Another term for discharge is **flood magnitude**. Flood magnitude can change from a variety of natural and man made factors. The United States Geological Service (USGS) maintains a network of stream gauges nationwide that produce both historic and real time hydrographs (see figure 3.3). While hydrographs simplify the complex interactions of stream flows and the floodplain, it is information that is critical to understanding *Recurrence Intervals*, *Flood Timing* and *Flood Duration* defined in this section.

Figure 3.3: Example of USGS Stream Gauge Data (Source: www.usgs.gov)



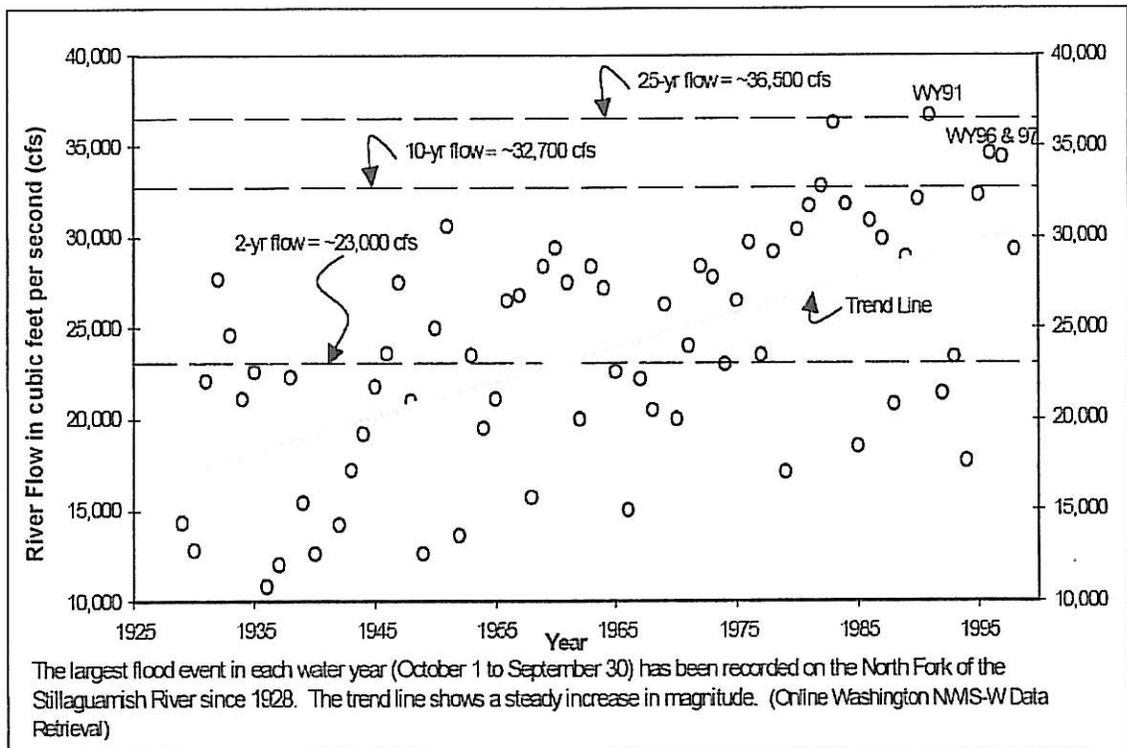
Provisional Data Subject to Revision

Source: <http://waterdata.usgs.gov/wa/nwis/>

Recurrence Intervals-

A Recurrence Interval is the frequency of flooding likely to occur for a high flow event. (i.e. 25, 50, 100, 500 year). Recurrence intervals are based on existing information about river discharge. Recurrence intervals are often misunderstood. For instance, volumes for 100-year flood do NOT mean these discharges occur once every 100 years. Instead, a 100 year flood should be interpreted as having a 1% chance of occurring every year. Similarly, a 25 year flood event has a 4% chance of occurring in a given a year, a 10 year event has a 10% chance of occurring and so on. The standard for measuring discharge is presented in cubic feet per second or cfs. Discharge measurements help us gain a variety of information about the magnitude and frequency (figure 3.4) of flooding for a basin. With some analysis, they can also reduce the level of uncertainty about future flooding events. Discharge information can help better define the Recurrence Interval of floods by looking at past events to predict the likelihood of discharge levels for a given time period. For example, with enough stream gage data, a percentage can be calculated for the likelihood that a specific discharge will happen during a 10 year time period. Below is an example of estimated peak discharge volumes for various recurrence intervals for the Stillaguamish Watershed in the Puget Sound (10 year flood=32,700cfs).

Figure 3.4: Example of Recurrence Interval and Flow Data



Source: Snohomish County Public Works-Surface Water Management

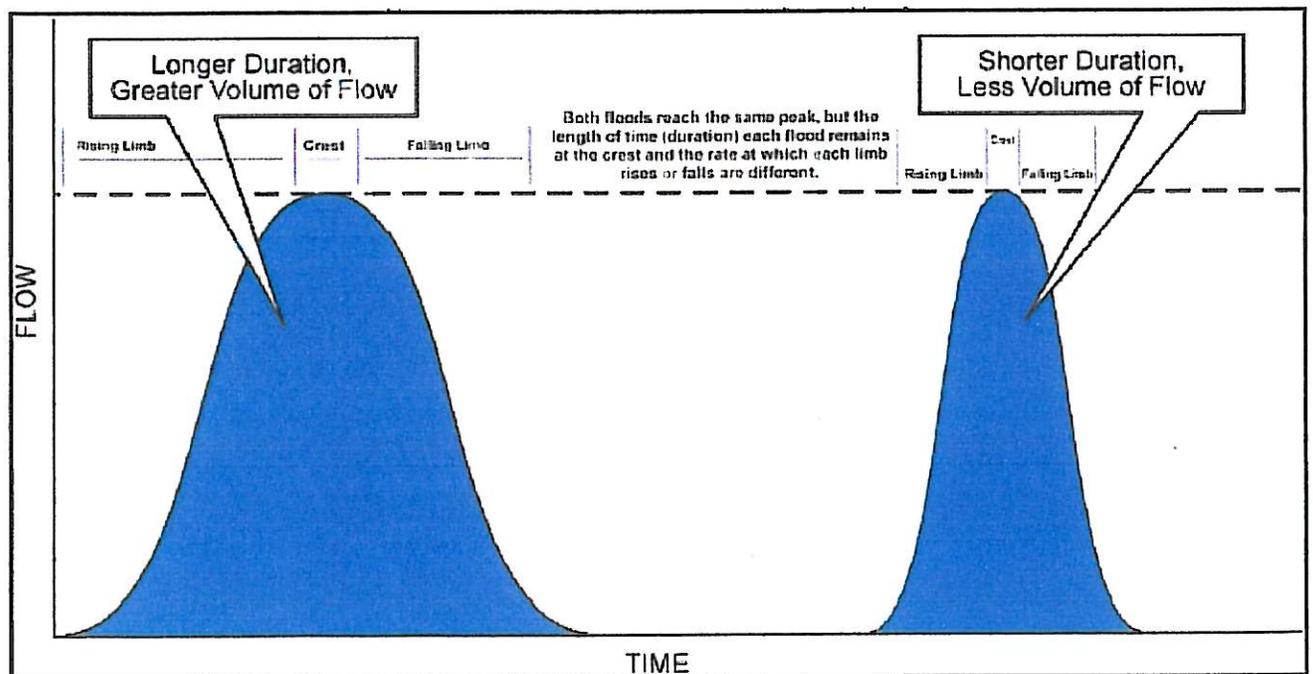
Flood Timing-

Flood Timing is a factor in understanding how quickly a stream channel can transfer a discharge from one point in the watershed to another. Man-made influences can change the rate of water through activities like construction of impervious surfaces and instream structures (dams, weirs, rip-rap, etc.). Flood timing is an indicator of the “flashiness” of a basin, which can sometimes increase erosional forces downstream. **Flood Elevation/Stage** is the depth of water associated with a particular flood measured at a specific location on the river. It can be measured as stage (river depth) or as the ground elevation to which the water rises. Generally when flood warning information is provided to the public, it is provided in terms of stage or elevation that corresponds to the peak that water levels rise at a particular location along the river. This peak is also commonly referred to as the river crest. The river crests in the upstream reaches of a river first, and then moves downstream. Faster moving crests tend to have higher velocities, which can accelerate the bank eroding power of river flow.

Flood Duration-

The principle of flood duration is critical to understanding all types of flooding. Duration is directly related to the amount of time a given volume of water persists for a specific area. Flood duration depends on the combination of factors above in addition to the soils capacity to drain water.

Figure 3.5: Depiction of hydrograph patterns indicating flood duration



Source: Stillaguamish Flood Plan, 2003

Channel Migration Zone (CMZ)-

Channel Migration Zone (CMZ) is the area where a stream or river is susceptible to channel erosion. The State of Washington has developed a framework for delineating these areas in light of flooding risks for its communities. CMZ delineations help reduce risks to human communities by guiding development in and along river systems away from such areas. Limiting development within CMZs also reduces the costs of repairing or replacing infrastructure and major civil works that might otherwise be threatened or damaged by channel migration. Mapping these zones for the watersheds of Wahkiakum County would be an important tool.

National Flood Insurance Program (NFIP)-

The National Flood Insurance Program (NFIP) was established in 1968 with the passage of the National Flood Insurance Act. The purpose of the National Flood Insurance Program was to relieve the national Treasury and local jurisdictions from the burden of disaster relief.

The NFIP enables property owners in participating communities to purchase insurance to protect against flood losses in exchange for State and community floodplain management regulations that will reduce future flood damages. The Federal Insurance and Mitigation Administration within FEMA administers the NFIP.

The NFIP administers two separate programs. The Emergency Program identifies flood prone communities and preliminarily delineates flood hazard areas on a Flood Hazard Boundary Map (FHBM). Based on the FHBM, the community must adopt minimum floodplain management regulations. The Regular Program provides full flood insurance to communities that have adopted a local floodplain management ordinance that has been approved by FEMA. The basis of the ordinance is a detailed flood insurance study resulting in the Flood Insurance Rate Map (FIRM) and a report. Wahkiakum County's *Flood Damage Prevention Ordinance* is the local ordinance satisfying FEMA's requirements for participation in the NFIP.

Flood Insurance Rate Map (FIRM)-

The Flood Insurance Rate Maps display the results of a community's Flood Insurance Study (FIS). The FIS's use detailed hydrologic and hydraulic analyses to develop base flood elevations and to designate floodways and risk zones for developed areas of the floodplain. The FIS usually generates the following information:

- Base Flood Elevations: presented as either water-surface elevations or average depths of flow above the ground surface
- Water Surface Elevations: presented for the 10-year (10% annual chance); 50-year (2% annual chance); 100-year (1% annual chance); and, 500-year (0.2% annual chance) floods
- Boundaries of the regulatory 100-year floodway
- Boundaries of the 100- and 500-year floodplains (the 100-year floodplain is referred to as the Special Flood Hazard Area)

(Note: Additional flood mapping is a need in Wahkiakum County would reduce the risk of future damage and is identified as a specific action item in Chapter 6)

Community Rating System (CRS)-

The Community Rating System (CRS) provides discounts on flood insurance premiums in those communities that establish floodplain management programs that go beyond NFIP minimum requirements. The CRS provides credits to communities for more restrictive regulations, acquisition, relocation, flood proofing, preservation of open space, and other measures that reduce flood damages or protect the natural resources and functions of floodplains.

The CRS adjusts flood insurance premium rates to reflect the reduced flood risk result from community activities that meet the three goals of the CRS. These goals are: 1) reduce flood losses; 2) facilitate accurate insurance rating; and, 3) promote awareness of flood insurance. Activities that can receive credits include the implementation of local mitigation, outreach, and educational activities. All communities in Washington that participate in the National Flood Insurance Program (NFIP) must adopt and enforce floodplain management regulations of the NFIP and of Washington's Floodplain Management Law at RCW 86.16.

Flood Control Assistance Account Program (FCAAP)-

FCAAP is a major source of federal funding for the development and implementation of CFHMPs administrated through the State of Washington's Department of Ecology. Municipalities are eligible for funding of flood hazard management projects through FCAAP provided they complete and adopt a CFHMP using guidelines established by the Department of Ecology.

Map Modernization Program (DFIRM)-

The Federal Emergency Management Agency (FEMA) developed a plan in 1997 to modernize the FEMA flood mapping program. The plan outlined the steps necessary to update FEMA's flood maps for the nation to digital format and streamline FEMA's operations in raising public awareness of the importance of the maps and responding to requests to revise them. Since that time, the plan has continually evolved as new products, processes, and technical specifications have been developed and implemented within present funding levels, which have not approached the levels necessary to fully update the national map inventory. Department of Ecology is the lead agency for determining priority mapping needs for the State of Washington under this program.

B. Wahkiakum County Climate Patterns

Climate is a key driver of understanding the source of flow variability in the watersheds of Wahkiakum County. Climate in Wahkiakum County has been characterized as being a “mid latitude Marine West Coast Climate.” Residents of the area experience seasonal patterns of cool, dry summers, very wet winters, and moist air throughout most of the year. Long-term data sets from the Western Climate Center confirm these seasonal trends (figure 3.6), with the highest volume of precipitation taking place from November to January. Within these wetter months precipitation intensities can be considerable in the area, with daily averages known to exceed four (4”) inches (VTN, 1974).

In addition, individual watersheds inherently express natural variations in precipitation. Information collected from the WRIA 25 Limiting Factors Analysis demonstrates this phenomenon (figure 3.7). Precipitation data at the watershed level provides a more precise context for understanding flow variations at a smaller scale.

