CHEHALIS BASIN
LEVEL 1 ASSESSMENT

ENVIROVISION CORPORATION
In Association with:
WPN and SAIC

DECEMBER 2000

CHEHALIS BASIN
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Prepared for:
The Chehalis Basin Partnership

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SECTION 1: INTRODUCTION

1.1 OVERVIEW

The purpose of this document is to provide the Chehalis Basin Partnership (CBP) with an assessment of the Chehalis Basin Watershed. Through this process, gaps in available data were identified and recommendations for a second level of analysis were developed. The first section of this document provides an overview of the process leading to the Chehalis Watershed Assessment and a description of the basin. Section 2 provides a technical summary of the analyses (geology and hydrology, water rights and use, water quality, and fisheries). Section 3 provides a detailed analysis of the five subbasins selected for more detailed analysis (Chehalis River headwaters (#1), Lower Newaukum River (#7), Cloquallum Creek (#14), Mainstem Chehalis- Lower Reach-1 (#19), and Humptulips River (#25)). These subbasins were selected to represent the diversity within the Chehalis Basin. In addition to the detailed analysis, some conclusions have been formulated. Section 4 summarizes results, limitations, and datagaps from the Level 1 Assessment and provides recommendations for the Level 2 Assessment. In addition to these main sections of the document, technical appendices have been provided for the four assessment topics (Geology and Hydrology, Water Rights and Water Use, Water Quality, and Fisheries).

1.1.1 ESHB 2514/ESHB 2496

The 1998 Washington State legislative session produced a number of bills aimed at salmon recovery including ESHB 2514 and ESHB 2496. The Watershed Management Act (ESHB 2514) was established to address the diminishing water availability and quality, and the loss of critical habitat for fish and wildlife in the state. The bill aims to develop watershed planning and management that will support economic growth and promote water availability and quality for the state. The bill also provides a framework to collaboratively solve water-related issues and allows local citizens and governments to join together with tribes and state agencies to develop watershed management plans for entire watersheds. To complete the goals outlined in ESHB 2514, a Watershed Assessment needs to be completed for each Water Resource Inventory Area (WRIA) to evaluate water supply and use, and recommend strategies for satisfying water supply needs, meeting minimum in-stream flows, and improving water quality.

The 1998 state legislative session also produced ESHB 2496 the Salmon Recovery Planning Act. ESHB 2496 established, in part, a statewide process to identify habitat factors limiting salmon production in the state. This process requires assemble of a technical advisory group of basin experts, and utilizes a set of habitat criteria that will be applied statewide to produce what has been termed a Limiting Factor Analysis for each river. (It is important to note that this does not constitute a complete limiting factors analysis since it does not address non-habitat related parameters such as harvest rates, influence of hatchery programs and impacts of hydropower.)

1.1.2 STAGE 1 – APPROACH TO LEVEL 1 ASSESSMENT

The first step for completing the watershed plan was to develop an approach for the Level 1 Assessment. For the Chehalis Basin, a technical workshop was held in late October 1999. The goal of this workshop was to solicit ideas and agreement from professionals working in the Chehalis Basin about the specific direction that the Level 1 Assessment should take in the areas of water quantity, water quality, and fish habitat. In addition to getting input and agreement on specific data and tools to use in the analysis, the workshop also provided a means for gaining early participation and knowledge of the project by local professionals. Results and ideas from the workshop were used to formulate a specific approach to the watershed assessment that was then approved by the CBP. Some of the critical decisions made in development of the Level 1 approach were to; not assess marine or groundwater quality, and to avoid duplication of efforts with 2496 planning efforts.

Marine water quality was not addressed at this level primarily because it would not greatly benefit the focus of the planning effort, which is watershed based and water quantity driven. Groundwater quality was not specifically addressed due to the paucity of data for most of the basin.

To avoid duplication of fishery assessment efforts, close coordination was maintained with Conservation Commission staff including sharing resources and reviewing draft reports. Contract deliverables made some areas of overlap necessary (such as fish stock status summaries), although in other cases, responsibility was taken by the ESHB 2496 team (such as developing in-depth discussions of fish habitat conditions in the Grays Harbor estuary). Conversely, the ESHB 2496 team expects to utilize much of this assessment (such as hydrologic analyses and water quality summaries) for their work.

1.2 WATERSHED DESCRIPTION

The following description is largely adapted from the *Chehalis River Basin Action Plan* (Chehalis River Council, 1992) with additional information incorporated from this Level 1 Assessment effort.

With the exception of the Columbia River Basin, the Chehalis Basin is the largest river basin in the state of Washington. The basin is bound on the west by the Pacific Ocean, on the east by the Deschutes River Basin, on the north by the Olympic Mountains, and on the south by the Willapa Hills and Cowlitz River Basin. Elevations vary from sea level at Grays Harbor, to 5,054 foot Capitol Peak in the Olympic National Forest. The basin encompasses 2,520 square miles and drains 2,660 square miles. The Chehalis River system flows through three distinct ecoregions; Cascade (including the Olympic Mountains), Puget Lowland, and Coast Range before emptying into Grays Harbor near Aberdeen (Omernik, 1987).

The geology and associated hydrogeologic conditions of the Chehalis Basin vary widely and reflect the complex geologic history of the area. The basic geology of the basin can be summarized as older bedrock of both sedimentary and volcanic origin exposed on hillslopes and ridges, with more recent depositions of glacial and alluvial sediments overlying these rock units in the valley bottoms and lowland prairies. Groundwater in substantial quantities is present in the glacial deposits as well as alluvial sediments in the major river valleys. Five major soil groups are found in the Chehalis Basin (Table 1.2-1). These soil groups exemplify the diverse landscape, precipitation patterns, and vegetation communities across the basin.

Table 1.2-1
Major soil groups of the Chehalis Basin.

Soil Group	% Land	Location	Geographic Description	Dominant Vegetative Species
Group A	6	southern Olympic slope in the northern basin tip	steep & very steep well-drained soils	true fir, mountain hemlock
Group B	1	coast from Grayland - Westport & north beach area - Copalis	deep, sandy, poorly-drained deposits; tidal estuaries	shore pine; Sitka spruce, western redcedar, western hemlock adjacent to estuaries
Group C	27	eastern third of the basin, Chehalis-Centralia urban area	steep glacial plains & rolling grassy prairie terrain	Douglas fir & Oregon white oak interspersed with prairie areas; Scotch broom increasing
Group D	19	Chehalis floodplain & major tributaries	level & gently sloping alluvial soils	western redcedar, red alder, black cottonwood & willow on poorly drained floodplain fringes, cropland, & pastures; some Douglas fir on better drained soils
Group E	47	western two thirds of the basin between Thurston County line & coast	Forested foothills & steep slopes	Sitka spruce-western hemlock-western redcedar along coast; Douglas fir-western hemlock in eastern part of basin

Mild summer and winter temperatures characterize the Chehalis Basin. Average temperatures range from 38° to 40° F during January, and from 59° to 64° F during July. Temperature variations prevent snow from accumulating over any prolonged period of time, except in mountainous portions. The frost-free season varies from 163 to over 190 days except for mountainous localities. Wet winters and dry summers also characterize the basin. Annual precipitation varies from a minimum of 40 inches in the central portions of the basin (Chehalis/Centralia), to a high of 220 inches in the headwaters of the Wynoochee and Humptulips Rivers (Olympic Mountains). Precipitation usually falls as rain with snowfall in the higher elevations of the Olympics. River discharge peaks between December and March. Approximate average annual discharge of the entire basin is 11,208 cubic feet/second (cfs). Delayed runoff from snow melt is relatively minor, and likely restricted to the Wynoochee, Satsop, and Humptulips Rivers.

The basin encompasses large portions of Grays Harbor, Lewis, and Thurston counties, and lesser parts of Mason, Pacific, Cowlitz, Wahkiakum, and Jefferson counties. The mainstem and South Fork Chehalis drain uplands south and west of Chehalis. Two major tributaries in mid-basin, the Newaukum and Skookumchuck Rivers, have their headwaters in the foothills of the Cascade Range. Another mid-basin tributary, the Black River, originates in wetlands near Black Lake. The largest tributaries, the Satsop and Wynoochee Rivers, arise in southern extensions of the Olympic Mountains and join the mainstem shortly before its terminus at Grays Harbor. The Humptulips River, as well as the Hoquiam and Wishkah Rivers, also have their headwaters in the southern Olympic Mountains and flow into Grays Harbor; the Humptulips into North Bay, the Hoquiam into the inner estuary of Grays Harbor, and the Wishkah into the Chehalis River near the mouth. The Johns and Elk Rivers flow into the South Bay of Grays Harbor. The terminus of all rivers is where they enter another river or Grays Harbor (saltwater influence). For purposes of this assessment the Chehalis Basin has been divided into 30 subbasins for analysis. Map 1 depicts these subbasin boundaries for the basin. An additional subbasin (Grays Harbor) was added for the water right and water use assessment. These subbasins were largely determined by the location of in-stream flow stations.

The majority of the basin (87%) is upland mixed species forestland. Map 2 depicts general landuse throughout the basin. Most forested acres are corporate-owned with the remainder being government owned. However, the Capitol State Forest, and portions of Mt. Baker-Snoqualmie National Forest and Olympic National Forest are located in the basin (DNR, 1990). Another 7% of the land base is agriculture (DNR, 1990). Commercial dairy, livestock and crop farming operations are predominantly located in the low-lying valleys adjacent to the Chehalis River and its major tributaries, including the South Fork Chehalis, Newaukum, Skookumchuck, Black, Satsop and Wynoochee Rivers, and Scatter Creek. Principal crops include pasture, hay, and silage, with some vegetables and small grains. Berries are grown in the Chehalis-Centralia area. Several Christmas tree farms are located along the Skookumchuck River and in the Chehalis-Centralia area. Several private aquaculture facilities are located in the Grand Mound/Rochester area. The remaining land base is spread among rangelands, lakes and reservoirs, urban and rural residential, commercial, industrial, and other minor categories (DNR, 1990). Industrial development is mostly limited to the Chehalis/Centralia and Aberdeen/Hoquiam areas and to the coal mine/power plant site south of Bucoda, with isolated industrial facilities located throughout the basin. The principal industrial use of water is in the manufacturing of wood, pulp and paper products.

Only 1.5% of the Chehalis Basin's land-base is urbanized, but as population continues to grow, more and more land is being converted to residential use. The basin's location halfway between Puget Sound and the Columbia River, the proximity of major transportation routes, a rich natural resource base, and the aesthetic beauty of the area are factors which contribute to its rapidly expanding population base.

The major population centers are Chehalis (~6,000) and Centralia (~12,000) in the upper basin, and Aberdeen (~19,000) and Hoquiam (~9,700) at the mouth of the Chehalis. However, the portions of Thurston County in the upper basin are undergoing rapid development along the I-5 corridor and around Black Lake. The Chehalis Indian Reservation is also located near the mouth of the Black River. The total population of the basin is approximately 130,000 people (Bureau of

Census, 1990). The four major population centers of the basin, Chehalis, Centralia, Aberdeen, and Hoquiam, depend on surface waters for a portion of their municipal and industrial supplies.

At the present time, there are few dams or diversion structures on the rivers of the basin. The Hoquiam and Wishkah Rivers have diversion structures to supply municipal and industrial water to the Hoquiam/Aberdeen area. These structures allow Hoquiam to remove 2.5 cfs from the Hoquiam River and Aberdeen to divert 10 cfs from the Wishkah River. Beneficial uses of the Wynoochee Dam on the Wynoochee River include fish and wildlife habitat, irrigation, recreation, flood control, and municipal and industrial water supply for the City of Aberdeen. The reservoir has a maximum retention capacity of 70,000 acre-feet. The Bloody Run Dam on the Skookumchuck River supplies up to 54 cfs for use in the Centralia Steam Electric plant. A dam on the North Fork of the Newaukum River contributes municipal and industrial water (up to 7 cfs) to the cities of Chehalis and Centralia. Other small dams scattered throughout the basin contribute to rural water supplies (USGS, 1992).