Figure 3.6: Wahkiakum County Precipitation Patterns

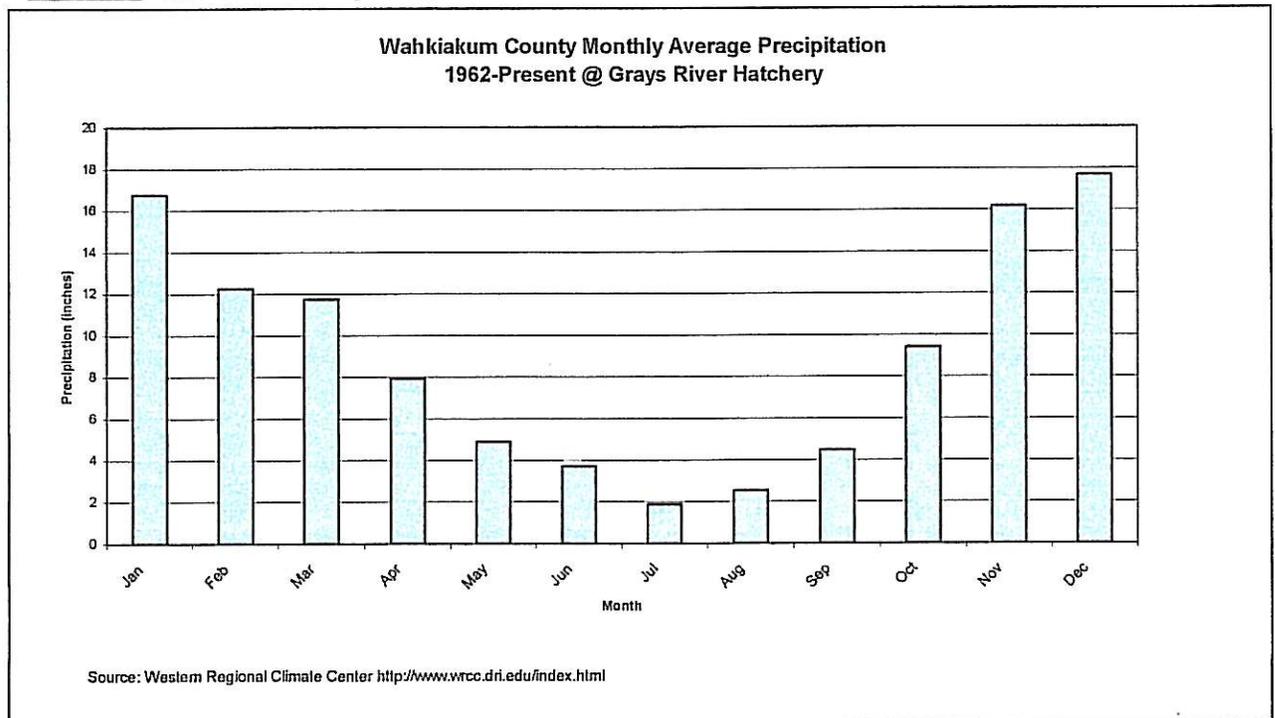
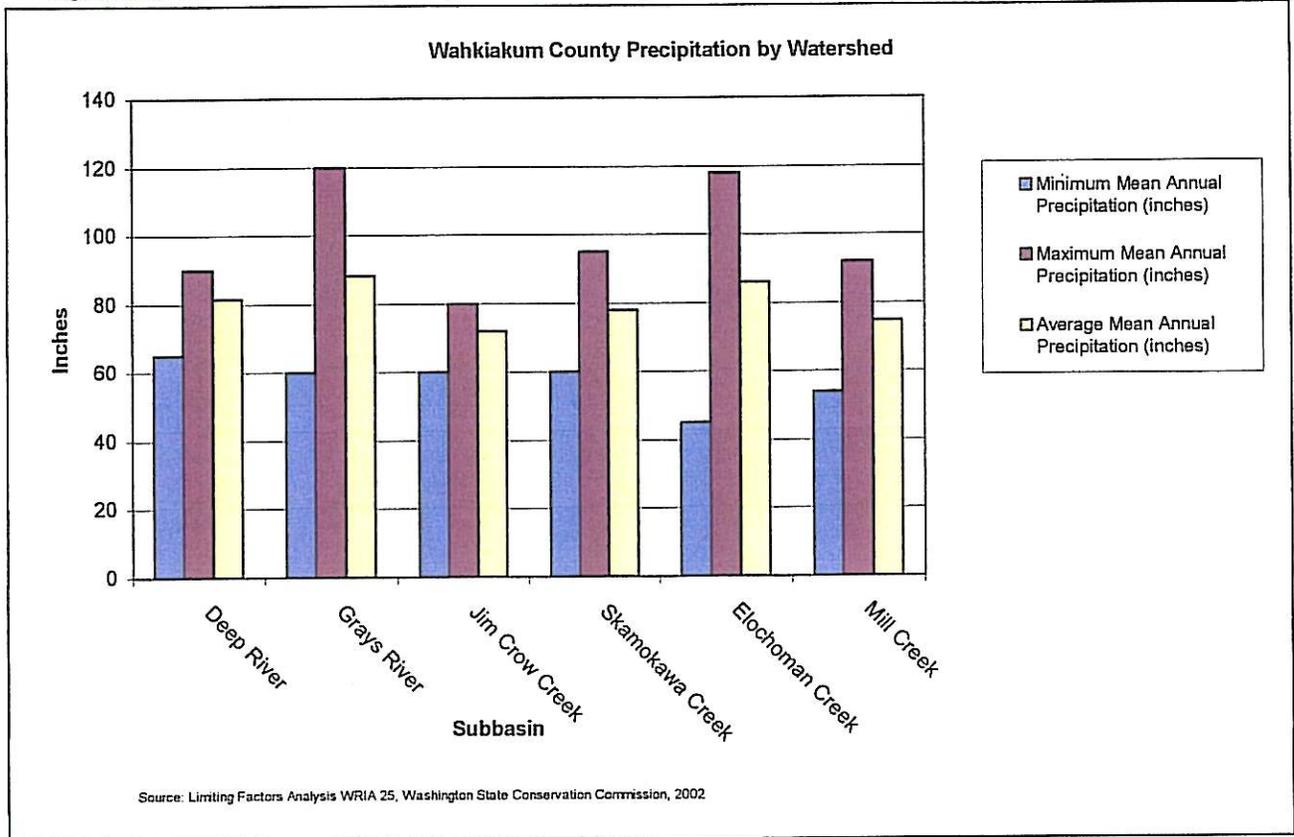


Figure 3.7: Wahkiakum County Precipitation Patterns by Watershed



The climate regime for Wahkiakum County is also influenced by wind patterns based on seasonal changes in air pressure. In spring and summer, a large high-pressure area covers most of the northeastern Pacific Ocean. Prevailing winds during this time period originate from the northwest. In the fall and winter, the wind pattern shifts to a more southwest-southerly pattern. As a result, fogs banks frequently form offshore and move inland at night, but eventually evaporate by noon. Wind patterns can amplify erosive shoreline wave patterns and increase elevations especially when susceptible to Columbia River storm surges.

Flow patterns from snow melt is minor for the watersheds of Wahkiakum as figure 3.8 shows. This phenomenon can affect the intensity and timing of high flow events in a watershed. The Washington State Department of Natural Resources recognizes five climate zones: *lowlands*, *rain dominated*, *rain on snow*, *snow dominated*, and *highlands*. These zones begin to provide an indication of how a watershed is expected to respond during winter runoff. Below is a summary of the data collected divided up into these zones. Of all the basins Elochoman Creek has the highest degree of snow accumulation covering almost 10% of its watershed.

Figure 3.8: Climate Zone Characterization (Percent of Watershed)

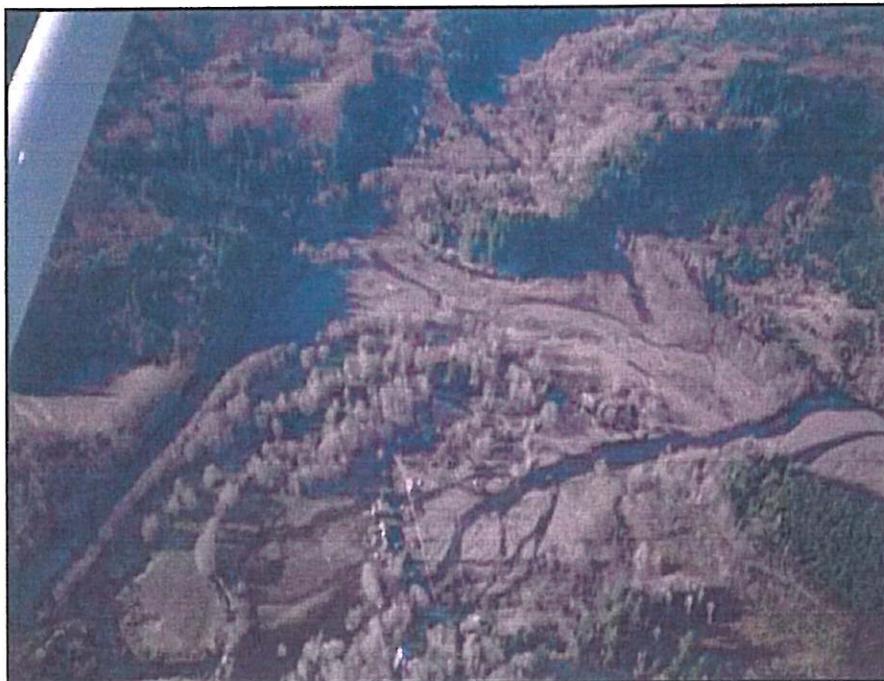
Watershed	Lowlands	Rain on			Highlands
		Rain Dominated	Snow Dominated	Snow Dominated	
Deep River	48.2	51.8	0	0	0
Grays River	36.6	62.4	1	0	0
Jim Crow Creek	96	4	0	0	0
Skamokawa Creek	79.1	20.1	0.6	0.2	0
Elochoman River	16.6	73.6	9.8	0	0

Source: WRIA 25 Limiting Factors Analysis

C. Topography

The variations of topography from the Coast Range's Willapa Hills, uplands, and volcanic outcroppings creates unique pockets of microclimates in Wahkiakum County as indicated above. Topography also influences the rate which water travels through the watershed (timing) and therefore the energy it carries. Enough energy in the water column moves material downstream and can even create new channels needed to carry its volume as witnessed in *avulsion* events such as the one that occurred in 2001 at Gorley Springs (figure 3.9). Information collected as part of a watershed characterization project conducted by Cowlitz and Wahkiakum Conservation Districts (figure 3.9) demonstrates this pronounced terrain as part of their Watershed Characterization project. Lower gradient streams at the valley bottoms are more exposed to runoff patterns of the Columbia River and daily tidal cycles. These sections of Wahkiakums watersheds experience lower rates of velocity and are therefore slower to drain and move material to its mouth.

Figure 3.9 Air photo Gorley Springs area avulsion



Source: Lower Columbia Fish Recovery Board

Figure 3.10: Topographic Variation for the Watersheds of Wahkiakum

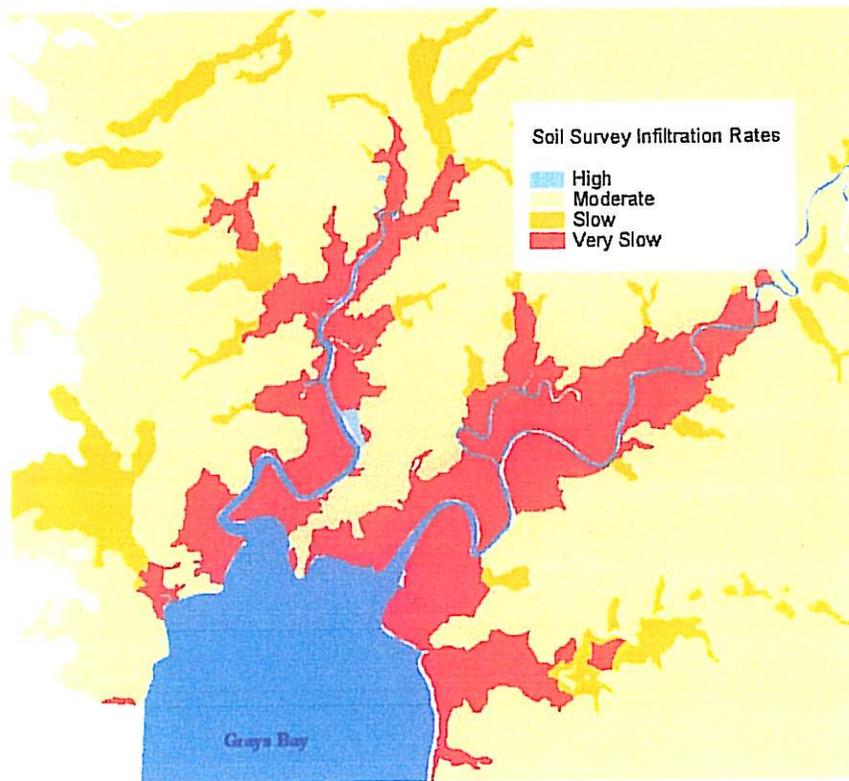
Watershed	Average Slope (%)	Maximum Elevation (feet)	Minimum Elevation (feet)	Average Elevation (feet)
Deep River	13.6	1000	5	291
Grays River	24.3	2840	5	948
Jim Crow Creek	20.3	1480	5	490
Skamokawa Creek	25.2	2600	5	570
Elochoman River	23.7	2673	5	883

Source: WRIA 25 Limiting Factors Analysis

D. Flooding and Local Soil Conditions

Soils are a critical variable in understanding flow patterns in a watershed. The soil characteristics help determine how quickly water infiltrates through the ground and into surface water flows. The Wahkiakum County Soil Survey classifies these soils according to their texture and structure for land use purposes in the County. This information can also be readily applied to learning about the causes of flooding. Soils with a high percentage of sand or coarser material tend to drain water faster than finer, more cohesive soils with a clay-like consistency. Infiltration rates have been assigned to all the soil types in the County. They are divided into four groups according to the dominant soil texture and rates. As figure 3.11 depicts for the Gray's Bay area, significant patches of soil with low infiltration rates have been identified. (See Appendix A-5 for soil infiltration classification for the whole County) As many residents know, these areas experience flooding from direct precipitation (see Chapter IV "localized flooding").

Figure 3.11: Soil Infiltration Rates Grays Bay Area



Source: Natural Resource Conservation Service (NRCS)

Source: SSURGO Data, Natural Resource Conservation Service (image produced by CREST)

The County Soil Survey also provides information on a soil types degree of erodibility. Erodibility is also a factor in assessing sources of sediment in the watershed. It can affect channel shape and its drainage capacity (see Surface Drainage Patterns). Currently, at the mouth of the major watersheds in Wahkiakum, channels are silting in or “accreting” with sediment. The sources of these sediment inputs are not well documented. However, understanding factors like climate, topography, and existing land use can assist in assessing potential sources of sediment.

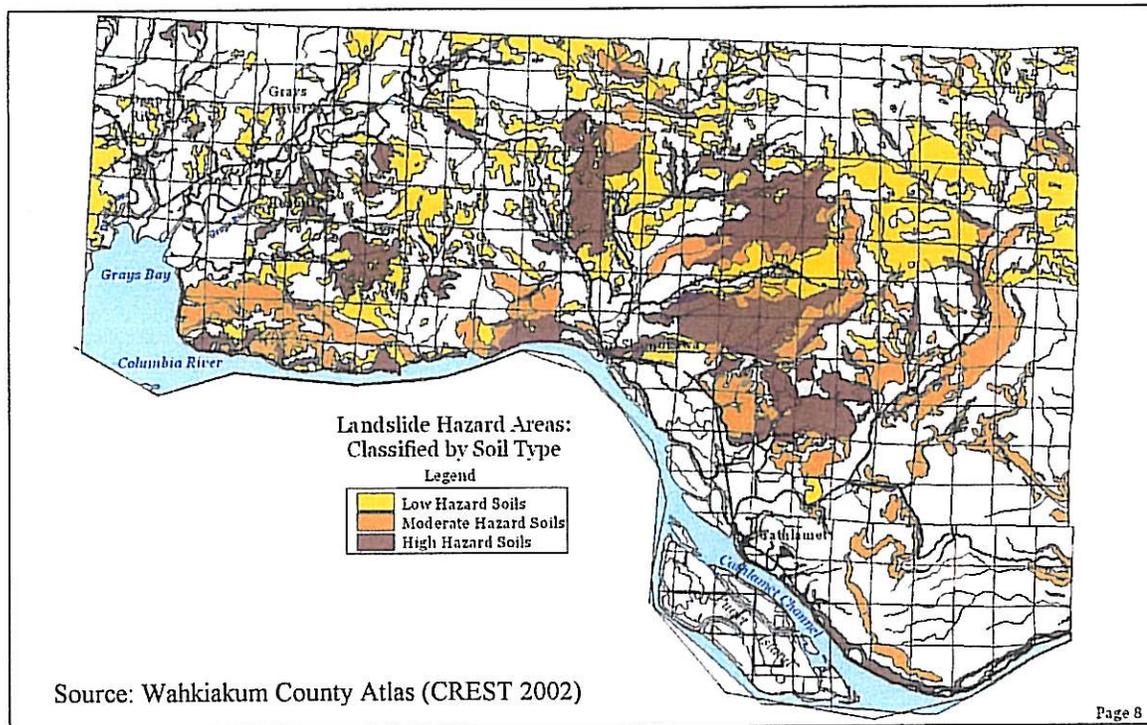
Figure 3.12 produced from County Soil Survey data show the distribution of soils susceptible to landslides based on the following factors:

- ◇ Depth of Soils Before Bedrock
- ◇ Slope
- ◇ Permeability
- ◇ Availability of Water
- ◇ Effective Rooting Depth
- ◇ Rate of Rapid Runoff
- ◇ Hazard of Water Erosion

Mass movements are examples of these variables converging creating potential sediment sources for Wahkiakum County’s watersheds. They also can be triggered by human land uses such as road building and forest practices. Forest practices and associated uses

increase the soils exposure to precipitation. Water penetrating the soil overtime lubricates loose soil particles causing them to move when located on moderate gradient slopes. While no formal assessment has been conducted for mass movement events, cursory knowledge of their extent and frequency was compiled during the Watershed Characterization project.

Figure 3.12: Landslide Hazard Assessment by Soil Type



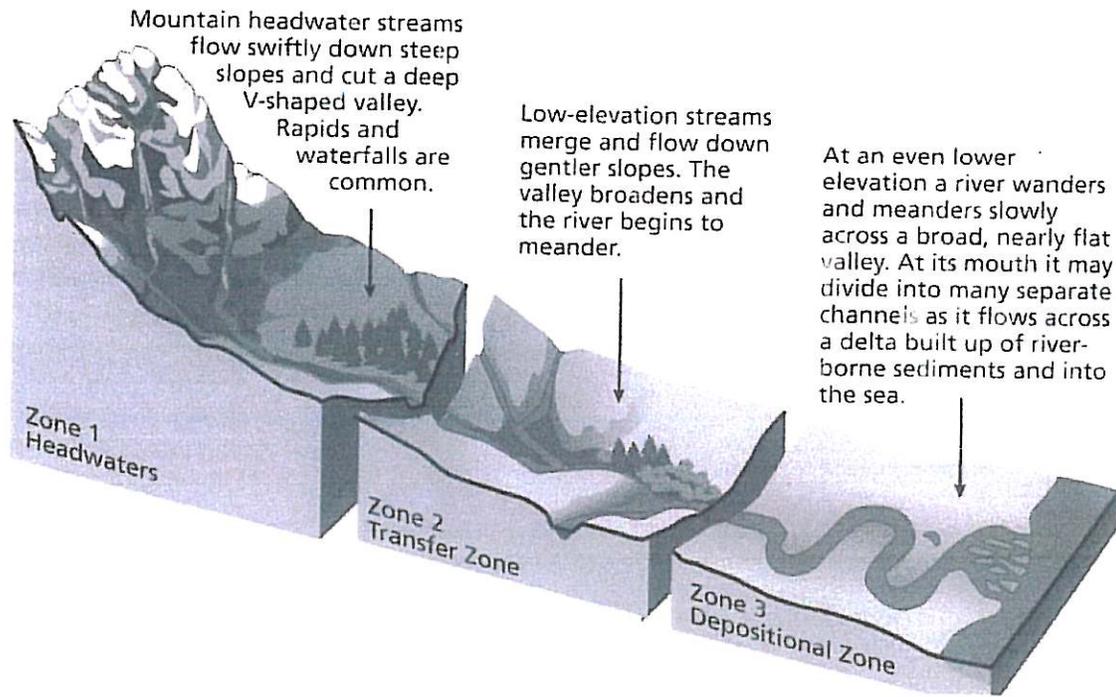
Other sources of sediment can include: unpaved roads, degraded culverts, dense road networks on steep slopes, streambank downcutting. Catastrophic events can also bring large pulses of sediment as witnessed during the Gorley Spring avulsion. Excessive sediment loading can be a contributing factor increasing the risk of future flooding events. No quantifiable information exists to prove or disprove this concept for Wahkiakum watersheds. However the science for this phenomena demonstrates the role of sediment load in channel migration patterns. The response of a river system to increased sediment supply depends on the ratio of transport capacity to the sediment supply. Significant aggradation, channel widening, bed filling, pool filling, or braiding occurs where the amount of introduced sediment overwhelms the local transport capacity. This consequently generates a response in channel shape, triggering a change in channel direction. This change in direction can have detrimental effects to private property as flow patterns are directed toward the erosion of streambanks. This is especially true for the stream reaches in Grays River where sediment inputs are causing extreme channel migration, erosion, and therefore compounding the entrainment of more sediment to a system that is already sediment laden.

Sediment sources and its interaction with the rivers of Wahkiakum is a complex process. More information is needed to understanding sediment patterns and trends in order to make better decisions about what are the best strategies for reducing sediment delivery to the stream channel. Currently, studies are being planned and conducted in the Grays River that determine what the sediment sources are and how they interact with existing flow patterns. This information can lead to a better idea of the channel change trajectory the river is on and ideally, will assist in the planning of long term flood hazard mitigation strategies.

E. Surface Drainage Patterns

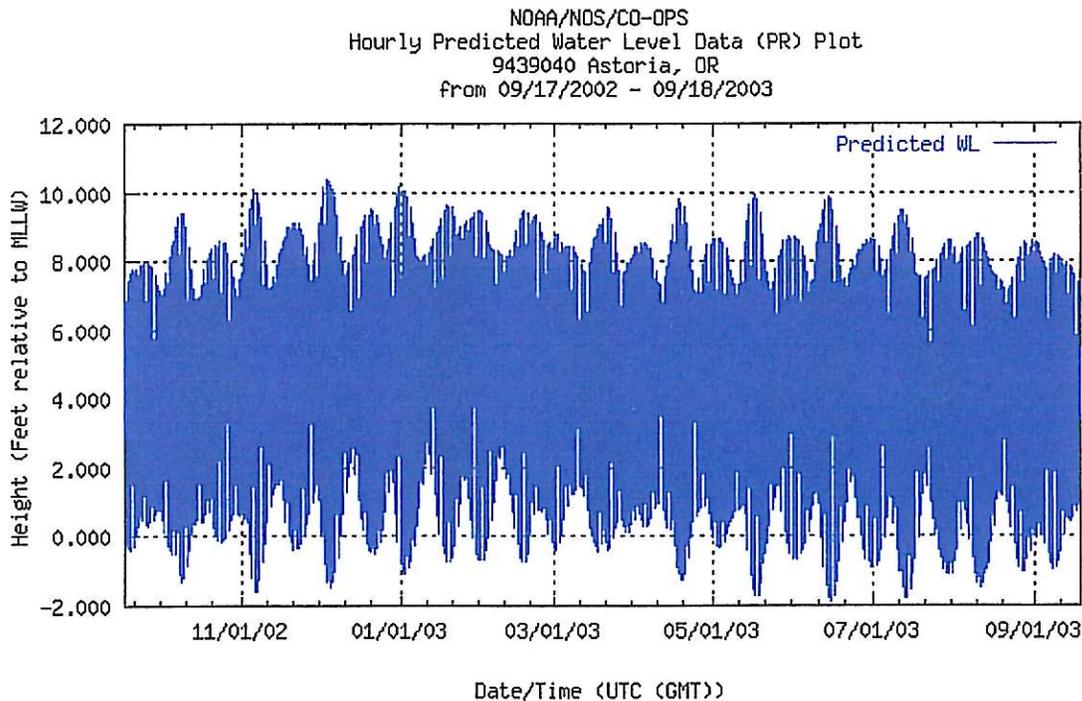
The climate and topographical variations described above shape flow patterns and intensity for the watersheds of Wahkiakum County. Almost all of the watersheds within Wahkiakum County flow into the Columbia, with the exception of the Naselle and Salmon Creek watersheds which ultimately flow into Willapa Bay. Generally speaking, most watersheds are characterized by several zones as seen in figure 3.13. The surface drainage patterns of the County are dominated by narrow steep channels in the upper portions of the watershed. As discussed above, depending on land use and soil erodibility, these areas can serve as sources of sediment. In Wakiakum's major basins these upper zones flow into "transfer zones" where stream power begins to lessen allowing coarser, heavier particles to deposit. Eventually the river energies diffuse even further when they interact with tidal forces allowing lighter sediment to settle and form deltaic landforms at the mouth. The Columbia River upstream drains an area of approximately 257,000 square miles. Since the construction of Columbia mainstem dams, flow patterns have changed the timing and magnitude of discharge and elevations. The placement of these structures and, in lesser degree, irrigation withdrawals have diminished the impact of the spring freshets that would re-configure drainage patterns on the Columbia's tributaries almost annually. The installation of pile dikes and other structures have further modified the drainage patterns in the tidal areas (figure 3.14) throughout Wahkiakum County. The cumulative effect of all these impacts has contributed to accelerated deposit of sediment in all the embayments of the Columbia River Estuary including the mouths of the Elochoman, Skamokawa, and Grays watersheds.

Figure 3.13: Conceptual Model of Watershed Drainage Patterns



Source: Oregon Sea Grant, 2002

Figure 3.14: Tidal Elevation Ranges on the Columbia River Estuary



Source: <http://co-ops.nos.noaa.gov/>

Human activities also have an effect on the drainage patterns of Wahkiakum's watersheds. Extensive diking and tidegate installation have taken place in all of the major basins in Wahkiakum County. While providing moderate protection against overbank flooding in the tidal area, these structures have altered the historic drainage patterns of the watershed. Previously a complex network of drainage patterns existed that served as off channel storage for high flow events and sediment material. Due to flood control measures, these backwater areas have been cut off, thereby confining discharge to inner portions of the floodplain. This in effect confines the channel to a specific area that challenges the capacity of the channel to carry its discharge consequently increasing the risk of raising the level of the active channel downstream. Below are summaries of surface drainage patterns for each watershed area, based on existing USGS flow data and previous studies. Figures are given for each area showing Special Flood Hazard Areas based on digitized coverages of FEMA Insurance Rate maps.