The lakes and streams within the Chehalis Basin provide vital habitat for numerous species of fish. Streams range in character from cold, swift-flowing, high elevation tributaries, to warmer, meandering, lowland valley rivers. There are 180 lakes, ponds, and reservoirs in the basin. Most of these are lowland waters supporting varied fish and wildlife species. The existing anadromous fish resources of the basin are of regional and national significance to sport, tribal, and, commercial fishing. The Basin is also important for a wide variety of wildlife and provides migrating and wintering area for waterfowl in the Pacific Flyway.

SECTION 2: TECHNICAL SUMMARY

2.1 INTRODUCTION

The following section contains a summary of each of the technical studies performed for this assessment. More detailed analysis is provided in each of the technical appendices and within Section 3.

2.2 GEOLOGY AND HYDROLOGY

2.2.1 GEOLOGY

The Chehalis Basin has several distinct geologic regions with unique geologic history. For example, the headwaters arise out of the Willapa Hills, which are primarily comprised of marine volcanic and sedimentary rocks, while some other regions are primarily glacially influenced. Much of the basin is underlain by old ocean floor that was dragged up with the Olympic Mountains. The hills and valleys were carved into these slabs of oceanic rock by erosion, resulting in low rounded hills and ravines. At the end of the ice ages, meltwater from the Puget Sound glaciers flowed down the Black River and Lower Chehalis. After the ice ages ended, sea levels rose by several hundred feet and flooded the mouth of the Chehalis. This created Grays Harbor, and caused the river valleys to fill in with sediment.

The complex geologic history of the Chehalis Basin dictates to a large degree the distribution, quantity, and movement of groundwater. Primary geologic units include bedrock of volcanic and sedimentary origin, as well as glacial deposits and alluvial material. Volcanic rocks (primarily basalt flows) underlie most of the basin, but have been overlain by sedimentary deposits of marine and non-marine origin or glacial material. Near surface volcanic deposits dominate the Black Hills west of the Black River, as well as the southern Olympic Mountains. Scattered volcanics occur throughout the remainder of the Chehalis Basin.

Sedimentary rocks include those of the Eocene/Oligocene epoch and younger rocks of the Miocene epoch. The older sedimentary rocks dominate the Lincoln Creek and South Fork Chehalis Basins, in addition to terraces along the mainstem Chehalis. The younger rocks are found primarily between the Satsop and Wynoochee River valleys.

Much of the basin possesses glacial deposits from at least four different glaciations. The Black River/Scatter Creek area is underlain by approximately 100 feet of deposits from the southern terminus of the Vashon stade of the Fraser glaciation, which inundated Puget Sound. In addition, alpine glaciers have flowed south from the Olympic Mountains, shaping the surface features of much of the lower Chehalis Basin. Finally, the major river valleys contain significant deposits of alluvial material. This material is often mixed with glacial deposits, forming a complex mosaic of unsorted material.

Groundwater conditions in bedrock units are not well studied. Well records indicate that the rock may hold groundwater, but it is often at considerable depth and not present as a contiguous aquifer. Groundwater in these deeper bedrock units exists in rock fractures under confined conditions and usually does not interact directly with surface waters.

The greatest quantity of groundwater exists in the glacial and alluvial deposits found in river valleys and upland terraces. In many cases, multiple aquifers are present, which interact directly with surface waters. Groundwater conditions and interaction with surface waters has been studied to the greatest degree in the Vashon glacial deposits in the Black River/Scatter Creek area. Conditions in the mainstem Chehalis and Newaukum basin have also received considerable study. While it is known that streams and rivers in the Chehalis depend heavily on groundwater discharge for low flow maintenance, quantification of this dependence has only recently been undertaken in the most heavily studied aquifers. The degree to which groundwater pumping may affect stream flows has not been adequately documented.

2.2.2 HYDROLOGY

The Level 1 assessment of surface water quantity in the Chehalis Basin included several independent analyses which can be summarized under the following four headings:

- Compilation of available data (streamflow, climate, structural features);
- Analysis of gaged flows;
- Analysis of natural climate variability; and
- Undepleted gaged flows.

The products presented in this report will serve as building blocks for the Level 2 efforts.

The majority of these analyses were conducted at the basinwide scale, while others produced information by WRIA or are specific to certain subbasins. In many cases, this information will have to be refined at a subbasin level. A notable local example is the Black River Subbasin, where the hydrology of the upper basin has been greatly modified. Although Black Lake historically flowed into the Black River, at the present, at least during the dry season, there is no surface water connection from the lake to the river, and the lake flows out of the Chehalis Basin toward Percival Creek (Berg, 1993). Some of the factors believed to be contributing to this change in hydrology include: a ditch built in the 1920s from Black Lake to Percival Creek to prevent flooding; a pipeline installed in the 1960s through wetlands at the southern end of the lake, which has formed a topographical high point; and several dozen beaver dams.

Compilation of Available Data

A substantial amount of hydrologic and climatic data is available for the Chehalis Basin. Of particular notice, were several streamflow stations, which have been continuously monitored since the early part of the 20th Century. Characteristics of current and historic streamflow and climate data stations located in or near the Chehalis Basin (Map 4) were identified and are presented in Appendix A, Tables A-1 through A-3. Structural features identified in the Chehalis Basin included seventy dams (Map 3). The majority of these are concentrated near the City of Aberdeen and in the Black and Skookumchuck Rivers subbasins.

Analysis of Gaged Flows

In order to obtain an understanding of the existing flows in the Chehalis River, gaged flows at or near the mouth of each WRIA were examined. The gaged flows along the Chehalis River are influenced by upstream dams and myriad diversions. Dams typically influence the flow regime of a river by reducing the peak flows and augmenting low flows; pre-dam and post-dam data sets can represent two distinct population of flows dependent on operation policies.

The Chehalis River at Porter (#12031000) is located at the downstream end of WRIA 23 and, therefore, reflects surface water quantity totals for this WRIA. Fifty-four dams were identified within WRIA 23, 14 of which had storage rights listed in the water rights database. The largest dam in WRIA 23 is the Skookumchuck Dam (Subbasin #9), completed in 1971. The USGS gage log notes minor effects of flow regulation from this dam on the streamflows recorded at the Chehalis at Porter gage. At this level of analysis, the impact of this and the other dams on the flow in the Chehalis River is unknown.

The mean monthly hydrograph for the Chehalis River at Porter (1952-72,1975-98) is displayed in Figure 2.2-1. This hydrograph represents gaged flows in the Chehalis River at Porter; it is not adjusted for regulation or the numerous unidentified diversions throughout WRIA 23. For perspective, the average bimonthly instream flows at the Porter control point (as set by WAC 173-522-020) were added to the total water right allocation for WRIA 23 (961 cfs), and plotted on Figure 2.2-1. This graph indicates that the combination of the instream flow and the instantaneous water right allocation (which includes both surface water and ground water rights) exceeds the gaged mean monthly flows from May through September.

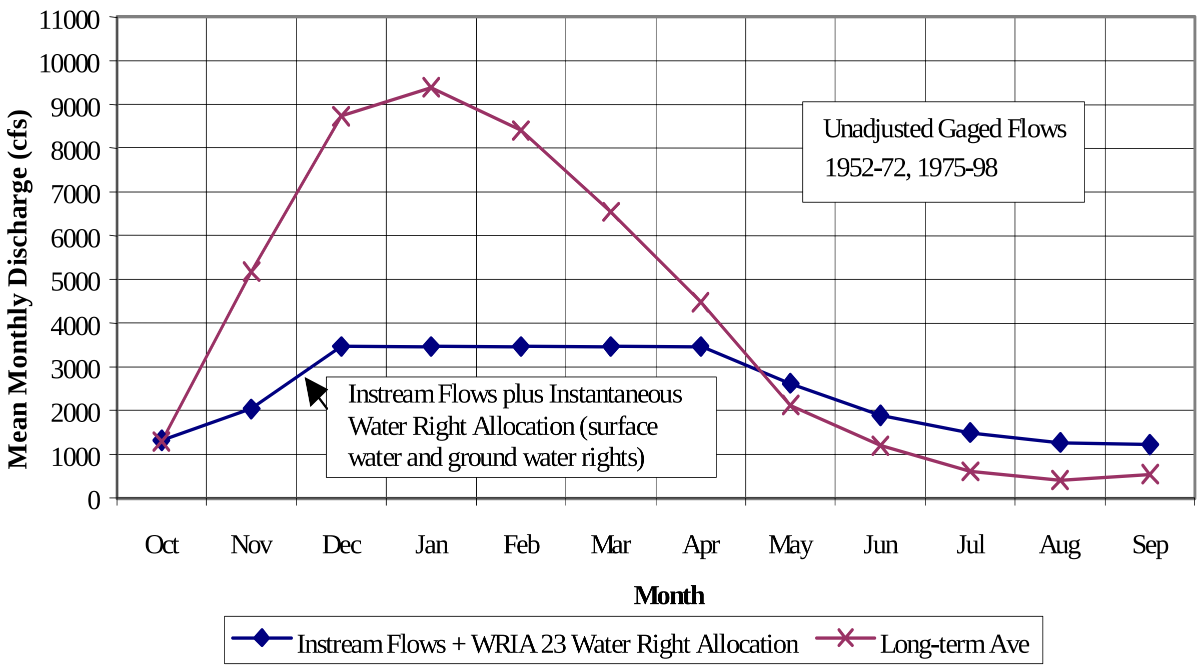

Figure 2.2-1
Chehalis River at Porter (12-031000) Regulated Mean Monthly Hydrograph
Unadjusted Gaged Flows

A flow duration curve for the Chehalis River at Porter (Figure 2.2-2) was generated based on the gaged flows. Flow duration curves provide an indication of the frequency distribution of flows at a station. Since exceedance values are indirectly proportional to the flow, the 90% exceedance values are always less than the 50%, the median flow value of the data series (half of the flows will be less than the 50% exceedance value and half will be greater). Of the mean daily flows recorded at the Porter gage, half have been equal to or greater than 1,980 cfs and 90% of the flows have equaled or exceeded 370 cfs. As with the hydrograph, the flow duration curve represents flows as measured at the Chehalis River at Porter gage, not adjusted for regulation or the numerous unidentified diversions throughout WRIA 23.

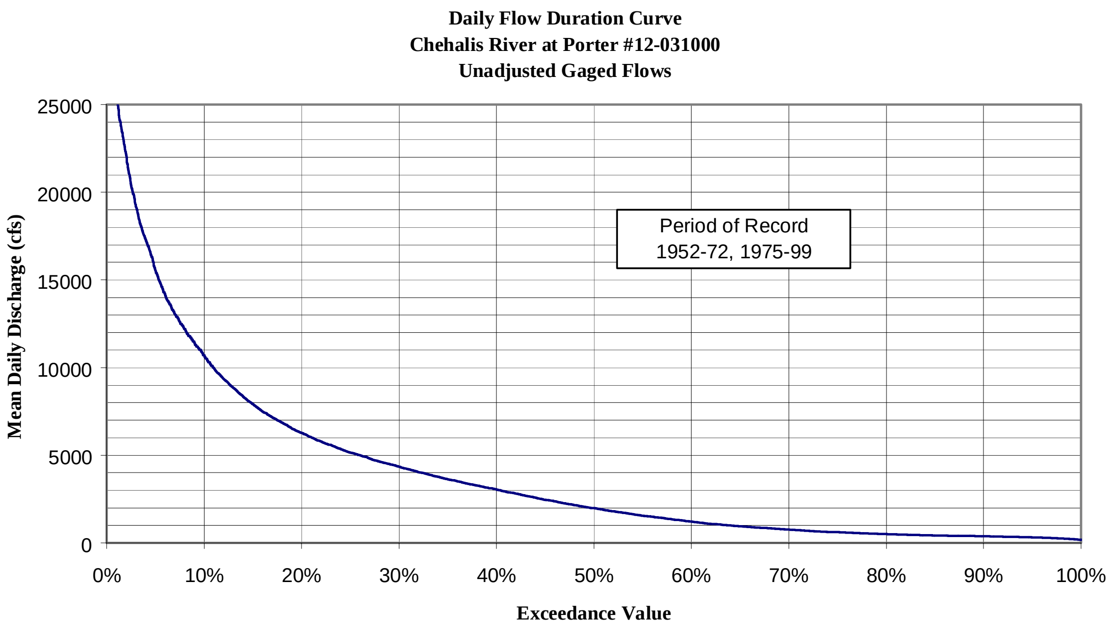

Figure 2.2-2
Chehalis River at Porter (12-031000) Flow Duration Curve
Unadjusted Gaged Flows

WRIA 23 Comparison Of Streamflow And Allocated Water

Figure 2.2-3 compares the 50% and 90% exceedance values for the Chehalis River at Porter with the instream flows and the total allocated water for consumptive uses for the entire WRIA 23. In addition, the graph includes a series for the combined instream flow plus the instantaneous water right allocation. This graph indicates that the combination of the instream flow and the instantaneous water right allocation (which includes both surface water and ground water rights) exceeds the gaged 50% exceedance flows from April through October, two more months than shown in the mean monthly flow graph (Figure 2.2-1).