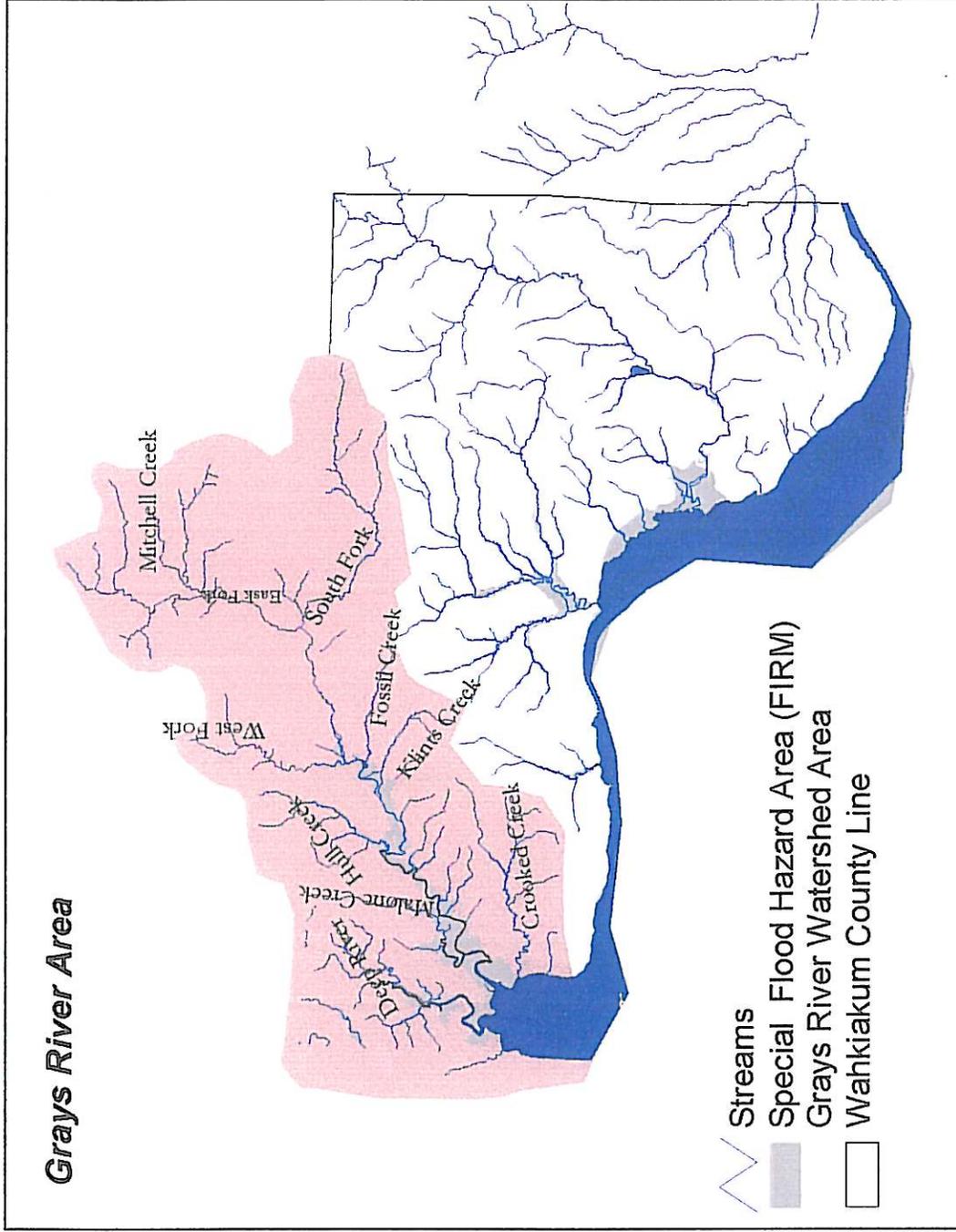
Grays River

Grays River is the largest watershed in the County typified by steep headwaters forming a network of ridges and mountain peaks where elevations can vary up to 1,500 feet in one mile (figure 3.15). The basin expands over three different counties with approximately 55% of the total watershed outside of Wahkiakum County. The rivers direction roughly heads southwest along the counties northern boundary before its floodplain broadens and develops more meander-like channel patterns. Grays River's major tributaries are the West Fork, Fossil, Klints, King, Thadbar, Nikka, Impie, Seal, Malone, and Hull Creeks.

Grays River Flow Data

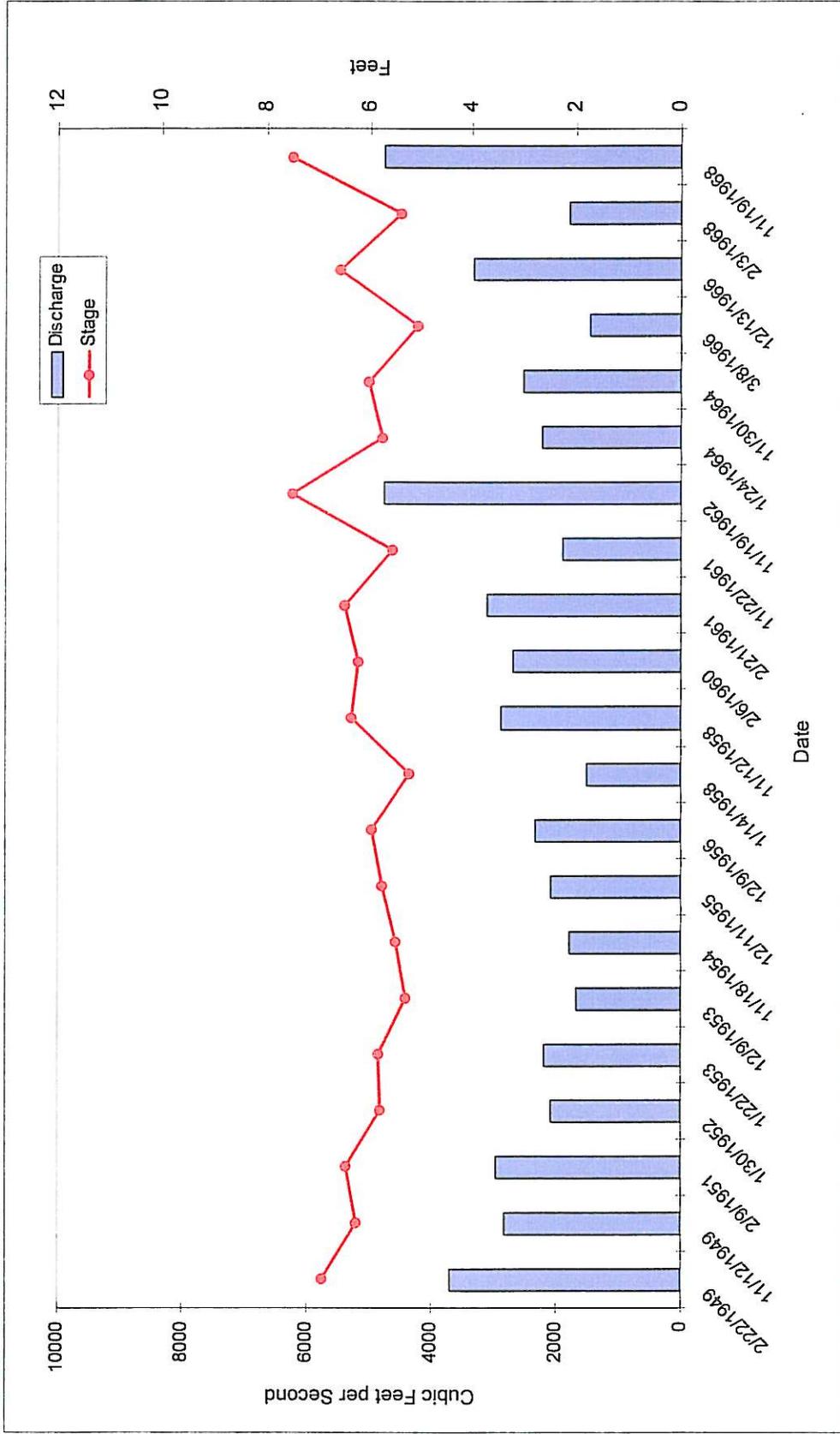
Flow data is very sparse for the Grays River Basin. Data was collected for very short periods of time at three (3) gage stations managed by United States Geological Service (USGS). These gage stations took daily stream discharge measurements that are important to understanding the flow dynamics for a given time period. Figures 3.16 and 3.17 show annual peak flow and river stage elevation data collected from these stations. As mentioned before, flow data collected over a long period of time can assist in developing the predictability of the frequency and intensity of flooding events. Annual Peak Flow data is also available indicating high flow events that conducive to overbank flooding. For this data set, coarse estimates of corresponding flood stage are given that can be useful for understanding elevation changes for each high flow event.

Figure 3.15: Grays River Watershed Area



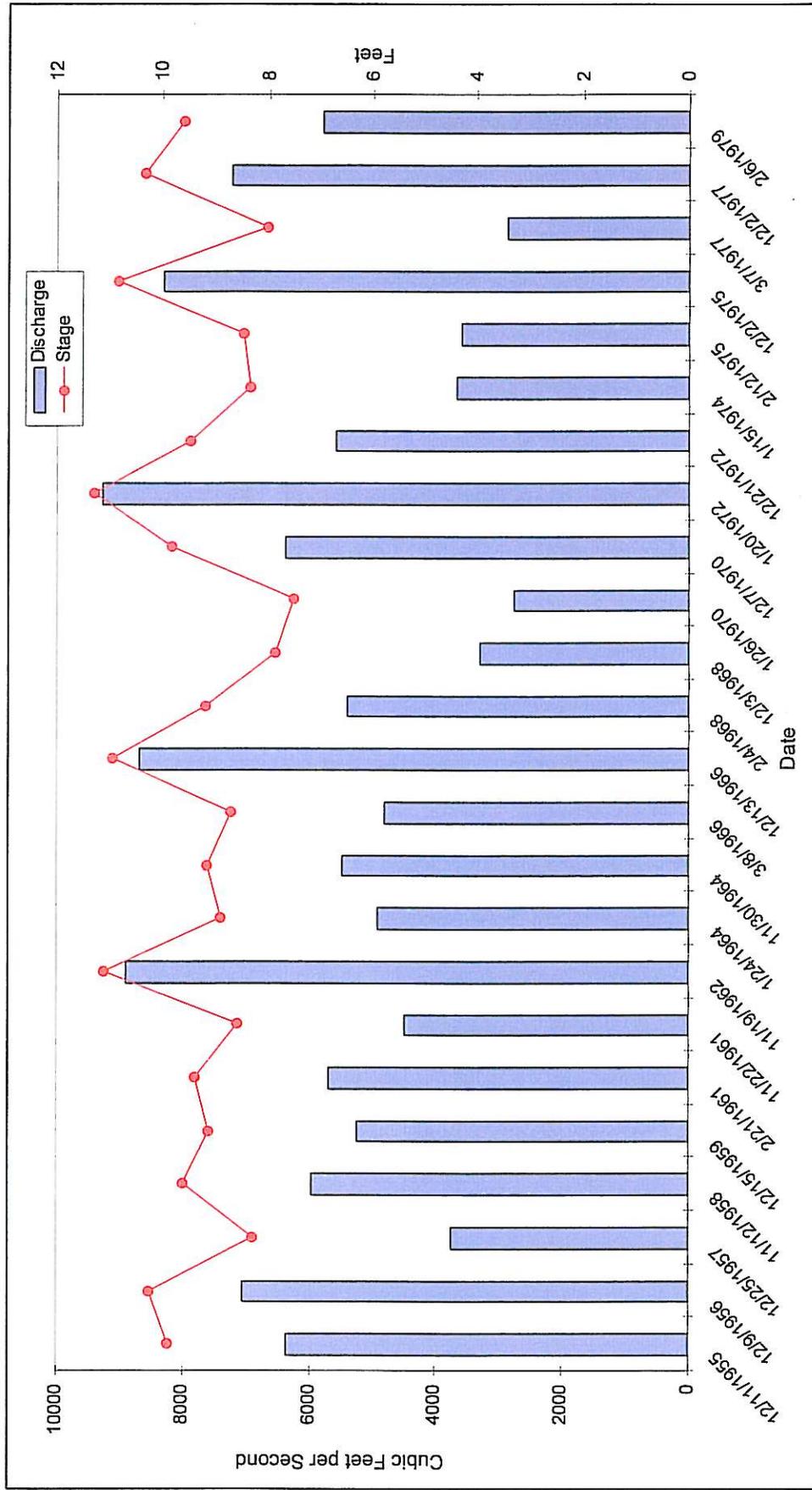
Source: CREST 2003

Figure 3.16: Grays River Annual Peak Discharge-Flood Stage, West Fork Grays River (1949-1968), USGS Gauge # 14250500



Source: <http://wa.water.usgs.gov/data/realtime/historical.html>

Figure 3.17: Grays River Annual Peak Discharge-Flood Stage, (above South Fork) 1955-1979, USGS Gauge # 14249000



Source: <http://va.water.usgs.gov/data/realtime/historical.html>

Grays River Hydrologic Modeling Results

The Lower Columbia Fish Recovery Board, as part of their Watershed Planning effort, contracted with Pacific Water Resources, Inc. to model stream flow dynamics in Grays River. This effort, titled “*Hydrologic Modeling of Effects of Land Use Changes WRIA 25/26*”, was intended to accomplish the following objectives:

- ✓ Improve understanding of the effects of changes in land use and land cover on stream flows in WRIAs (Water Resource Inventory Area) 25 and 26.
- ✓ Develop capabilities for forecasting effects on flow of specific changes in land use and land cover in selected subbasins.
- ✓ Provide numerical estimates of stream flows and variability at ungauged locations throughout the subbasins modeled, to support development of target flows for management purposes
- ✓ Assess how further changes in land use/land cover may affect stream bank stability, erosion, and sedimentation.

The study evaluated existing sets of data that included variables discussed above: precipitation, slope stability, soils, and land cover (pre-settlement vs. current conditions). Figure 3.18 is a sample graph displaying hypothetical flow outputs from the model for 2-Year Peak Flows. (Grays River=GRY_30 and GRY_50). Several watershed principles are imbedded in the model that affect its output. They are:

Precipitation Patterns, intuitively, are the driver of flow events as mentioned above

Soil Infiltration Rates, as mentioned above, are important to understanding the timing and release of water from once it hits the soil. Soil type has a major effect on how water infiltrates, runs off or is stored below the ground surface.

Vegetation Cover Type Composition. Vegetation cover generally slows runoff and also uses water by evapotranspiration. Practices such as road building and timber have altered historic vegetation, increasing the area of exposed soil. This can potentially accelerate the rate of delivery to a stream channel.

Slope can affect the rate of water to run off. Higher sloped areas tend to run off more quickly than on those with flatter slopes. However in lower sloped areas, the soil composition tends to be laden with finer sediment that slows the rate of infiltration.