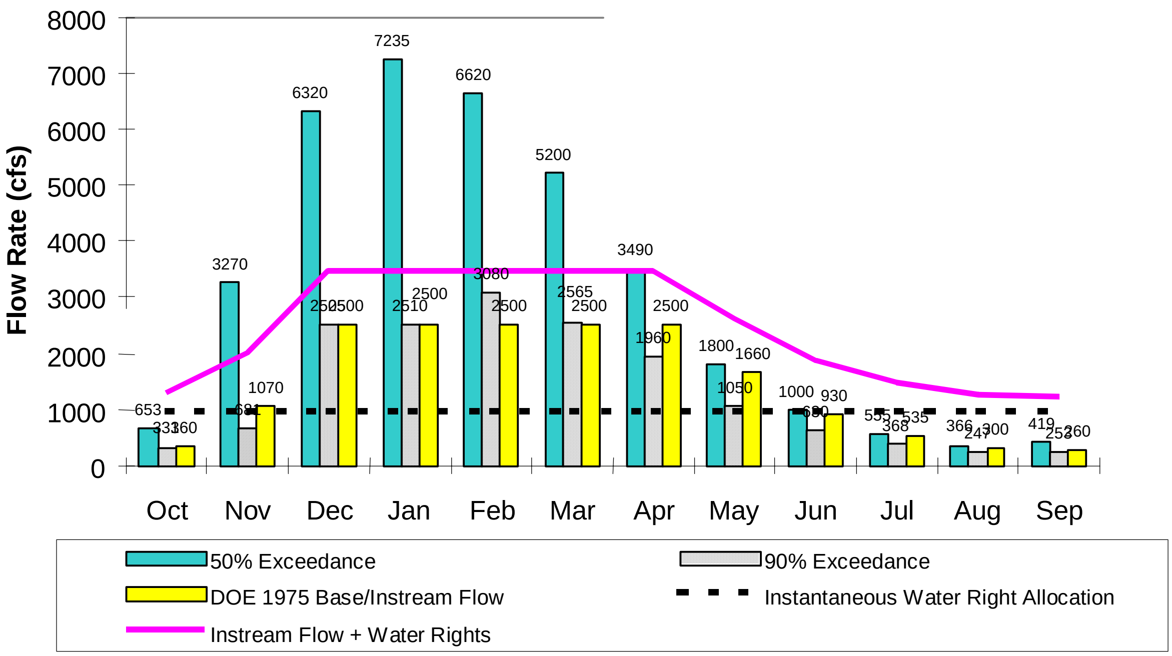

Figure 2.2-3. WIRA 23: Chehalis River at Porter
Comparison of Streamflow and Allocated Water

Surface water quantity totals for WRIA 22 were more difficult to estimate since there was no flow data available near the mouth of the Chehalis River. Additionally, WRIA-wide totals would not be hydrologically meaningful since several of the major tributaries in WRIA 22 drain directly to Grays Harbor, not to the Chehalis River. Instead, lower Chehalis River surface water runoff was estimated at Montesano, near the upstream end of the tidally influenced reach.

Flows at Montesano were estimated by adding gaged flows (Chehalis River at Porter, Cloquallum, Satsop, and Wynoochee) and incorporating unit runoff estimates for the ungaged portions along the river valley between Porter and Montesano. Accretion flow from the 165 mi^2 of ungaged drainage to the Chehalis River between Montesano and the Porter Creek confluence was estimated using a combination of unit runoff values and the relationship of flows at the Chehalis at Porter gage. Mean monthly unit runoff values were generated from the 8 years of gage records available at the historic Chehalis River at south Elma station located mid-basin. These monthly unit values compared favorably to values from the longer-term base gages and therefore were used. Exceedance values for the ungaged area between Montesano and Porter were derived by using a ratio of the mean monthly to the 50% and 90% exceedance value at the Chehalis River at Porter gage. These exceedance values were then added to the accumulated values of the gaged flows (Porter gage + Cloquallum, Satsop, and Wynoochee) to represent flows available at Montesano.

The Chehalis River at Montesano exceedance values listed in Table A-6 were based on data from 1957-72 and 76-98, the coinciding years of record at the four gages. This period did include both pre- and post-dam years on the Wynoochee and, therefore the values do not represent an estimate of natural flow. Instead, the exceedance values were based on the addition of unadjusted gaged flows, which reflect the many unidentified diversions throughout both WRIA's and regulation of the Wynoochee River. There is no instream flow control point on the lower Chehalis River near Montesano.

Table 2.2-1
Flow Exceedance Values for Chehalis River at Montesano

Month	Estimated Flow Exceedance Values[1] Chehalis River at Montesano			
	50% Exceedance (cfs)	50% URO[2] (cfs/mi^2)	90% Exceedance (cfs)	90% URO[2] (cfs/mi^2)
October	2078	1.05	827	0.42
November	8296	4.19	2424	1.23
December	13144	6.65	5596	2.83
January	13445	6.80	5020	2.54
February	12987	6.57	6026	3.05
March	10260	5.19	5045	2.55
April	6853	3.46	3828	1.94
May	3761	1.90	2336	1.18
June	2124	1.07	1438	0.73
July	1333	0.67	893	0.45
August	915	0.46	611	0.31
September	985	0.50	627	0.32

[1] based on the addition of daily data from four gages USGS station #12-031000, Chehalis R. at Porter, Cloquallum #12-032500, Satsop R #12-035000, and the Wynoochee R. #12- 037400 for coinciding record years 1957-72,76-98 + accretion flow to Montesano; drainage area = 1,978 mi^2
[2] URO = unit runoff

WRIA 22& 23 Comparison of Streamflow and Allocated Water

Figure 2.2.4 compares the 50% and 90% exceedance values for the estimated Chehalis River flows at Montesano with the instream flows on the Chehalis below Satsop (the most downstream instream flow control point) and the total allocated water for consumptive uses for both WRIAs 22 &23. In addition, the graph includes a series for the combined instream flow plus the instantaneous water right allocation. This graph indicates that the combination of the instream flow and the instantaneous water right allocation (which includes both surface water and ground water rights) exceeds the estimated 50% exceedance flows from April through October.

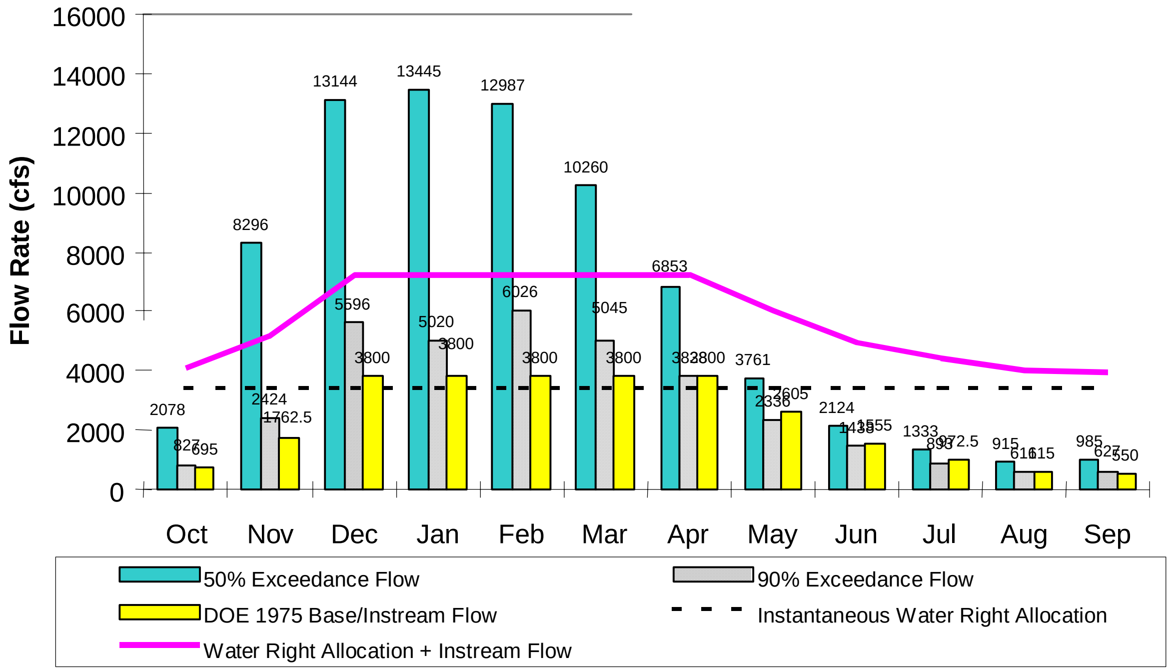

Figure 2.2-4. WRIA 22 & 23 Chehalis River at Montesano Comparison of Streamflow and Allocated Water

Analysis of Natural Climate Variability

The cycles in natural climate variability in the Chehalis Basin were investigated using data from two climate stations (Centralia, and Aberdeen) and one streamflow station (Satsop near Satsop). All of the stations analyzed in the Chehalis Basin showed adherence to the regionally identified phases of natural climate variability; no alternative trends in either streamflow or precipitation were identified at this level of analysis. Appendix A and Section 3 discuss how the period of record at selected gages in the Chehalis Basin represent regional patterns. In general, the longer duration streamflow and climate stations showed a mix of wet and dry years mimicking the regional climate variability patterns.

Undepleted Gaged Flows

Of the 30 subbasins identified in the Chehalis Basin, all but five (Decker Creek, M Fk Hoquiam, E Fk Hoquiam, Elks River, and the Chehalis Lower Reach 2 to the mouth) had some systematic streamflow records located within the boundaries. Prior to using these streamflow records to generate summary statistics representative of “natural” flows, two factors were investigated: 1. the extent of upstream regulation and abstraction of water, and 2. the climate variability over the period of record. Few of these streamflow stations have recorded flows unhampered by human uses. The actual flow at some of the stations may be near "natural" or “undepleted” by withdrawals, while many of the stations recorded flows that were substantially depleted from natural flows due to regulation or withdrawals of water for municipal, irrigation, or other uses. A detailed streamflow depletion analysis was not conducted for any of the gages in the Chehalis Basin but could be considered for a level 2 analysis; the term undepleted is used in this report to qualify the reviewed gage records.

Twenty gages located in thirteen of the 30 subbasins were identified as having sufficient streamflow data reflective of "undepleted" flows; these were termed base gages. (Note: A list of these gages and their locations is included in Appendix A). For these stations, summary statistics were generated on a monthly basis and normalized into runoff per square mile to allow comparison of runoff production across the basin. For this analysis, information was produced two scales: 1) general estimates of runoff for 6 defined hydrologic regions; and 2) specific information for the five subbasins selected for more detailed analysis.

Primarily due to the extreme variation in precipitation across the Chehalis Basin, the amount of runoff varies dramatically (up to four-fold) from 3 cfs/mi^2 along the low lying valley bottom area to more than 12 cfs/mi^2 in the upper watersheds draining the Olympic Mountains. Based on the unit runoff data, precipitation isohyets, geology, and other characteristics, the Chehalis Basin was divided into 6 hydrologically similar areas as presented in Table 2.2-2. Insufficient streamflow data existed on the South Bay tributaries (Johns, Elk, Charley) to determine representative unit runoff ranges in the Level 1 assessment.

These regions of similarity will be useful for Level 2 analyses to produce flow estimates in ungaged basins. Level 2 analyses may also involve hydrologic techniques such as correlation analysis between miscellaneous flow measurements and concurrent gage data and normalization of flows by drainage area (per unit runoff calculations for various flow events). Additionally, a core period of record could be selected to assure that undepleted flow estimates reflect the natural variability in climatic conditions. Base station streamflow records could be extended through correlation analysis with nearby gages as appropriate to cover the selected core period of record, then unit runoff calculations could be updated.

Table 2.2-2.
General Areas of Hydrologic Similarity within the Chehalis Basin

Description of Hydrologically Similar Areas	Annual unit runoff range (cfs/mi^2)	Winter average unit runoff[1]	Summer (low flow) average unit runoff)[2]
North Bay/ Inner Harbor low-lying tributaries (Hoquiam, Lower Humptulips)	5-8	10-15	1-2
Humptulips to Wynoochee Upper Watersheds	10-12	21-24	3-4
WRIA 22 & 23 Low-lying valleys along Chehalis and tributaries	3-4	7-9	<1
Satsop River Basin	6-7	9-13	1
WRIA 23 Mid-basin major tributaries with headwaters in foothills of cascade range (Black, Skookumchuck, Newaukum)	4-5	8-9	1
WRIA 23 Upper Chehalis headwaters in Willapa Hills (Elk, SF, Stillman...)	3-5	7-10	<1

[1] Winter Season for this study is defined as December through March
[2] Summer Season for this study is defined as July through September

Detailed hydrologic analyses were undertaken in five of the 30 subbasins (Section 3) to estimate monthly exceedance values reflective of undepleted flows. For watershed planning purposes, it is important to understand the amount of time that streamflow can be expected to be at different levels e.g. low flows, median flows. In this report, the 90% exceedance flow was presented as a marker of low flows while 50% exceedance value was indicative of normal flows.

The records generated for each of the five basins reflected some degree of anthropogenic effect. In some of the basins, (e.g. #25 the Humptulips) the estimated undepleted flows may be closer to the true value while in other basins the gaged streamflow was depleted by the cumulative impact of many small diversions upstream. Deregulating a streamflow record in mixed use, high agricultural use areas (e.g. #7 Newaukum), or mainstem (Subbasins #19) is beyond the Level 1 effort. Documenting the amount of upstream diversions may be necessary in the Level 2 assessment. In addition, in high unit runoff areas (e.g. Humptulips), the effects of neglecting a few minor water withdrawals may not substantially impact the magnitude of the flow duration curve except during the low flow season; in basins with low unit runoff, more emphasis should be placed on identifying diversions upstream of stream gages. Adequate estimates of natural flow may never be obtained short of conducting continuous hydrologic modeling.

2.3 WATER RIGHTS/ WATER USE

The Level 1 Assessment of water rights and water use for the Chehalis Basin involved reviewing and using numerous databases and reports. The primary resources included:

- Department of Ecology's Water Rights Allocation Tracking System (WRATS)
- Department of Ecology's GEOWRATS
- Department of Health's public water systems data
- USDA, National Agricultural Statistics Service, 1997 Census of Agriculture
- U.S. Department of Commerce, Census Bureau, 1990 Census Data
- WSU Cooperative Extension
- Lewis County Conservation District

2.3.1 WATER RIGHTS

The GEOWRATS and WRATS databases were used to determine the subbasin in which each water right was located. After each water right was assigned a subbasin, a summary of water rights was conducted by number of certificates, permits, and applications for ground and surface water, instantaneous right, annual volume limitations, and irrigated acres. Table 2.3-1 summarizes the instantaneous water right (Q_i) and the annual volume limit (Q_a) by primary purpose in each WRIA and for the total Chehalis Basin. Map 5 indicates locations of water rights in the basin. The rights were categorized as consumptive or non-consumptive rights. The latter have a lesser degree of impact on the stream network since most of the water withdrawn returns to the river downstream. Most power rights in western Washington are usually for hydropower generation and these are generally non-consumptive, however, the Centralia Steam Plant generates thermoelectric power which is highly consumptive. This must be kept in mind when viewing Table 2.3-1.

There were a total of 769 water rights in WRIA 22 (Lower Chehalis Basin) including 9 storage rights for a total allocated diversion/withdrawal amount of 3,718 cfs and volume limits at nearly 120,000 acre feet. Storage rights totaled 71,190 acre-feet. The largest number of rights was attributed to irrigation (406) and secondly domestic use (200). There were about 10,204 acres associated with water rights assigned irrigation as a primary beneficial use; another 1,355 irrigated acres were associated with water rights for which other beneficial uses were primary, such as domestic or stock watering. In WRIA 22, 30 of the largest water rights represented 90% of the total allocated diversion/withdrawal rate; 27 surface water rights and 3 ground water rights.

WRIA 23 (Upper Chehalis Basin) contained more than double the number of water rights than WRIA 22; 1,828 water rights for a total allocated amount of 961 cfs for direct flow diversions and ground water withdrawals. The volume limit was 116,728 acre-feet plus an additional storage volume of 35,657 acre feet (14 storage rights). Irrigation rights were tied to 33,947 acres. Forty percent of the rights (724 in number) represented 90% of the allocated water. There were a significant number of small water rights throughout WRIA 23 that spread the allocation to many rather than a few as in WRIA 22. Twenty-two rights (~1%) covered 40% of the allocation

Table 2.3-1
Summary of Water Right Quantities by Use[1]

Primary Purpose	WRIA 22 (Lower Chehalis Basin)		WRIA 23 (Upper Chehalis Basin)		TOTAL	
	Qi (cfs)	Qa (acre feet)	Qi (cfs)	Qa (acre feet)	Qi (cfs)	Qa (acre feet)
Consumptive Rights						
Commercial	86.66	1,348	9.18	1,518	95.84	2,866
Domestic	616.60	5,920	45.88	6,990	662.48	12,910
Irrigation	175.84	13,102	411.60	48,202	587.44	61,304
Municipal	206.20	112,837	60.92	14,003	267.12	126,840
Stock	12.80	1,765	51.02	6,871	63.82	8,636
Other	9.53	1,236	18.82	2,249	28.35	3,485
Thermal Power*	80.0	54,360	-	-	80.0	54,360
Subtotal	1,187.63	190,568	597.42	79,833	1,785.05	270,401
Non-Consumptive Rights						
Fish Propagation	157.56	411	128.94	37,426	286.50	37,837
Wildlife	1.84	157	2.57	125	4.41	282
Hydro Power*	1,409.43	0	232.32	35,001	1,641.75	35,001
Subtotal	1,568.83	568	363.83	72,552	1,932.66	73,120
TOTAL	2,756.46	191,136	961.25	152,385	3,717.71	343,521

[1]Envirovision and Watershed Professionals Network assume no responsibility for the accuracy of the data provided by the Washington Department of Ecology.
*Power rights for hydropower are generally non-consumptive, however, thermal power is highly consumptive. Most power rights were assumed to be for hydropower.

2.3.2 Water Use

The main categories that were investigated for water use included commercial, residential, irrigation, and stock watering. Residential water use was estimated using 1990 population data that was projected forward by applying "average" growth rates from the data for the three primary counties in the watershed. Results are summarized in Table 2.3-2.

Table 2.3-2
Population Data for WRIA 22 and 23 Based on Average Growth Rates

Year	WRIA 22	WRIA 23
1990	57,600	77,000
1995	60,480	84,700
2000	64,109	94,000
2005	66,032	103,400
2010	68,673	110,640
2020	76,914	122,810

The per capita demand was estimated using design standards from the Department of Health's Water System Design Manual (WDOH, 1999). The average and maximum day demands in each WRIA were estimated using the population data and the per capita figures calculated from the Design Manual. The average per capita demand ranged from 118 gcd to 144 gcd (Table 2.3-3); a higher demand was computed for WRIA 23 since precipitation is lower there. The maximum day demand is assumed to be double the average (WDOH, 1999).

Table 2.3-3
Estimated Current Residential Water Demand

WRIA	Average Per Capita Water Demand (gcd)	Year 2000 Average Day Water Demand (cfs)	Year 2000 Maximum Day Water Demand (cfs)
22	123	12	24
23	144	21	42
TOTAL		33	66

The total residential demand is substantially lower than the allocated water; the former was estimated at 66 cfs and the latter was roughly 267 cfs (Table 2.3-1). This discrepancy was apparent in other use sectors as well. Public water systems accounted for about 55% of the demand, the remaining 45% was associated with self supplied water users. Map 6 depicts locations of public water systems. This category can be defined as those water users outside of a public water system service area that may be withdrawing/diverting water under a water right or under an exempt well (RCW 90.44.050). A pilot study was conducted to assess two different methodologies for determining exempt well usage and is described below. Given average growth rates, future residential water use is anticipated to increase by 3 cfs over the next 20 years in WRIA 22, and by 6 cfs in WRIA 23 for the same time period.

Actual commercial/industrial water use was not determined at this level of analysis. However, the largest six commercial/industrial water rights in WRIA 22 accounted for 86% of the allocated water, while there were 27 rights for a commercial/industrial allocation of 9.13 cfs in WRIA 23.

Irrigated agriculture appears to be on the decline in both counties as cropping patterns have changed. Even in Ecology's 1976 report, it appeared that the total water allocated for irrigation was not being put to beneficial use. Actual data for the watershed was, therefore, used from the 1997 Census of Agriculture report (USDA, 1999) as a surrogate: 5,765 acres irrigated in Lewis County and 3,067 in Grays Harbor County. By contrast, there were 12,444 acres allocated for irrigation in WRIA 23 and 11,559 acres in WRIA 22.

While the number of acres irrigated may be less than the water rights, it still represents a significant use of water. Irrigated agriculture is the highest consumptive use in the Chehalis Basin with perhaps one exception; the thermoelectric steam plant in Centralia. Because of the significance of this impact on the watershed, an assessment of the relative volumes of monthly consumptive use was undertaken.

As an example of irrigation demand, if it is assumed that pasture grass is grown on the 5,765 acres irrigated in WRIA 23 and the on-farm efficiency is 50%, the annual volume demand would be 16,960 acre feet/year. For WRIA 22, a similar number was calculated and equaled 4,150 acre-feet/year. Over a four-month irrigation season the former translated to roughly 70 cfs and the latter to about 17 cfs.

Given the order of magnitude difference in the allocated and potentially irrigated acreage in both WRIAs, investigation into the actual use of irrigation water may be a worthwhile effort. As irrigated lands decline, and the fact that there appears to be substantially less irrigation than the acreage allocated under water rights suggests, it would be useful to know which water rights were actually being used and which ones were not. Because irrigation represents such a high consumptive use of water, this effort may be worth the time and cost to sort out in a Level 2 Assessment. However, it would require cooperation by the farm community to be useful.

Based on the county data and water use defaults from the WDOH, in WRIA 22, probably less than 0.5 cfs is used for livestock operations, while in WRIA 23, use may be as much as 1 cfs (WDOH, 1999). Water rights associated with stock watering totaled 12.80 cfs in WRIA 22 and 51.02 cfs in WRIA 23. In addition to stock watering, these rights also were associated with 1,256 and 4,242 irrigation acres, respectively. In any event, the water rights were significantly higher than the calculated estimates of stock water demand. Relative to other water uses, this sector does not warrant further investigation.

2.4 WATER QUALITY

There is a large quantity of water quality data available for the Chehalis Basin, much of it collected as part of WDOE's Ambient Monitoring Program. This means there is a relatively standard data set available for a fairly long period of record. The goal of the Water Quality Assessment was to optimize the use of this and other data to provide a summary of the water quality condition. The key questions the analysis needed to address were these; Are water quality criteria being met? Has there been a change in water quality over time? Does the quality change with distance down the mainstem? What is the condition of the tributaries, or what is known about their condition?

To answer these questions, the analysis focuses on the parameters that are most closely linked to the objectives of this watershed planning effort. This is not meant to imply that other pollutants such as heavy metals or pesticides are not a concern in the Basin. There are of course sources of these pollutants. Some may be prioritized for more detailed evaluation at some later time in the planning process. The ambient monitoring data was prioritized for the analysis because it has a higher value for answering the key questions. This technical summary primarily focuses on the mainstem. Appendix C contains the detailed assessment of the Chehalis Basin's water quality in addition to an assessment for each subbasin for which there is adequate data.