Results are from two subwatersheds in the Grays and show a slight increase in discharge resulting from the loss of vegetative cover. While the model is limited in its scope (i.e. it doesn't include tidal circulations) and simplicity, it does identify fundamental variables (i.e. vegetation changes, soils, land use) relevant to altering flow patterns in Grays River. Part of the results included sets of continuous flows and descriptive statistics where no flow gages are presents. This data is important to characterizing what low and high flow conditions are for the Grays River watershed. These are important to understanding the degree of variation for the system, especially high flow events that can affect streambank stability and habitat forming processes.

Figure 3.18: Grays River Hydrologic Modeling Results for Low Flow and 2, 10, 100 year Peak Flows

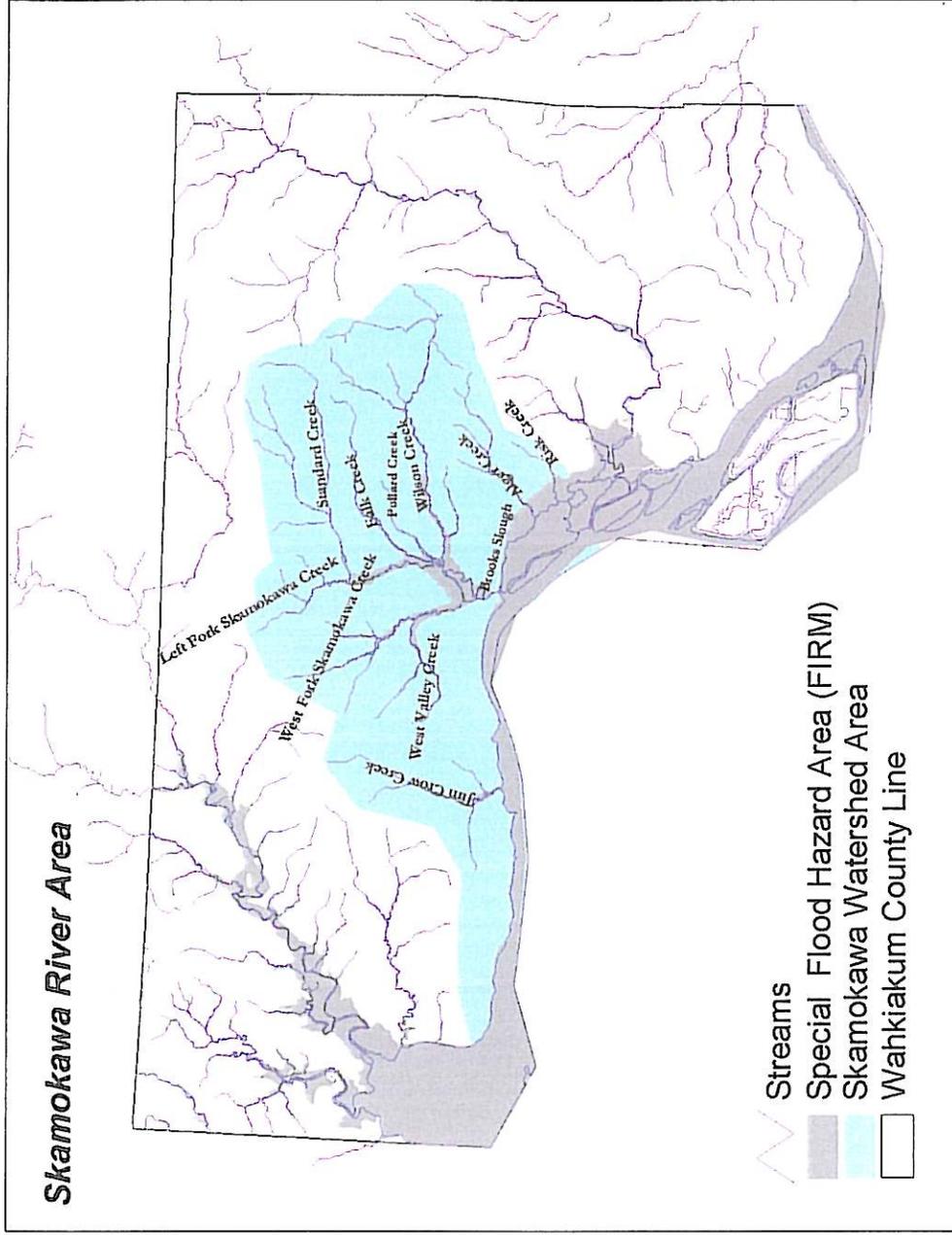
Sub-Watershed (Control Point) Location	Drainage Area (Sq-Mi)	Low Flow			Peak Flows								
		10-Year 7-day (cfs)			2-Year (cfs)			10-year (cfs)			100-year (cfs)		
		Historic	Existing	% Change	Historic	Existing	% Change	Historic	Existing	% Change	Historic	Existing	% Change
Mainstem Above Hull Creek	94.4	32.6	35.6	9.4	10,313	10,505	1.9	15,376	15,580	1.3	18,835	19,034	1.1
Site of USGS flow gage- West Fork	15.4	5.4	6.0	11.9	1,708	1,729	1.3	2,539	2,576	1.5	3,123	3,158	1.1
Mainstem above West Fork	66.1	22.6	24.3	7.5	7,467	7,522	0.7	11,233	11,346	1.0	13,759	13,871	0.8
Site of USGS flow gage-Below South Fork	59.8	20.5	22	7.4	6,538	6,933	1.4	10,226	10,304	0.8	12,531	12,627	0.8
South Fork at Confluence	20.2	6.9	7.5	7.9	2,193	2,204	0.5	3,266	3,311	0.7	4,054	4,078	0.6
Site of USGS flow gage-Above South Fork	39.6	13.6	14.5	6.6	4,595	4,767	1.5	6,945	7,004	0.9	8,520	8,595	0.9
Mainstem above Mitchell Creek	15	5	5.3	6.8	1,895	1,912	0.9	2,761	2,774	0.5	3,335	3,362	0.8
Upper Main Stem above Cabin Creek	8.6	2.8	3.1	9.2	1,060	1,070	1.0	1,567	1,580	0.8	1,909	1,923	0.7

Source: Lower Columbia Fish Recovery Board

Skamokawa Creek

The Skamokawa Creek sub-basin or “Middle Valley” is located in the central part of the County. Draining an area of approximately 14,100 acres, it contains eleven sub-watersheds that cover approximately 20% of the total land of the county. Major flood prone tributaries include: West Valley Creek, West Fork, Left Fork Skamokawa, Wilson, Falk and Pollard Creeks. Other major tributaries of the Skamokawa Creek area include Jim Crow Creek and Brooks Slough. Elevations in this basin range from sea level to 2,220 feet. Tidal influence on the mainstem of Skamokawa Creek extends up approximately 2 miles from its mouth. Alger Creek and Risk Creek drain into Brooks Slough, a major tidal channel that flows through the Julia Butler Hansen Refuge. Jim Crow creek is a separate drainage isolated by steep hills and not technically part of the Skamokawa watershed. It is partially influenced by tidal forces from the Columbia at the valley bottom and shows moderate flood hazard risk in its floodplain as shown by Figure 3.19.

Figure 3.19: Skamokawa River Watershed Area



Source: CREST 2003

Skamokawa Creek-Inventory/Evaluation & Watershed Management Plan

In 1992, the Wahkiakum County Conservation District conducted a study and management plan for the entire Skamokawa Basin. The impetus behind this study came from landowner concerns about streambank erosion, flooding, and sedimentation on their property as well as safe passage on access roads. In addition actions were directed for the management of other natural features of the watershed including: wildlife, endangered species, wetlands, stream corridors, water quality, flow, and mass movements. Additional flow information for Skamokawa is spotty with only one-year worth of continuous USGS flow data available.

The process entailed an attempt to make the connection between the upstream forest management practices and their effect on agricultural practices downstream. The report assessed watershed factors contributing to flood hazards in the basin such as the condition of soils, vegetation, land use practices, road densities, and climate. Similar to the Grays River Modeling effort described above, the plan makes connections between vegetation changes and their effect on increasing peak flows which can consequently cause streambank erosion from increased lateral channel migration. Table 3.20 shows an estimate of projected peak flows as a result of predicted forest harvests for a given flooding event. It also indicates what peak flows would be for a forest with 'Old Growth' Conditions.

Figure 3.20: Skamokawa Creek Estimated Flow Changes from Forest Practices

<i>Flooding Event</i>	<i>Present Discharge (cfs)</i>	<i>Future Discharge (cfs)</i>	<i>Old Growth Conditions (cfs)</i>
10 Year	1,832	1,918	1,347
50 Year	3,074	3,205	2,422
100 Year	3,562	3,681	2,844

The information developed during the assessment process directed efforts to discussing a list of concerns and action items for improving watershed management in the Skamokawa Basin. Several of these concerns relate directly to flooding variables. A summary of these Concerns and Action items related to flooding are listed in Figure 3.21.

Figure 3.21: Flood Concerns and Actions for Skamokawa Basin as Identified in “Inventory/Evaluation & Watershed Management Plan”

Concern: Condition of the stream, primarily bank erosion in the lower reach, is viewed as the consequence of total watershed activities. Specific recommendations appear in other related subject areas.

Actions:

(a): Through the distribution of this report, educate people as to cause and effect in watershed activities.

(b): Use newspaper article to alert residents as to good watershed management

Concern: Develop locally acceptable, cost-effective treatment to help control bank erosion.

Actions:

(a): Utilize local resources to install new or innovative erosion methods, e.g. bioengineering as well as conventional bank stabilization.

(b): Encourage the retention of a buffer strip on Type 4 and 5 waters.

(c): Manage streamside vegetation.

(d): Manage in stream debris (organic materials)

(e): Setup procedures for utilizing local contractors and landowners to be able to react to immediate stream corridor management opportunities. (Particularly after a flooding event)

Elochoman Creek

The Elochoman River originates in the northeastern corner of Wahkiakum County and flows in a south-southwesterly direction for a large part of its drainage before it turns west and meanders into the Columbia. The Elochoman watershed covers approximately 27% of the County (figure 3.23). The Elochoman watershed drains approximately 42,000 acres, making it the largest watershed in the County. Following a pattern similar to the other basin in the County, the upper portion flows through a narrow valley with steep slopes draining major tributaries such as Otter Creek, North, West, and East Fork. In its middle reaches, the river flows through a series of less steep valleys turning into broader floodplains draining Duck Creek to the west and to the east, Beaver Creek. The lower reaches are tidally influenced deltaic channel patterns featuring a network of slough channels and midchannel islands like Hunters Island at its mouth. Nelson Creek, while not a part of the Elochoman Valley, is included in this area because of its proximity to the Elochoman and its risk to property of its residents. Birnie Creek is also included in the Elochoman, although technically it is its own watershed and has its own distinct issues because of its proximity to the urban area of Cathlamet. As figure 3.22 shows, areas of Special Flood Hazard include: lower portions of Nelson, Beaver, and Alger Creek, and a significant portion of the Elochoman Creek mainstem.

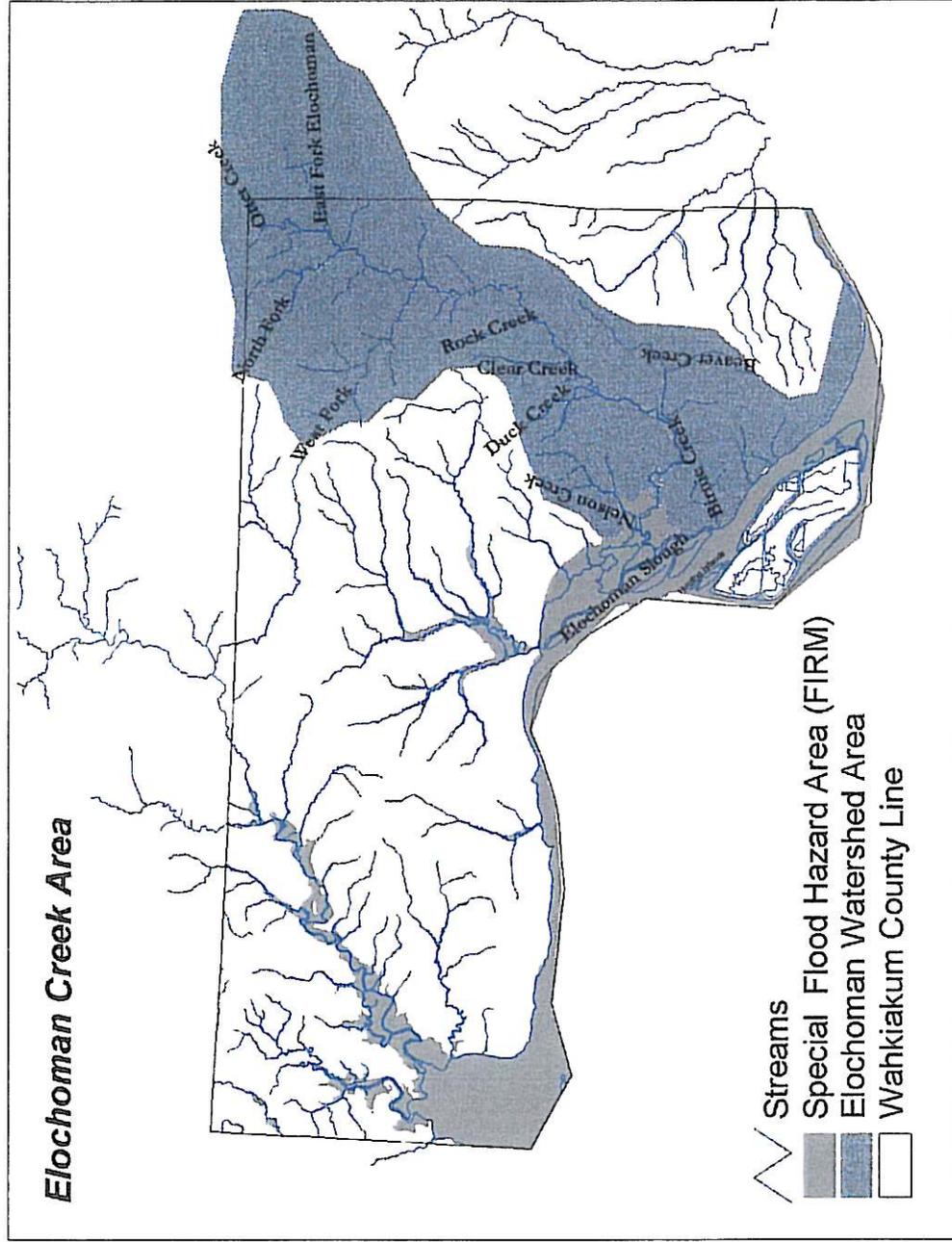
The figures below present the existing peak flow and flood stage info for the Elochoman area including estimates of flood event intervals on the Columbia River at the Town of Cathlamet based on a cursory flood study conducted by FEMA in 1986 (figure 3.22). Figure 3.24 shows existing peak flow data and stage from 1941-1979 derived from a USGS station near the Town of Cathlamet.

Figure 3.22: Flood Elevations for 10, 50, 100, and 500-Year Flood Events

FEMA Flood Study Results-City of Cathlamet	Flood Elevations			
	10-Year	50-Year	100-Year	500-Year
<i>Flooding Source and Location</i> Columbia River Near Cathlamet at Cathlamet Channel (RM 40)	9.7	10.5	10.9	11.8

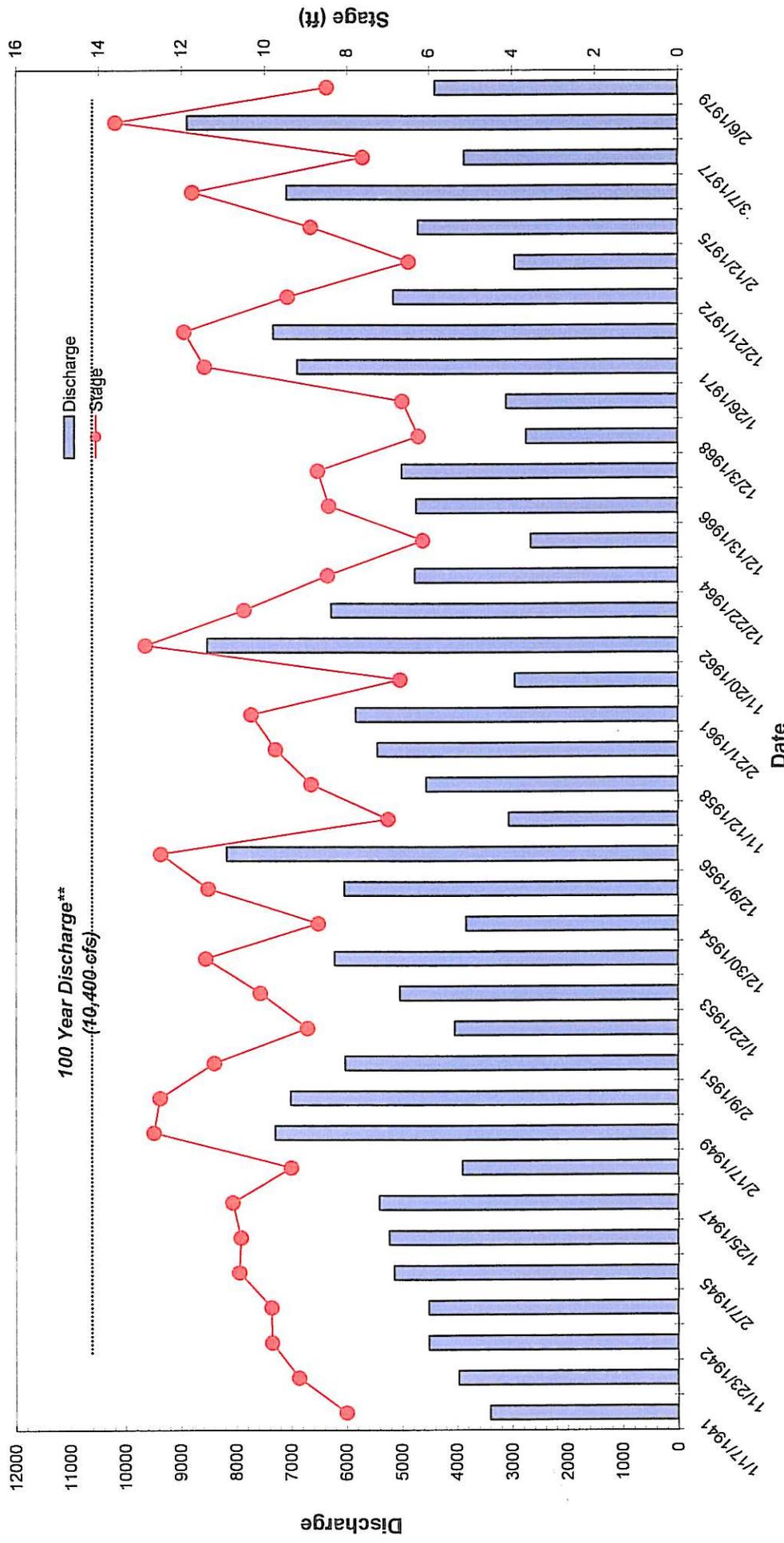
Source: Federal Emergency Management Agency, 1990

Figure 3.23: Elochoman Watershed Area



Source: CREST 2003

Figure 3.24: Annual Peak Discharge-Flood Stage, USGS Gauge # 14247500 Elochoman River near Cathlamet, WA



Source: <http://wa.water.usgs.gov/data/realtime/historical.html>

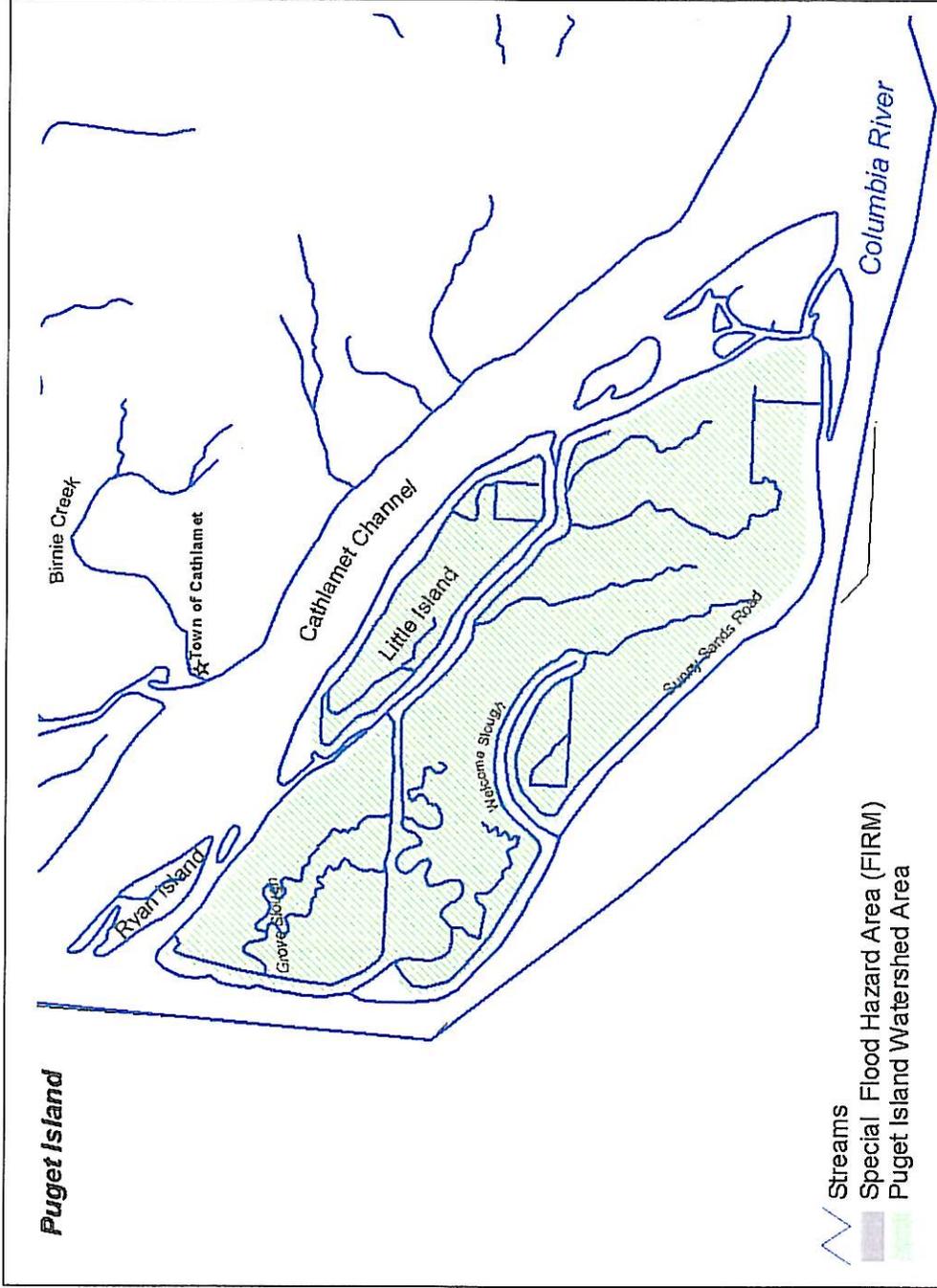
** FEMA Flood Insurance Study

Puget Island

While technically not a watershed, the Puget Island area, due to its location, inherently experiences different drainage patterns and flooding issues. This mid-channel island likely possessed a network of slough channels created by bi-directional flow patterns of the Columbia River and diurnal tide cycles resembling that of other islands in the upper portions of the Columbia River Estuary (3.25). Diking, filling, installation of flood structures, and other activities associated with human development have partially disconnected the island from the Columbia River Floodplain. Flood control structures at Grove Slough have been installed to control tidal elevations. Pumps have also been installed at this location to maintain adequate water levels for properties along the Grove Slough channel network.

Surface water patterns maintaining the island landform have been manipulated by dredging and the construction of pile dikes. The channels around the island are products of both tidal and riverine forces. Cathlamet Channel on the islands northeast side is silting in due to minor inputs of material from the Elochoman system and because of current depositional patterns on the Columbia River. The Columbia River Navigation Channel is located on the islands southeast side and is maintained by the Portland District Army Corps of Engineers. The Portland district also maintains the pile dikes that are currently contributing to the erosional forces on shoreline areas adjacent to Sunny Sands road and Welcome Slough Road. Studies have been completed that detail the causes of this phenomenon that is causing severe risk to private property.

Figure 3.25: Puget Island Area



Source: CREST, 2003

F. Habitat Conditions-Terrestrial and Aquatic Species

The biological resources of Wahkiakum County are diverse and abundant. The diversity of landforms and climate contribute to a mosaic of upland forests, riparian corridors, and lowland wetlands. These habitat types perform a variety of habitat functions for both terrestrial and aquatic communities in the County. Two (2) comprehensive inventories have been recently completed characterizing the habitat needs and behaviors of both aquatic and terrestrial species. One set of biological data includes work conducted by Washington Department of Fish and Wildlife (WDFW), which presents the distribution of *Priority Species Habitat Database* for species throughout the County.

The most current set, developed in 2002 by the Washington Conservation Commission, involves a *Limiting Factors Analysis (LFA)*, which identifies habitat-limiting factors for multiple anadromous species. The LFA covers the watersheds of Wahkiakum that were nested into Watershed Resource Inventory Areas 24/25 or WRIAs.

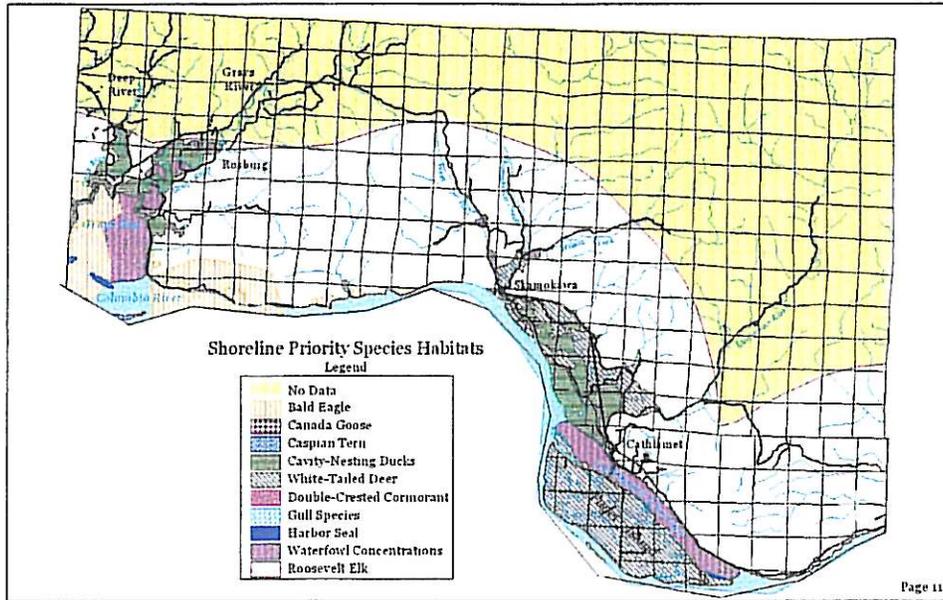
Additional information included in this section includes:

- Priority Species Habitat
- Existing Habitat/Riparian Information
- Summary of LFA Key Findings

WDFW Priority Habitats and Species

The Priority Habitats and Species (PHS) Program developed by the Washington Department of Fish and Wildlife provides comprehensive information on important fish, wildlife, and habitat resources in Washington. PHS is the principal means by which WDFW provides important fish, wildlife, and habitat information to local governments, state and federal agencies, private landowners, consultants, and tribal biologists for land use planning purposes.

Figure 3.26: Shoreline Priority Species Habitat



Source: Washington Department of Fish and Wildlife (map produced by CREST)

The PHS Database consists of polygons or points that describe occurrences of priority habitats and species (figure 3.26). All priority species mapped areas represent known use areas; they are not potential habitats. Priority habitats are areas that support diverse, unique and/or abundant communities of fish and wildlife. Locational data are associated with reports detailing each priority habitat and species.