2.4.1 METHODS

Water quality data for the Chehalis River is available from as far back as the late 1970's. WDOE monitors a few stations on the Chehalis as part of their Ambient Monitoring Program. The result is a set of routinely collected (and therefore comparable) data for three to five stations on the mainstem of the river. There is also ambient monitoring data available for stations at or near the mouths of a number of the major tributaries. In the Upper Chehalis (WRIA 23) this data set includes: South Fork Chehalis, Newaukum, Skookumchuck, and the Black Rivers. In the Lower Chehalis (WRIA 22) recent data are available for the Hoquiam (@ RM 9.3) and the Humptulips (@ RM 23.6). Ambient monitoring data from the 1970's is available for the Wynoochee and Wishkah Rivers. Map 7 depicts the locations of these ambient monitoring stations and 303D listed stream segments.

To assess possible long-term trends in the mainstem, data for the three stations that had been monitored since the late 1970's were used. Because data was only available for the last three years in the 70's, only data from the last 3 years of each decade were used for the trend analysis, to equalize the size of the data sets between decades. During the 1990's, 5 stations were routinely monitored on the mainstem. This data is assessed separately to allow for a more comprehensive look at possible trends with distance downstream.

Parameters were selected for analysis either because they were directly related to fish habitat and flow problems (dissolved oxygen (DO) and temperature), or because they are appropriate indicators of water pollution (total phosphorus (TP) and total suspended solids (TSS)), or because they are important in the basin since they are tied to a commercial industry (fecal coliform bacteria (FC)).

A pollutant loading analysis was performed for the mainstem of the river using average concentrations and average instantaneous flow measurements. The analysis also included an estimation of point source discharge loads and a comparison to measured seasonal loads in the mainstem. Where data was available, some pollutant load estimates are also provided for subbasins. These are also based on instantaneous flow measurements.

A pollutant load and yield analysis was also performed using estimated or extrapolated median flow values (50% exceedances flows) for the mainstem and tributary stations for which the hydrologic analysis required for calculation of median flows had been done. The use of median flow values allowed for a more valid comparison with values reported in a Puget Sound-wide study and also a less flow biased comparison between subbasins within the Chehalis.

2.4.2 WATER QUALITY CRITERIA

Water quality standards have been set for all surface waters in the State of Washington (WAC 173-201A). These standards for rivers and streams range from Class AA (Extraordinary) to Class C (Fair). The Class assigned to a particular stream or river reach is based on present and potential future beneficial uses of the water. However, the fact that a water body is listed as, for example, Class A does not signify that Class A water quality standards are met. It only means that the set of standards that define Class A waters will be used as the “ruler” to determine whether the stream or river is meeting acceptable standards.

Washington State water quality criteria (WAC 173-201A) for temperature, dissolved oxygen, and fecal coliform levels vary within the Chehalis Basin. The majority of the basin is defined as Class A (excellent) waters. Exceptions to this classification include three rivers and one mainstem reach for which Class AA (extraordinary) criteria apply, and two river sections for which Class B (good) criteria apply. Surface waters rated as Class AA include the Chehalis headwaters (Subbasin 1 and 2), the upper portion of the Humptulips (Subbasin 25), the Middle, East, and West Fork Satsop (Subbasin 17 and 18), the upper Skookumchuck (Subbasin 9), and the West Fork Wishkah and southern tributaries (Subbasin 21). Surface waters rated as Class B are the lower reach Hoquiam (Subbasin 22) and the first six miles of the Wishkah (Subbasin 21). Standard criteria for the different classes are provided in Table 2.4-1.

A notable exception to the Class A criteria on the mainstem Chehalis is the “Centralia Reach” (river mile 65.8-75.2). A natural sill in the river causes the water to “pool” upstream. This naturally slow moving reach has merited setting separate criteria for dissolved oxygen and temperature. The criteria for this reach includes a special condition stipulating that dissolved oxygen shall exceed 5.0 mg/l from June 1-September 15 and temperature shall be between 18 and 20.4°C (exact temperature standard depends on segment).

Table 2.4-1.
Washington State Water Quality Criteria.

Class	Temperature	DO	Fecal Coliform
AA	shall not exceed 16°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 9.5 mg/L	shall not exceed a geometric mean of 50 colonies/100mL and shall not have > 10% of all samples exceeding 100 colonies/100mL
A	shall not exceed 18°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 8.0 mg/L	shall not exceed a geometric mean of 100 colonies/100mL and shall not have > 10% of all samples exceeding 200 colonies/100mL
B	shall not exceed 21°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 6.5 mg/L	shall not exceed a geometric mean of 200 colonies/100mL and shall not have > 10% of all samples exceeding 400 colonies/100mL

(Note: On a biannual basis the EPA creates a list of “impaired” waterways in the U.S. This is the official 303(d) List of Impaired Waterbodies, referred to as the “303(d) list”. Although there are numerous ways that a waterbody can be justified for inclusion in this list, the most frequently used method for Washington State waters is a simple assessment of whether State water quality criteria are being met. If criteria aren’t met, the waterbody, or in this case stream segment, will be added to the list. Once a stream segment is listed as impaired, it becomes the States responsibility to develop or support a plan for handling the problem. One tool used for developing strategies to improve water quality is a Total Maximum Daily Load (TMDL) study. (Appendix C contains a summary table depicting 303(d) listed segments for the Chehalis Basin.)

Water temperature has been documented as a problem in the Chehalis Basin and in a number of its tributaries. This documentation includes both direct temperature measurements, as well as field observations of reduced or eliminated riparian canopy, as described in Appendix D. Figure 2.4-1 depicts average wet and dry season temperature with river mile along the mainstem. (Figures 2.4-2 is provided to illustrate the relationship between river miles, as used in Figures 2.4-1; 2.4-3 through 2.4-7, and selected cities and tributaries.) As depicted, in terms of average dry season temperatures in the mainstem, the criteria are met. Temperatures appear to be slightly cooler at the upper mainstem station. There was no difference between the decades, thus no trend of deteriorating quality. Although comparisons between decades are interesting and may show recent water quality trends, the 1970’s would not represent a baseline condition for any of these water quality parameters. At that time, land conversion and associated loss of riparian canopy and forest cover along the river and tributaries would already have occurred.

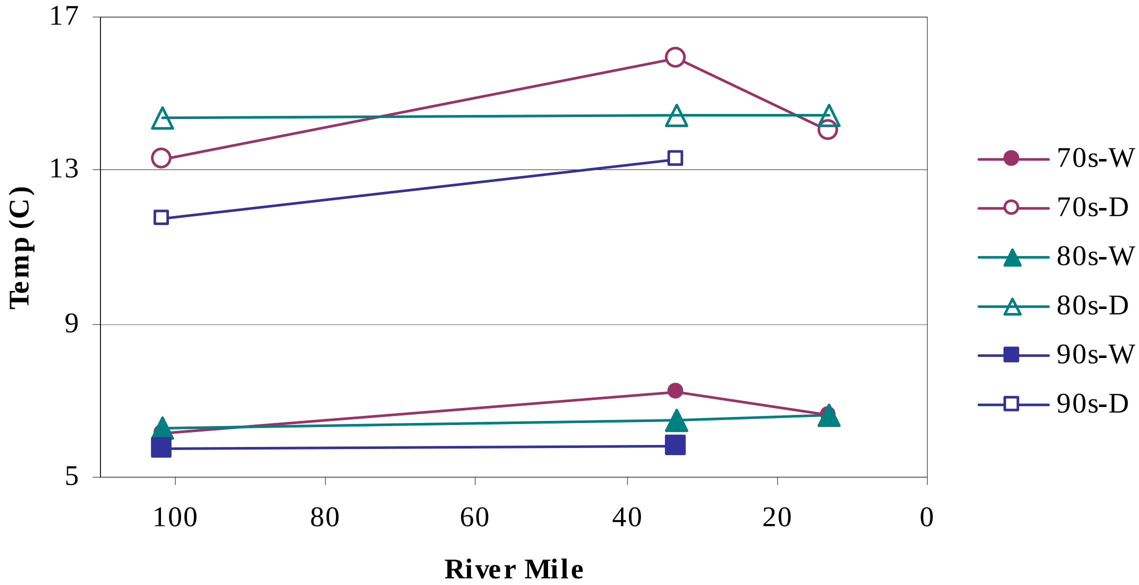

Figure 2.4-1
Comparison of Temperature (3-Year Average) Along the Mainstem Chehalis over Three Decades.

Although it is informative to know that the long term average seasonal (in this case August 1 through October 31) record does not indicate a temperature trend change, water quality exceedances and comparisons to criteria are more appropriately assessed by individual dates, sites, and measurements. Of the 25 segments of the Chehalis that are listed (303(d)) as having impaired water quality, 9 are listed due to temperature exceedances during the summer months when flows are lowest. All of these segments are within the upper basin except for the Humptulips. (Appendix C contains a summary table depicting 303(d) listed segments for the Chehalis Basin and those for which high temperatures are problematic.)

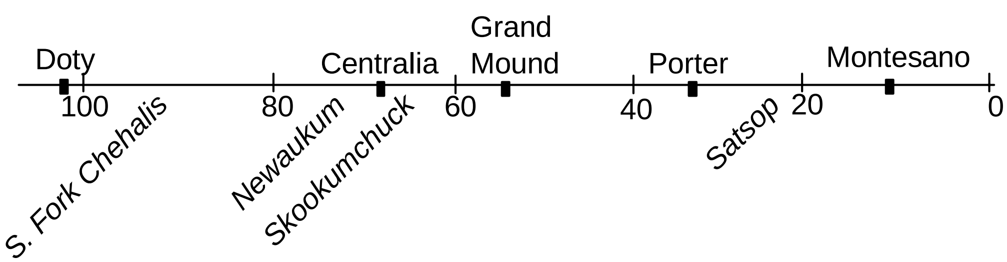

Figure 2.4-2
Mainstem Chehalis Rivermiles in Relationship to Selected Cities and Tributaries

Dry season temperature exceedances in several tributaries in the Upper Chehalis have been reported (Pickett, 1994a). For example, the Upper Chehalis Basin exceeded temperature criteria on 62% and 24% of occasions during the June and July periods, respectively. (Not surprisingly, the highest temperatures were measured in the slow flowing Centralia Reach.) This lead to the "Upper Chehalis Temperature TMDL" (Butkus, and Jennings, 1999). TMDL recommendations were to increase riparian shading along the upper mainstem and its tributaries and disallow additional water withdrawals. Given the width of the Chehalis, it is doubtful that increased shading to the mainstem will substantially reduce temperatures. Notwithstanding the many other benefits from riparian shading of the mainstem, increases in shading of the tributaries may have a more significant impact on temperature regimes throughout the upper basin. Another recommendation of the study (Butkus and Jennings, 1999) was to reduce the width-to-depth ratio in three tributaries (Black River, Newaukum River and South Fork of the Chehalis River) to improve dry season temperatures (Butkus and Jennings 1999).

Similar to temperature, it is the late summer period (dry season) when dissolved oxygen concentrations can reach critical levels. As depicted in Figure 2.4-3, the average dry season dissolved oxygen concentrations at the three mainstem stations met the water quality criterion (8.0 mg/l) for Class A waters. Dissolved oxygen does appear to decline with distance downstream. No differences were found across the three decades.

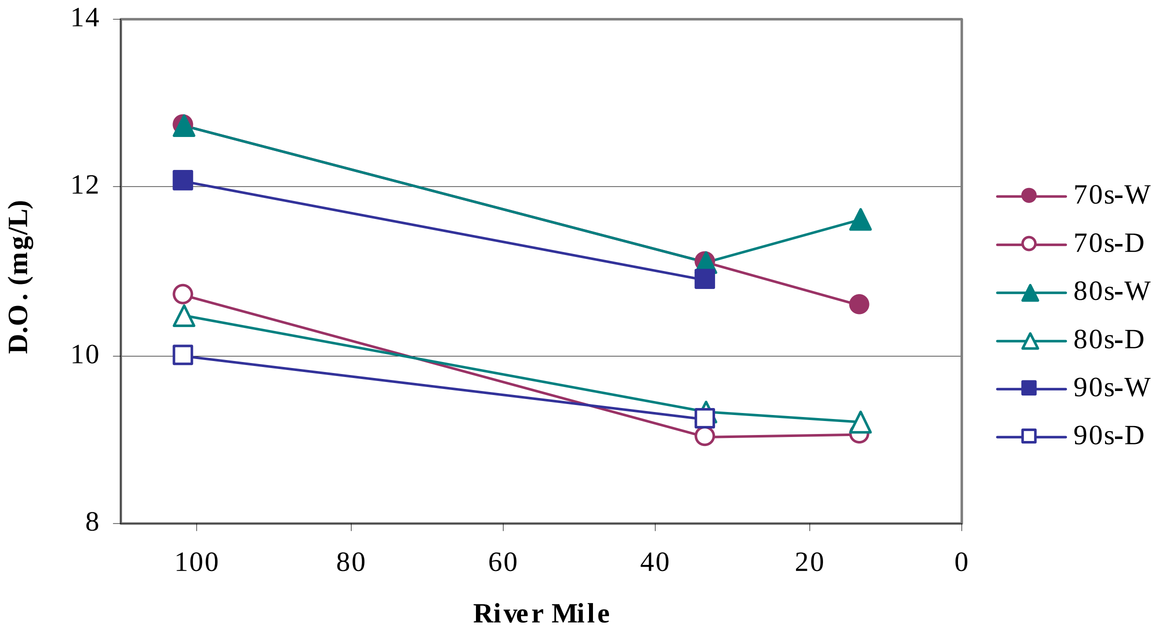

Figure 2.4-3
Comparison of Dissolved Oxygen Concentrations (3- year average) along the Mainstem of the Chehalis over Three Decades.

As with temperature, individual measurements of dissolved oxygen indicate that at some locations, the criterion is not met. Dissolved oxygen concentrations have also been found to be problematic in segments of the Chehalis. Of the 25 impaired segments listed on the 303(d) list, 11 are listed due to dissolved oxygen problems. With the exception of the Humptulips, all tributaries that did not meet the DO standard are located in the Upper basin. As previously described (Section 2.4.2), the slow-flowing Centralia Reach represents a natural condition that is largely responsible for the temperature and DO problems. New standards have recently been set to reflect this natural condition.

A TMDL was carried out by WDOE to examine contributing factors to the oxygen conditions in the upper basin (WRIA 23). The author recommended reductions in point and non-point sources of oxygen depleting contaminants (Pickett, 1994a).

Other than the Black River, there were no tributaries where both temperature and dissolved oxygen did not meet standards. However, this combination of high temperature and low DO existed throughout most of the Chehalis mainstem. This represents a critical set of conditions for fish health and survival.

FC bacteria represent a third parameter for which there is water quality criteria. It is the most common reason for listing of tributaries or segments in the Chehalis. Of the 25 listed segments, 19 are listed due to FC bacteria exceedances. Again, these segments are almost exclusively located in the Upper Basin. (Appendix C contains a summary table depicting 303(d) listed segments for the Chehalis Basin.)

Figure 2.4-4 depicts FC bacteria loads as estimated for the mainstem stations. At the upstream station, there is little difference between wet and dry season loads and there is no change across the decades. This could indicate that these load values represent a close to baseline condition. However, it is also possible that reproduction of bacteria during warmer weather is compensating for the increased load during wet, or that a local nonpoint source (e.g. manure spraying) is higher in summer. Although the data record is incomplete for the downstream stations, it suggests only slight increases in load during the dry season and more notable increases during the wet season. This indicates the fecal coliform sources located downstream of RM 101 (Doty) are also nonpoint related.

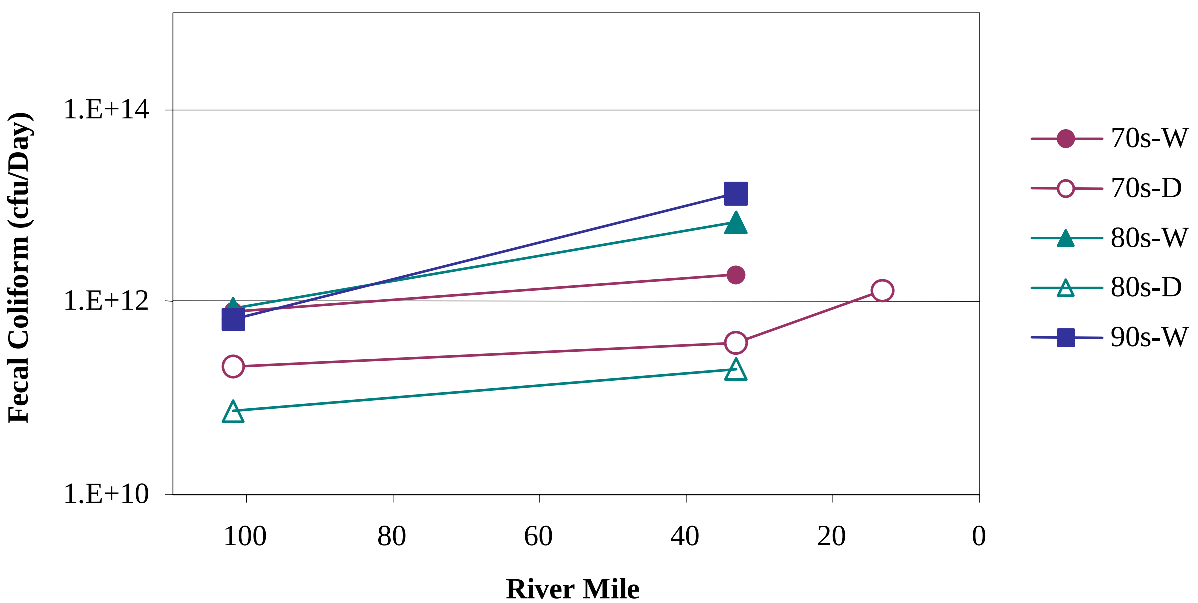

Figure 2.4-4
Comparison of Fecal Coliform Loads (3-year geometric mean) along the Mainstem of the Chehalis over Three Decades.

2.4.3 POLLUTANT LOADING

Phosphorus (TP), suspended solids (TSS), and fecal coliform (FC) bacteria were selected for the loading analysis. Although all are naturally occurring substances, they are also indicators of pollution when they occur at high levels. Calculations of "pollutant load" (the volume contributed per day) and "pollutant yield" (the load standardized by watershed size) can be useful for comparing between sources and contributing areas.

Under natural conditions, or conditions where all the land and water in the watershed is contributing equivalent amounts of these constituents, it would be expected that the load would increase with distance downstream. This would simply occur from continued inputs of water with its natural concentrations of these constituents/pollutants. To some extent the difference between wet and dry season loads of pollutants can be used to make general determinations about point and nonpoint sources of pollution. Generally, point sources of pollutants have a tendency to contribute a consistent pollutant load throughout the year. Thus, in a stream where point sources are prevalent, the pollutant loads may not change greatly between seasons. Conversely, nonpoint sources of pollution tend to be associated with the wet season and will result in increased loading during that season.

Figure 2.4-5 and 2.4-6 depict the changes in pollutant loads for total phosphorus (TP), and total suspended solids (TSS) for the three mainstem Chehalis stations for all three decades. (FC bacteria loads were previously described (Figure 2.4-4). These figures were all based on averages of instantaneous flow and pollutant concentration data for the stations.

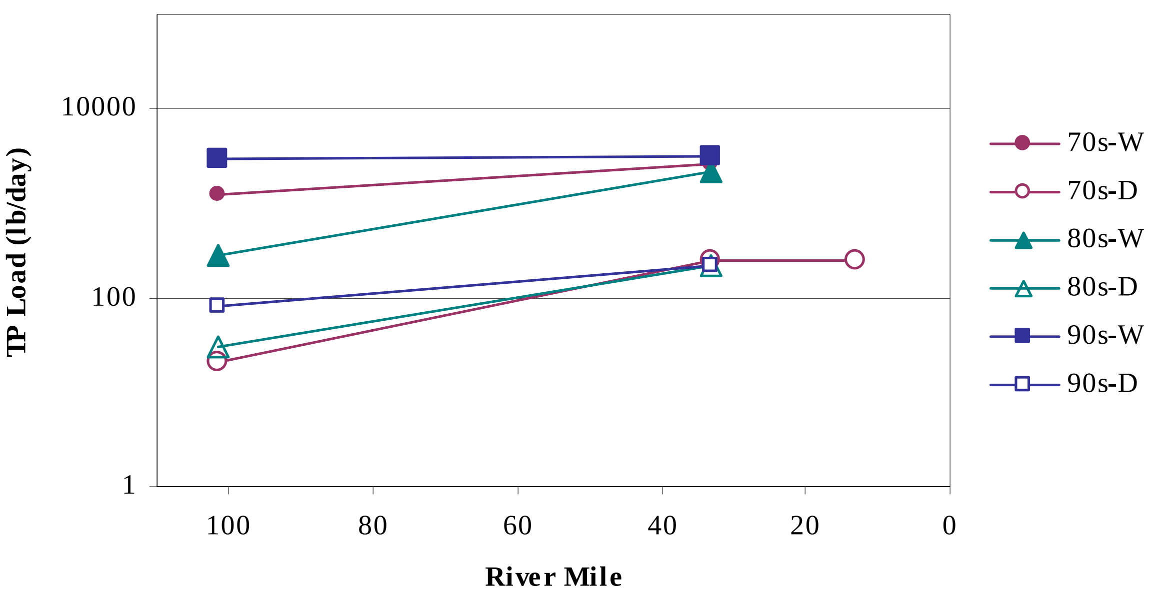

Figure 2.4-5
Comparison of TP Loads (3-year mean) along the Mainstem of the Chehalis over Three Decades.

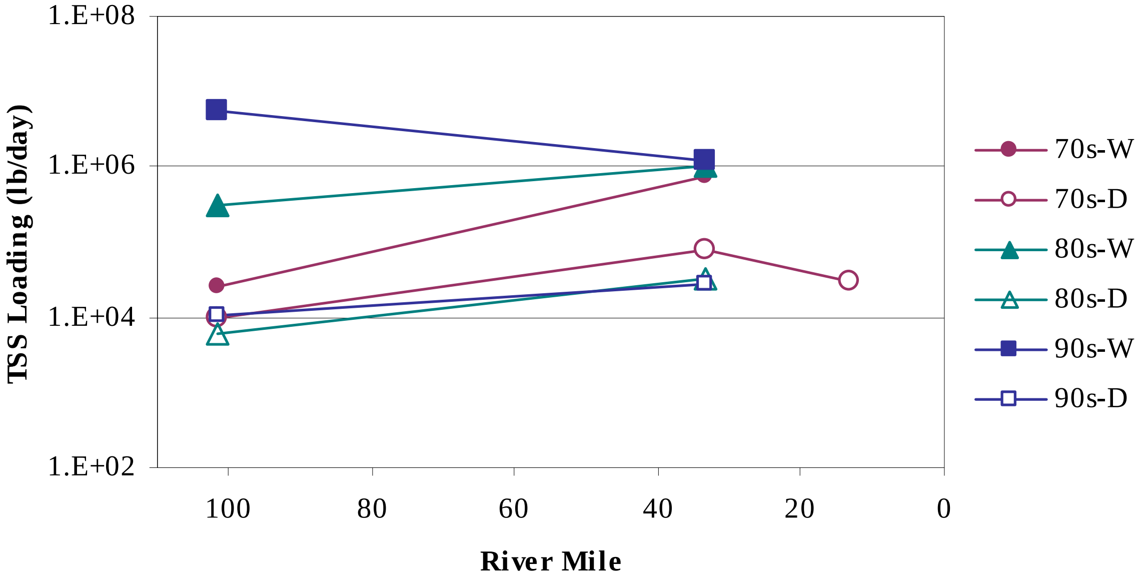

Figure 2.4-6
Comparison of TSS Loads (3-year mean) along the Mainstem of the Chehalis over Three Decades.

The load of all three pollutants was higher during the wet season and there was a general increase with distance downstrem. This indicates that nonpoint sources of pollution are important in the basin. Further, the pollutant load for all three parameters did increase with downstream distance in the dry season, indicating that the difference between stations may represent the natural affect of increased basin size on loading. What is perhaps more interesting is to note that for both TP and TSS, the wet season load in the 1980's and 1990's were consistently at the same level at the station furthest upstream and the downstream station. This is a notable exception to what would normally be expected. It indicates that the upstream portion of the basin is contributing a significant pollutant load and is likely a nonpoint source. The fact that FC bacteria did not display this tendency may further indicate that the source is not likely to be agricultural, pointing to current or past logging practices as a likely source or cause of TP and TSS loading.