Habitat Information

While each species has its unique habitat requirements, it is important to take a broader scale landscape approach to understanding the historic and current connections between habitats and what function they perform for both terrestrial and aquatic species. Like most Counties, in Wahkiakum County land use activities have impacted the landscape by redistributing habitat structure and corridors needed for the survival and productivity of multiple aquatic and terrestrial species. Several sets of information exist showing habitat structure and condition that currently support the species identified above. Below is a brief characterization of existing wetland and riparian condition based on information collected and map products.

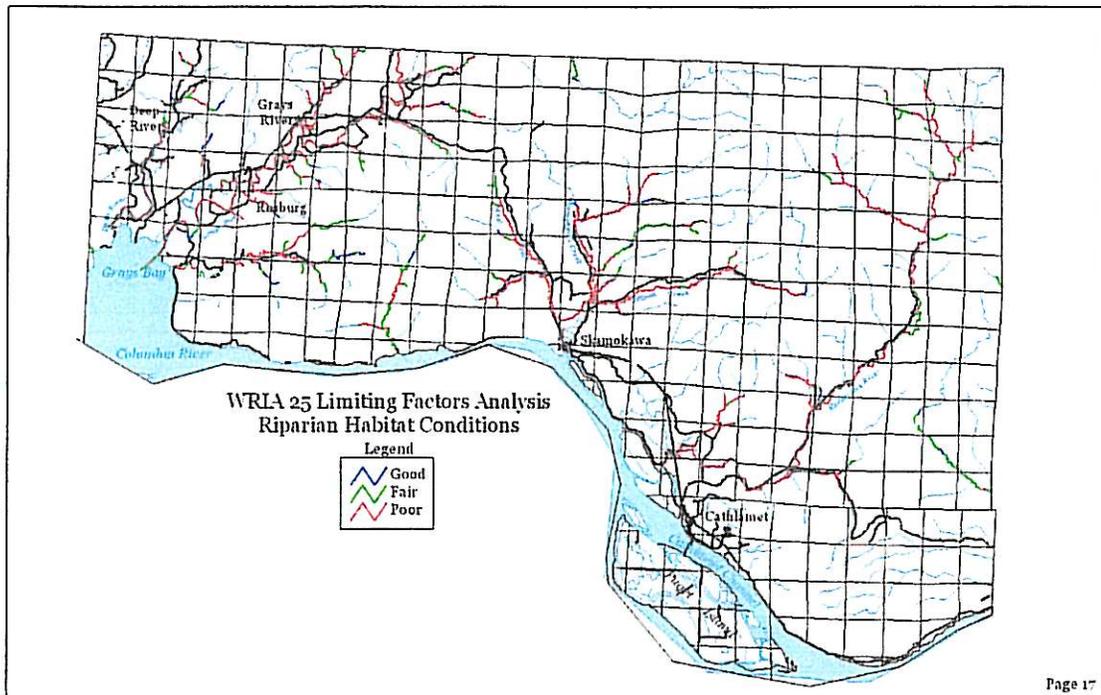
Riparian/Wetland Habitat

Riparian/Wetlands areas serve as the interface between terrestrial and aquatic habitat environments. Riparian areas are defined by the zone of vegetation in proximity to the stream corridor. Wetlands are defined by the unique oxygen-reduced or “hydric” soils created by extended saturation and/or inundation. These conditions promote unique plant communities valuable to the survival and reproduction of a variety of species. Continuous patches of mature plant cover from these areas perform numerous functions that benefit the health of the watershed:

- ✓ Provides migration corridors, dispersal routes and habitat connectors for wildlife;
- ✓ Promotes shade and cover from direct radiation maintaining cool aquatic temperatures for salmonids, birds, and other animals;
- ✓ Serves to hold and trap sediment delivery from upland and riverine sources;
- ✓ Contributes organic matter to support food web dynamics;
- ✓ Slows the energy associated with velocity of stream discharge, thereby preventing erosive processes downstream;
- ✓ Root structure of some riparian/wetland plant species binds soil particles together, thereby enhancing the structural integrity of the soil and protecting it against erosive forces.

LFA information about the riparian areas indicate (Figure 3.27) streamside conditions are in “poor” or “fair condition” condition based on off-site methods that assess the width and species composition of the riparian area.

Figure 3.27: WRIA 25 Riparian Condition



Source: Washington State Conservation Commission (map produced by CREST)

Estuarine Habitat

Tidal wetland habitat performs important functions for migrating juvenile salmonids in the Columbia River Estuary. They serve as low velocity refuge areas during the transition from freshwater to the ocean-derived conditions of the Estuary. Significant losses of these unique habitat types have severed historic habitat linkages important for a diversity of salmonid species during their life cycle. An analysis conducted by CREST in the 1980s shows percentage loss of tidal marsh and swamp habitats throughout the Columbia River Estuary. Figure 3.27 shows an approximation of the habitat distribution in Grays Bay and demonstrating an intricate complex of tidal flats, marshes, and swamps as well as shallow and deep-water area. Since European settlement, diking, filling, and tidegate installation have modified these habitat types. In Grays Bay, CREST data shows more than an 88% decrease in tidal swamp habitat while showing an increase in tidal marshes and flats due to siltation of the Bay. For the upper portion of the Estuary, which includes Puget Island, Skamokawa Creek, Brooks Slough, and parts of the Julia Butler Hansen Wildlife Refuge substantial losses of both tidal marsh and swamp habitat types (Figure 3.26) are indicated.

Figure 3.27: Historic Habitat Types-Grays River 1870 (CREST, 1994)

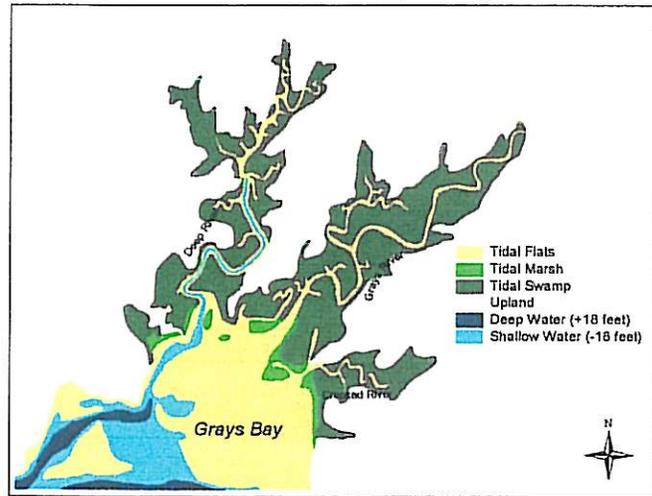


Figure 3.28: Estuarine Habitat Type Changes Grays Bay and Upper Estuary Region (1870-1980)

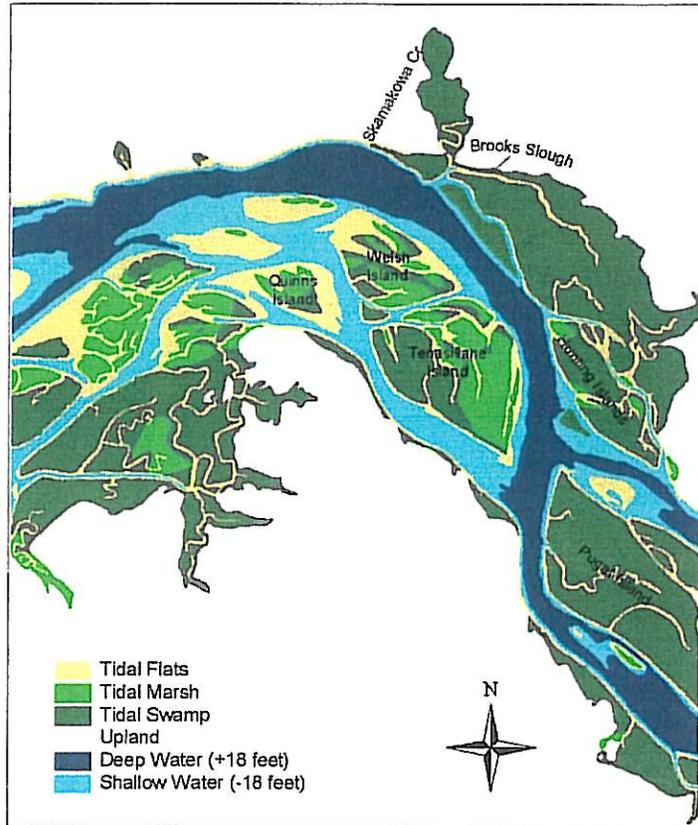
Grays Bay

Habitat Type	1870 Acreage	Present Acreage	Pct. Change
Deep Water	2,270	1,690	-25.6%
Medium Depth	2,230	2,040	-8.5%
Shallows/Flats	3,790	4,330	14.2%
Tidal Marshes	310	760	145.2%
Tidal Swamps	4,410	510	-88.4%

Figure 3.29: Historic Habitat Types-Upper Estuary 1870 (CREST, 1994)

Upper Estuary

Habitat Type	1870 Acreage	Present Acreage	Pct. Change
Deep Water	6,520	5,060	-22.4%
Medium Depth	2,710	2,790	3.0%
Shallows/Flats	1,770	2,710	53.1%
Tidal Marshes	1,430	510	-64.3%
Tidal Swamps	11,180	2,250	-79.9%



Source: Columbia River Estuary Study Taskforce (1983)

These modifications of estuarine habitat have changed the life history patterns of migrating salmonids in the Estuary. Recent estuary science is now looking at the critical linkages of these habitat types to salmon behavior. Historically these habitat types were highly productive areas that jump started critical food web linkages for multiple species of the Estuary. Now cut off from tide, these critical pathways are more dependent on material from upstream sources.

Washington Conservation Commission-Limiting Factors Analysis

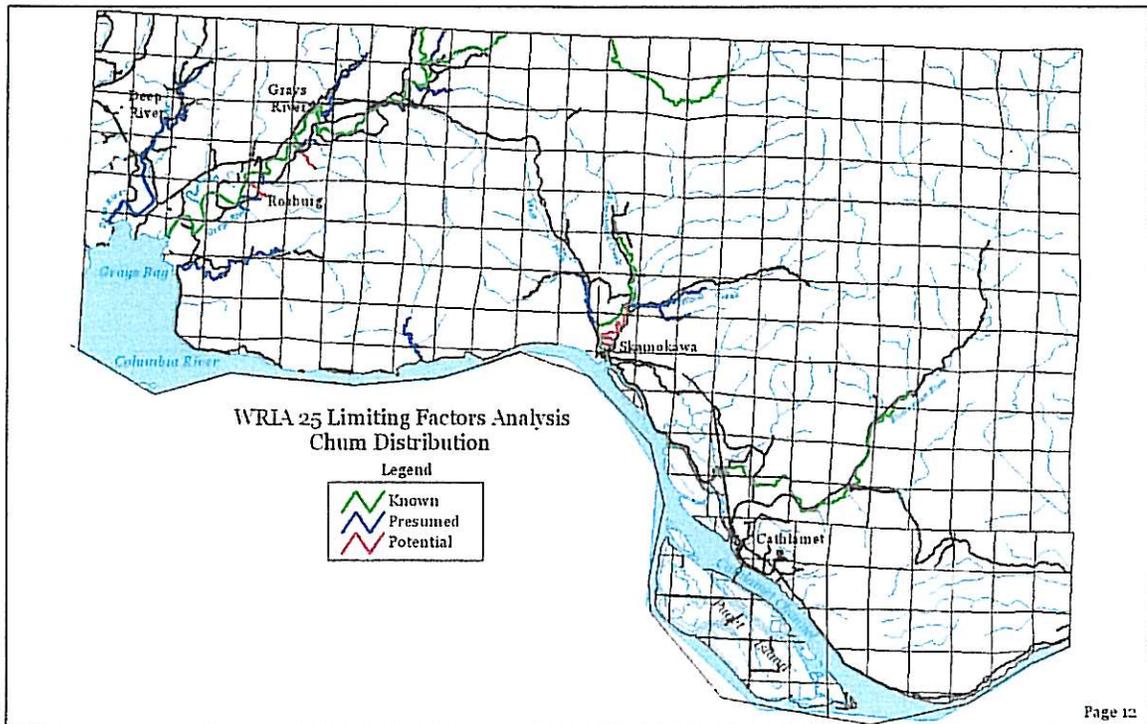
The goal of the limiting factors project is to identify habitat factors limiting production of salmonids in the state. The report identifies habitat-limiting factors pertaining to salmon, steelhead trout and includes bull trout when they share the same waters with salmon and steelhead. The report includes a characterization of a variety of factors effecting anadromous fish life cycles for Watershed Resource Inventory Areas 25 and 26. The watersheds of Wahkiakum County are a subset of these WRIsAs and include drainages outside the scope of this plan such as the Chinook (Pacific County) and Germany and Abernathy Creeks (Cowlitz County). The LFA characterizes the linkage between habitat conditions and respective salmonid habitat needs according to species and life stage. It goes on further to describe current watershed conditions and lists by watershed the barriers to productive salmonid stocks.

Figure 3.31: Listing of Columbia River Salmonids under the Endangered Species Act (ESA)

<i>Species</i>	<i>ESA Status</i>
Lower Columbia River/ Southwest Washington Coho	Candidate
Snake River, fall-run Chinook	Listed
Snake River, spring/summer-run Chinook	Listed
Lower Columbia River Chinook Salmon	Listed
Upper Willamette Chinook Salmon	Listed
Upper Columbia River, spring-run Chinook	Listed
Columbia River, Chum	Listed
Snake River Sockeye Salmon	Listed
Upper Columbia River, Steelhead	Listed
Snake River Basin, Steelhead	Listed
Lower Columbia River Steelhead	Listed
Upper Willamette Steelhead	Listed
Middle Columbia River Steelhead	Listed
Southwestern Washington, Columbia River Coastal Cutthroat	Proposed

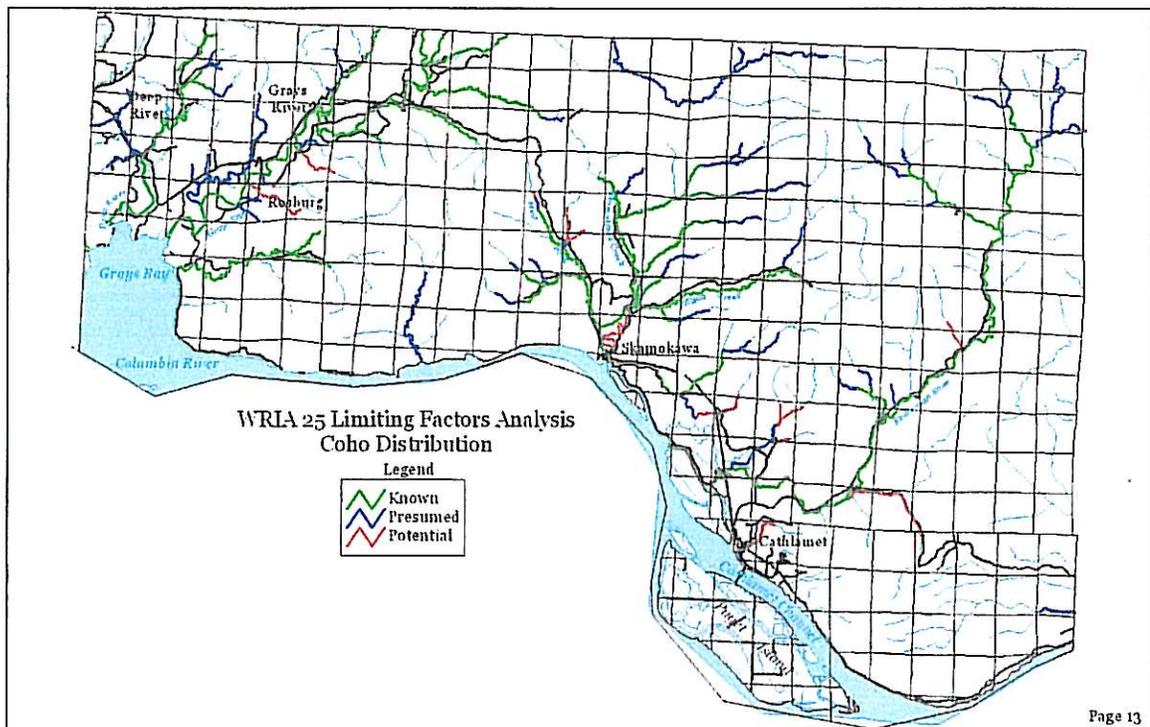
Salmonid use of Wahkiakums' watersheds has been well documented in both the LFA and several recent reports conducted by the Lower Columbia Fish Recovery Board. The unique combination of upland spawning and tidal estuarine wetland habitat combine to play a vital role at various life cycle stages in the survival and productivity of endangered anadromous stocks. Salmon life histories patterns in the Lower Columbia are highly varied and complex among anadromous fish species. The introduction of artificially produced fish has modified salmon behavior in the Lower Columbia. Currently there are thirteen (13) stocks listed (figure 3.31) on the Federal Endangered Species List either as threatened or endangered. All these species use the tidal, brackish areas of the Columbia River Estuary for at least a portion of their life cycle. During the spawning stage salmon require access to specific habitat in middle to upper portions of the watershed. Information collected from various efforts was compiled for the LFA process and shows the current distribution of coho, chum, Chinook, and steelhead species. Below are summary maps demonstrating the extent of salmon use in Wahkiakum County (Figures 3.32-3.36).

Figure 3.32: LFA Chum Distribution Info (map by CREST)



Source: Washington State Conservation Commission

Figure 3.33: LFA Coho Distribution Info (map by CREST)



Source: Washington State Conservation Commission

Figure 3.34: LFA Fall Chinook Distribution Info (map by CREST)

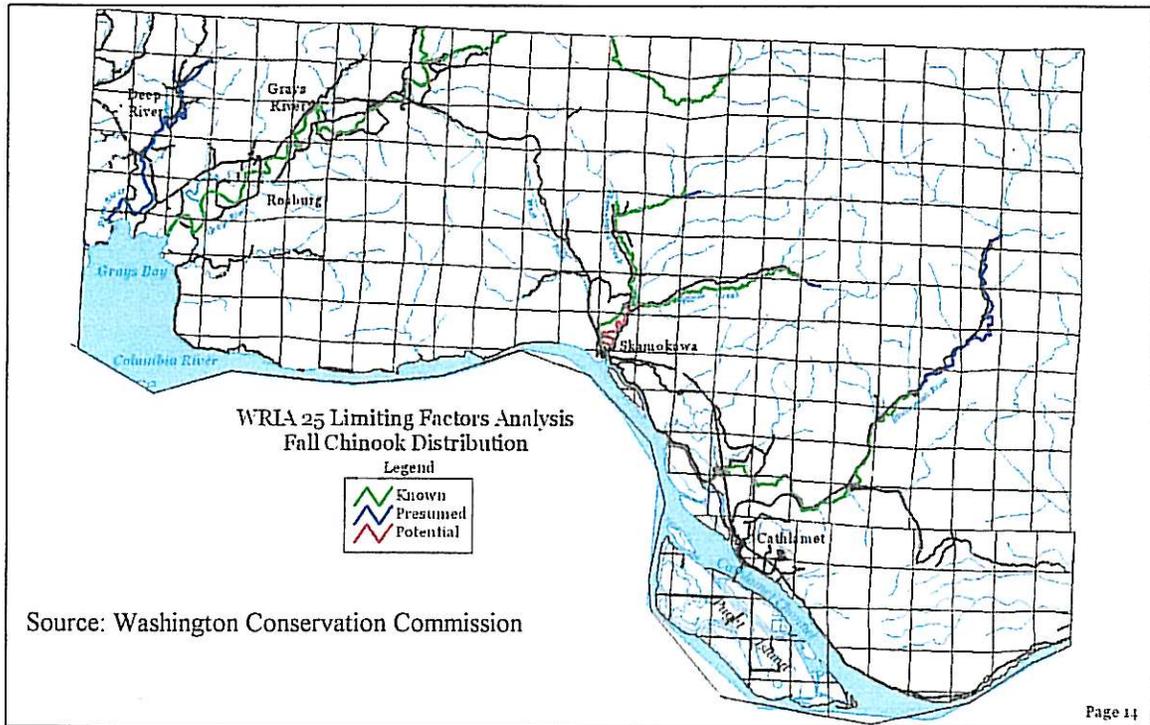
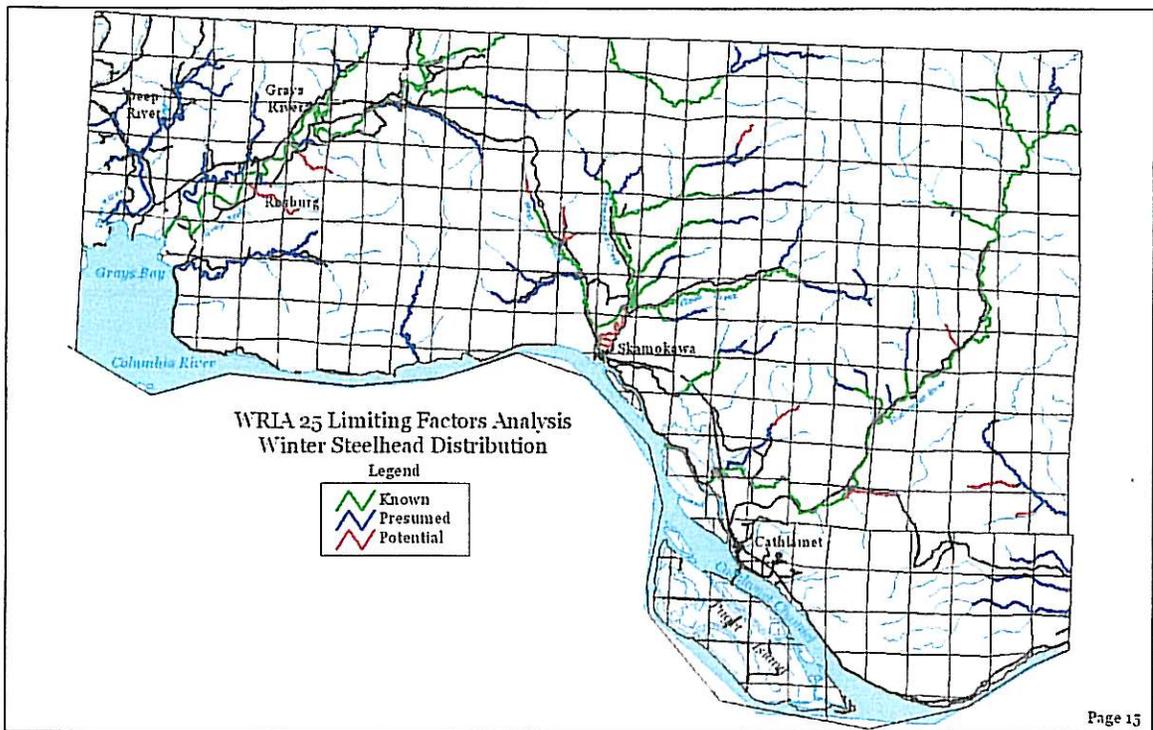


Figure 3.35: LFA Winter Steelhead Distribution Info (map by CREST)



The Limiting Factors Analysis also inventoried a variety of fish habitat conditions. These conditions included:

- Access
- Floodplain Connectivity
- Side Channel Availability
- Bank Erosion / Stability
- Riparian conditions
- Large Woody Debris
- Percent Pool
- Water quality
- Water Quantity
- Biological Processes

These conditions are summarized below:

Access:

- Several culvert sites and natural barriers were identified that require additional assessment to determine passage problems in this subbasin.
- Low flows were identified as a concern in Deep River, Seal River, the lower West Fork Grays River, and the section of the main stem Grays River between the Covered Bridge and the Canyon.
- Low flow concerns may be associated with the accumulation of bedload in the West Fork and mainstem Grays River.
- Technical Advisory Group members also identified potential passage problems over the Grays Bay bar.
- Several culvert sites were identified that require further assessment. Wahkiakum Conservation District is in the process of collecting information on public culverts in the subbasin. Forest industry representatives indicated that they are in the process of evaluating road and culvert condition to satisfy forest practices requirements.

Floodplain Connectivity / Side Channel:

- Most of the streams within the subbasin have been divorced from their floodplains and development of side channel habitats have been discouraged by several management practices particularly in the lower reaches of the watersheds. Practices include flood control measures, bank hardening, and channelization to improve agriculture and splash damming.

Sediment / Bank Stability:

- The Grays River flows through areas with extremely unstable soils and geology. This natural instability, combined with extensive road construction and timber management, has led to substantial sediment loads and unstable, aggrading stream channels. The extent of impacts to fish production from spawning substrate instability is unknown, but often considered the major limiting factor for chum and chinook salmon production the watershed.
- Bank erosion problems were generally noted in areas with alluvial deposits and with little or no woody vegetation. Bank erosion was extensive throughout the agriculture areas in the Skamokawa Creek watershed. A combination of conditions affect stability in these areas including alluvial soils, an entrenched stream channel, lack of riparian vegetation, and upper watershed conditions that may have increased peak flows. Bank stability problems occur in the West Fork Elochoman and North Fork Elochoman due to mass wasting. The lower reaches of Germany Creek are currently responding to increased inputs of coarse sediment load from past land use activities.

- Sediment fines are a significant problem in the subbasin. Numerous mass-wasting events and roads are major contributors of fine sediment to the stream system in both the Elochoman and Skamokawa watersheds.

Riparian Conditions:

- Riparian conditions fell below Habitat Rating Standards almost throughout the Subbasin. Exceptions included East Fork Grays, and Mitchell, Alder, Sage, and Cabin Creeks.
- Riparian conditions did not meet the Habitat Rating Standards almost throughout the Subbasin. Standard Creek in the Skamokawa Creek watershed was a notable exception, with a “good” rating.

Channel Conditions:

- Stream surveys have found that the pieces of LWD/mile and the percentage of pool habitat fall well below habitat standards in most of the watersheds in this Subbasin. Channels have frequently been simplified through channelization, diking, splash damming, and the removal of LWD. Areas in the upper watershed and tributary streams with a greater percentage of pool habitat also tend to be the areas with more LWD.
- Elevated water temperatures likely impact rearing juveniles and resident fish, and potentially migrating fish in the early fall. Fall freshets tend to rapidly cool water temperatures to current guidelines for spawning salmonids.

Water Quality:

- Elevated stream temperatures impact juvenile salmonids and resident fish, and may impact migrating fish in the early fall. Fall freshets tend to rapidly cool stream temperature to current guidelines for spawning salmonids.
- Turbidity was identified as a concern in Hendrickson Creek (Deep River), “Muddy Trib”(tributary to Grays River), West Fork Grays River and South Fork Grays River.
- Turbidity is elevated due to mass wasting and bank instability.
- Elevated water temperatures likely impacts rearing juveniles and resident fish, and potentially migrating fish in the early fall. Fall freshets tend to rapidly cool water temperatures to current guidelines for spawning salmonids.

Water Quantity:

- Both low flows and elevated peak flows were identified as limiting factors in many of the streams within the WRIA 25. Bedload accumulations increase low flow problems in the mainstem Grays, West Fork Grays River, and in the Elochoman River from the Beaver Creek hatchery upstream.
- High Road densities and hydrologic maturity contribute to elevated peak flows in all areas of WRIA 25.

Summary

This chapter is intended to provide a foundation for understanding flood related issues and natural processes as they apply to Wahkiakum County. A significant amount of information has been compiled to this point about watershed processes and some general comments about some of the inputs affecting the instability of Wahkiakum County’s floodplains. With this information in mind, the next chapter inventories the range of flood related issues that are in response to the watershed variables discussed in this chapter.