An additional monitoring station was included in the 1990's on the Chehalis mainstem just below the Centralia Reach. To further assess possible downstream trends in pollutant loads, TP data for the 1990's was graphed (Figure 2.4-7). In this case median flows were used to calculate the loads. The figure depicts a more definitive downstream trend of increasing loads that occurred during both seasons. It also indicates that the biggest change occurred within the segment marked by the Centralia Reach.

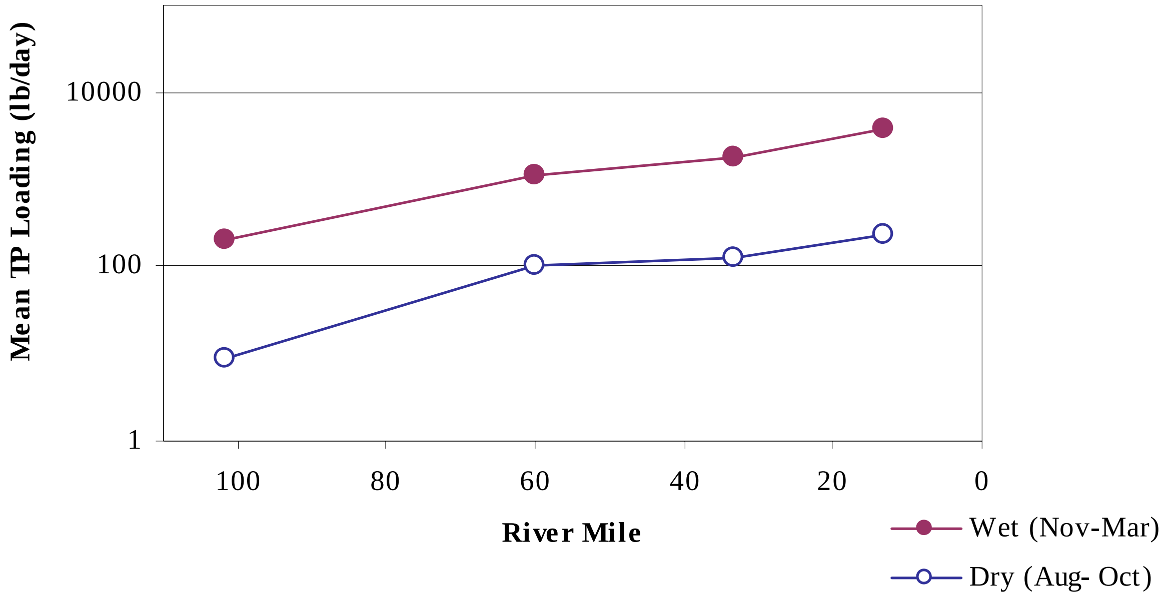

Figure 2.4-7
Comparison of the Chehalis River Mean TP Loading in 90s

To further address the question of point versus nonpoint sources of pollution, an analysis of point source contributions was undertaken. By using the list of NPDES permit holders in the basin and regional median wastewater pollutant concentrations (Embrey and Inkpen, 1998), an estimate of loading from permit holders was calculated. Then the total phosphorus loading from NPDES permitted discharges to the mainstem at Porter and Montesano was calculated to determine the contribution to seasonal loading.

The cumulative permitted TP loading to the mainstem at Porter was estimated at 377 lb/day. While this represents only 13% of the wet season load, it represents more than 100% of the average dry season TP loading. A similar result was calculated for Montesano. The cumulative TP loading from the municipal and industrial wastewater treatment plants was estimated at 427 lb/day, 16 % of the total wet season load and almost three times the dry season load. These NPDES contributions to the TP loads represent the potential for NPDES discharge. They were calculated based on discharging at design capacity and regional median concentrations. This can be expected to largely over estimate their actual contribution, especially during the dry season. However, it does reflect differences in expected seasonal loadings.

The final consideration in the loading analysis is whether there has been a change over the three decades that cover the period of record. There is no evidence of changes in loads of TP or FC over the period, at any stations during either dry or wet seasons. There does appear to be a steady increase in TSS loading at the uppermost station during the wet season.

2.4.4 POLLUTANT YIELDS & COMPARISONS WITH OTHER PUGET SOUND BASINS

Pollutant yields are load estimates that have been "corrected" to account for the land area that contributes to the basin. Table 2.4-2 contains a summary of calculated pollutant yields for four mainstem stations and the two tributaries for which median flows were available. TP yields were calculated to be similar along the mainstem, the highest was measured in Montesano. The Humptulips had the highest overall TP yield, however it was within the same range as the other stations. TSS yields were substantially higher at Dryad and in the Humptulips.

Table 2.4-2
Pollutant Yields for Chehalis Basin Mainstem and Tributary Stations.

River Mile	Location	TP Yield (tons/yr-mi^2)			TSS Yield (tons/yr-mi^2)			IN Yield (tons/yr-mi^2)[1]
Season		Wet	Dry	Average	Wet	Dry	Average	Average
101.7	Dryad	0.31	0.01	0.14	343	2.3	143	1.43
59.9	Prather Rd.	0.23	0.02	0.12	90	1.1	42	1.59
33.3	Porter	0.26	0.02	0.13	107	1.3	49	1.92
13.15	Montesano	0.39	0.02	0.18	93	30	48	2.22
0.1	Newaukum	0.15	<0.01	0.08	155	11.3	7.8	2.03
23.6	Humptulips	0.41	0.03	0.2	396	6.1	186	1.15

[1]IN=inorganic nitrogen. This information is provided to allow comparisons to other basins in the Puget Sound

Table 2.4-3 contains a summary of TP and IN (inorganic nitrogen) yield results from other large river basins in the Puget Sound region that can be used for comparison. The basins range from quite impacted urbanized systems (e.g. Green River and Puyallup), to more rural systems (e.g. Nooksack and Stilliguamish). As shown, there are no strong relationships between yields of these pollutants and known degraded systems (i.e. the Green and Puyallup are no higher overall than the Nooksack and Stilliguamish). By comparison Chehalis and tributary streams (Table 2.4-2) exhibited TP yields that were within the same range, although slightly lower than the average measured in other Puget Sound basins. The reverse was true for IN; the yields were basically within the same range, but generally higher in the Chehalis. In fact, with the exception of the Humptulips, all of the calculated yields were higher than the average IN yield calculated for the other large river basins.

Table 2.4-3
Pollutant Yields Measured in Selected Puget Sound River Basins.
(Source: Embrey and Inkpen, 1998)

River Basin	TP	IN
Deschutes	0.1	1.0
Nisqually	0.09	0.6
Puyallup	0.4	1.0
Green	0.2	1.2
Snohomish	0.2	1.8
Stilliguamish	0.4	2.0
Skagit	0.2	0.9
Nooksack	0.3	1.8
Average	0.24	1.29
Highest in Study[1]	0.4	2.8
Lowest in Study[1]	0.05	0.3

[1]These were the highest and lowest values measured in a study of 22 river and stream basins in the Puget Sound Basin.

2.4.5 GRAYS HARBOR

This water quality assessment encompassed the mainstem of the Chehalis River and its tributaries for which there is reliable data. This report does not provide an analysis of Grays Harbor. Grays Harbor, at the mouth of the Chehalis watershed, has been the focus of a number of studies. The conditions within the estuary vary depending on the location, the degree of tidal and wind mixing, and degree of density stratification (Jennings, 1996). The harbor is separated into an inner harbor area and an outer harbor area, each with different water quality classifications under the water quality standards. The inner harbor is designated as a Class B water and is listed under section 303(d) of the Clean Water Act as not meeting water quality standards for fecal coliform bacteria. The outer harbor is a Class A water body. While the outer harbor is not listed as impaired on the 303(d) list for fecal coliform, Jennings indicates that there is mounting evidence that this indicator parameter may be a concern in some areas of the outer harbor (Jennings, 1996).

A recently published TMDL conducted by WDOE indicated that the primary source of the fecal coliform loading was from the Chehalis River; with the Humptulips, Hoquiam, Wishkah, and Satsop rivers accounting for nearly 80% of the total loading (Pelletier, 2000). The TMDL established a 65% reduction in the non-point source load allocations; and the TMDL established wasteload allocations for the two major point sources (Weyerhaeuser Cosmpolis and Weyco) (Pelletier, 2000).

2.4.6 LAND USE RELATIONS

Recognized non-point sources of pollution to the watershed include agricultural and forest practices, urban stormwater, and failing septic systems (Pickett, 1994a). Land within the basin is dominated by forestlands (82.7%). Logging activities in these areas can contribute suspended solids to the streams. The high TSS loads measured at the upstream station on the Chehalis and the Humptulips likely reflect that affect. Although agriculture represents only 10.7 % of the landuse in the watershed to Montesano, the agricultural land is typically adjacent to the river corridor. Thus, the level of impact can outweigh expectations based on land use. Agricultural activities contribute fecal coliform, BOD, and nutrients (phosphorus, nitrogen, etc.) to the mainstem and a number of tributaries. Although urbanized areas represent less than 2% of the watershed at Montesano, they also contribute to increases in TSS, nutrients, and bacteria. In urbanized areas without municipal sewers, failing septic systems can result in fecal coliform and nitrate loading of a stream segment.

2.4.7 CONCLUSIONS

Water quality in much of the basin and its tributaries has been described as impaired in numerous WDOE studies. The Upper Basin is where most of the water quality problems have been documented. No long term improving or deteriorating trends were noted in this analysis. One or two subbasins have high TSS loads and yields, and generally IN yields appear to be high throughout the basin. However, it is the temperature and dissolved oxygen problems that seem most critical, in view of the fish habitat issues and relation to streamflows.

Last, it should be noted that one of the defining characteristics of water quality studies is that there is a strong tendency to look for problems where it is suspected some occur. As detailed in this assessment, the Upper basin of the Chehalis has the majority of documented water quality problems. Since there is more human activity in the Upper Basin, this probably reflects the real condition. However, it may also reflect the fact that little monitoring is occurring in the streams in the Lower basin.

2.5 FISH HABITAT/CHANNEL MODIFICATION/STOCKS

2.5.1 CURRENT FISH HABITAT CONDITIONS

While situations do vary to some degree between subbasins, some basin-wide patterns are clear. These also agree with the conclusions of previous analysts (Hiss and Knudsen 1993, Wampler et al., 1993). As a result of past and present land use practices, stream channels in the Chehalis watershed show a consistent pattern of riparian vegetation removal, shade reduction, and reduction in streambank stability leading to bank erosion and elevated levels of instream sediments. While few measures of existing woody debris levels were found, comparison to historic information and past legal stream cleaning practices indicate that instream woody debris levels are either non-existent or much lower than historic levels. While information about loss of side channel and wetlands habitats is more anecdotal, patterns of timber harvest and agricultural practices have left stream channels in a more simplified state than in pre-settlement periods, with less streambank stability, lowered shading levels, and simplified instream habitats with fewer, or no, side- or off-channel habitats available. While summer water temperatures in much of the Chehalis watershed may have been historically somewhat high (above preferable for salmonid fish, but sublethal) due to relatively low elevations of many of the stream channels in the basin, riparian vegetation removal, lowered shading levels, and degradation of streambank stability have most likely contributed to increases in the magnitude and range of this problem.

Because of the size of the Chehalis watershed, watershed-wide conclusions are necessarily very general. A more appropriate level of detail is the subbasin level. Habitat conditions by subbasin are presented in Appendix D. It is recognized that in some situations, habitat conditions may be in some partial recovery from past damages; this is most likely on forested lands managed under federal or state forest practices, where protection of riparian corridors has become the rule during the last few decades. Because little change in protection or restoration of riparian corridors on agricultural lands has occurred in the last few decades, riparian conditions in those land uses rely more on the individual landowner's discretion. In those land uses, riparian and stream habitat conditions will vary widely, and no estimation of the amount of recovery of riparian function can be made at this level.

2.5.2 CHANNEL MODIFICATIONS

As with most western Washington stream systems, the Chehalis has a land use history focused on timber harvest and agriculture. Many associated activities, such as splash damming and wood removal, have had an affect on hydrologic conditions and resultant channel/habitat conditions.

River channel conditions prior to European settlement were very different than those seen today. Most low-gradient river channels in Western Washington and Oregon consisted of complexes of river, wetlands, beaver ponds, sloughs, logjams, and side channels, with both standing trees and instream wood very common and plentiful. Draining land for farming began early in the settlement period in Grays Harbor County, from the mid-1800's. Ditching and draining activities by individual landowners were very common in the 1880-1920 period (Van Syckle, 1980; Sedell and Luchessa, 1981). In many rivers, woody debris was not only cleaned out of the stream channel, but was also used to dike off sloughs and side channels in order to consolidate and straighten the stream channel. During the 1930's, when the Works Project Administration was active, many stream channels in agricultural areas were cleared of brush (Sedell & Luchessa, 1981).

Riparian vegetation removal in many streams in the watershed has been a result of both timber harvest and agriculture. Buffer strips of varying widths began to be left during the 1980's, and are mandated now on forest lands. Therefore, while the historical disturbance was extreme, riparian areas on timberlands can be seen as in recovery from past practices, although the recovery period may be as long as several hundred years. In addition, riparian vegetation removal, and riparian areas in degraded condition as a result of agricultural practices, have been documented widely throughout the watershed (Wampler et al., 1993 see Appendix D for a summary by subbasin).

2.5.3 FISH STOCK STATUS AND TRENDS

A total of two spring chinook stocks, seven fall chinook stocks, two chum stocks, seven coho stocks, two summer steelhead stocks, eight winter steelhead stocks, one bull trout/Dolly Varden stock, and two coastal cutthroat stocks have been identified in the Chehalis watershed. No pink salmon or sockeye salmon stocks were identified in this area (SASSI 1993, WDFW 1998a, 2000).

Of the thirty-one stocks identified, stocks classed as “healthy” included:
Chehalis spring chinook,
Humptulips, Hoquiam, Wishkah, Wynoochee, Satsop and Chehalis fall chinook,
Humptulips and Chehalis fall chum,
all seven coho stocks in the watershed, and
Humptulips, Hoquiam, Wishkah and Wynoochee winter steelhead.

Stocks classed as “depressed” included:
Satsop summer chinook, and
Satsop and Skookumchuck/Newaukum winter steelhead.

Stocks classed as “unknown” included:
Johns/Elk fall chinook,
Humptulips and Chehalis summer steelhead,
South Harbor streams winter steelhead,
bull trout/Dolly Varden for the entire Grays Harbor/Chehalis area, and
coastal cutthroat trout for both the Humptulips and Chehalis
(SASSI 1993,WDFW 1998a, 2000).

One stock, Wynoochee spring chinook, was classed as “disputed”. For further discussion see Appendix D.

Some population trend information was identified. A stable or positive population trend was identified for Chehalis spring chinook, all of the fall chinook stocks except Johns/Elk and South Bay tributaries. It should be noted that, even with positive trends, most anadromous stocks in the Chehalis Basin are present at far fewer than their historical numbers (Hiss and Knudsen 1993).

Negative trends were identified for Satsop summer chinook, and Satsop and Skookumchuck/ Newaukum winter steelhead. These trends gave rise to the depressed classification for these populations.

Population trends of “unknown” were identified for Johns/Elk and South Bay tributaries fall chinook, Humptulips and Chehalis summer steelhead, South Harbor winter steelhead, Humptulips and Chehalis coastal cutthroat trout, and bull trout/Dolly Varden for the entire basin (SASSI 1993, WDFW 1998a, 2000). Wynoochee spring chinook were also identified as “unknown”, but the trend is probably negative, as discussed above.

No population trends were identified for the “healthy” Humptulips and Chehalis fall chum stocks; all seven coho stocks; and Chehalis, Humptulips, Hoquiam, Wishkah and Wynoochee winter steelhead stocks (SASSI 1993).

SECTION 3: SELECTED SUBBASIN ASSESSMENT

3.1 INTRODUCTION

3.1.1 SUBBASIN SELECTION RATIONALE

For five of the 30 subbasins, more detailed analyses of hydrology, water rights and water use, and fish habitat were undertaken. The five subbasins were chosen to represent the diversity of conditions in the Chehalis Basin in terms of basin size, historic and current land use, geography, climate, potential use of water resources, and geology (Table 3.1-1). Not all combinations of these factors could be realized with a choice of only five subbasins. Instead, selection was intended to maximize the diversity across the range of conditions present in the Chehalis watershed. All of the selected subbasins contain anadromous and resident salmonids, and four of the five have been extensively surveyed for fish habitat conditions and problems (Wampler, et. al. 1993). In addition to the diversity in subbasin characteristics, the amount and type of available information varied among these subbasins. Therefore, their selection also provided an example of variation in analytical methods and results.

The driving factors for selection of the 5 subbasins and desire to do more detailed analysis were water quantity related issues; hydrology and water rights/use. There was little that could be done in terms of more detailed water quality analysis. For those of the selected subbasins where median flows were available, pollutant yields were calculated. Otherwise the analysis was limited by available data. Detailed information for each of the subbasins is provided in Appendix C. Rather than repeating it in this section, summaries of the water quality analysis are provided to enhance comparisons.

The subbasins selected were:

- Chehalis River headwaters (#1),
- Lower Newaukum River (#7),
- Cloquallum Creek (#14),
- Mainstem Chehalis- Lower Reach-1 (#19), and
- Humptulips River (#25).

Table 3.1-1
Attributes of 5 selected subbasins

Subbasin	Basin Size (mi^2)	Geography	Precip. [1] and UR[2]	Geology
Chehalis headwaters (#1)	116	Headwaters, mid-elevation	89” (5)	Willipa Hills geologic zone
Newaukum (#5, 6, 7)	156	Cascade foothills	52” (3-5)	glacial outwash-lower; volcanic-upper
Cloquallum Creek (#14)	70.3	low elevation; potential for aquifer to be close to surface	68” (4)	glacial till-headwaters; glacial & alluvial-lower
Lower Mainstem Chehalis (#19)	94	Lowland valley floor	59” (3-4)	alluvial valley floor, some glacial material; side slopes sedimentary rock
Humptulips (#25)[3]	244.3	Olympic Mountains, coastal & relatively wet	127” (10)	volcanic-headwaters, Olympic mountain geology; alluvial & glacial drift-lower;

[1]Source: Washington State Department of Natural Resources Mean Annual Precipitation GIS Layer (WDNR,1991)
[2]UR = Annual Mean unit runoff in cfs/mi^2 are shown in parenthesis.
[3]Splash dams and gravel mining were important past activities in the Humptulips.

Table 3.1-2
Land use/ land cover area (acres) of 5 selected subbasins

Subbasin	Commercial	Agricultural	Forestry	Residential /urban	Other	Total
Chehalis headwaters (#1)	62	2,268	71,055	474	128	73,988
Newaukum (#5, 6, 7)	113	17,217	80,228	1,023	1,141	99,722
Cloquallum Creek (#14)	135	1,480	41,435	913	1049	45,012
Lower Reach 1 Chehalis (#19)	197	2,979	47,770	1,892	554	60,365
Humptulips (#25)	30	2,146	153,107	725	375	156,383

Source: Washington State Department of Natural Resources (WDNR), 1990

3.2 SUBBASIN 1: CHEHALIS HEADWATERS

3.2.1 GENERAL DESCRIPTION

The Upper Chehalis River (Subbasin #1) covers 116 mi^2 from the headwaters of the Chehalis to the confluence with Elk Creek near Doty, WA. The elevation ranges from 293 feet at the Elk Creek confluence to 3,134 feet in the Willapa Hills; mean basin elevation is 1,280 feet. The mean annual precipitation is about 89 inches (WDNR, 1991). Mean annual discharge measured at the USGS streamflow gage #12-020000, Chehalis near Doty, was 573 cfs. This translated into a unit runoff of approximately 5 cfs/mi^2; winter unit runoff averaged 11 cfs/mi^2, while summer unit runoff was less than 1 cfs/mi^2. The primary land use for this subbasin is forestry with some agricultural and residential land uses along the river valley (Figure 3.2-1) (WDNR, 1990).

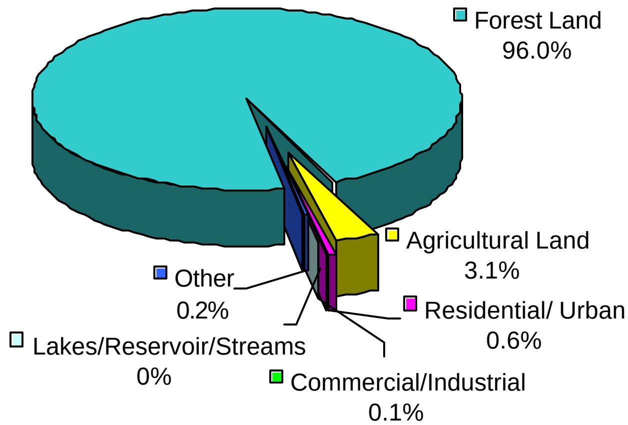

Figure 3.2-1 Subbasin #1
Chehalis River Headwaters Land Use/Land Cover Summary
Source: WDNR, 1990.

3.2.2 GEOLOGY AND HYDROLOGY

Geology

The upper three-quarters of the basin is underlain by Eocene epoch basalt (Crescent formation) and tuff (consolidated pyroclastic rocks). A small area of Eocene epoch marine sedimentary rocks of the McIntosh formation is located in the southwest corner of the subbasin. The lower one-quarter of the basin is underlain by younger Eocene epoch marine sedimentary rocks (Lincoln Creek formation) with recent alluvial material in the valley floor.

Ground Water Hydrology

Groundwater conditions in the area underlain by bedrock are not well studied, but minimal amounts of groundwater likely exist at depth in fractures in the rock. A shallow aquifer is likely present in the alluvial material in the valley floor.

Surface Water Hydrology

The USGS has collected mean daily discharge near the mouth of Subbasin #1 at the Chehalis River near Doty (station #12-020000) from 1939 to the present. Prior to using these streamflow records to generate summary statistics, two factors were investigated: 1) climate variability over the period of record, and 2) the extent of upstream regulation and withdrawal of water.

The period of record used for this analysis was 1939-98 since post-1998 data are still regarded as provisional. The 1939-98 period included 29 years above the long-term annual average and 31 years below normal, based on a trend analysis of the longer record of streamflow at the Satsop River near Satsop (1929-98) gage. In addition, the 1939-1998 period included almost equal years within each type of Pacific Decadal Oscillation phase (warm/dry, cool/wet). Therefore, the available streamflow data reflected the natural climate variability experienced in this region.

With regard to regulation and diversions/withdrawals of water, both the USGS's station remarks and Washington Department of Ecology's (WDOE) baseflow report (Sinclair and Pitz, 1999) stated that no regulations or diversions occur upstream of the gage. While it was likely that some withdrawals occur in the basin, the extent was deemed minor. The USFWS observed 7 water withdrawal pumps in Subbasin #1 during their 1992 habitat inventory (Wampler et.al, 1993); these pumps were located upstream and downstream of the Town of Pe Ell and along Rock Creek between the towns of Walville and McCormick. In addition, the WDOE GIS layer of dams statewide was reviewed and no dams were noted in Subbasin #1.

Since land use was predominantly forestry with no significant trend toward urbanization, and only minor diversions were occurring in Subbasin #1, the flow records, without adjustments, were determined to be representative of "undepleted flows". Monthly flow exceedance values were generated based on the actual time series of mean daily streamflow at station #12-020000; the 50% and 90% exceedance values are listed in Table 3.2-1, along with WDOE base/instream flows for the Chehalis River near Doty control point, coincident with the gage location.

Table 3.2-1. Subbasin #1: Chehalis River Headwaters Flow Exceedance Values

Month	Flow Exceedance Values[1] Chehalis River near Doty, 12-020000				WDOE 1975 Base/Instream flow[2]	
	50% Exceedance (cfs)	50% URO[3] cfs/mi^2	90% Exceedance (cfs)	90% URO[3] cfs/mi^2	1st-14th (cfs)	15th- month end (cfs)
October	117	1.04	29	0.26	39	49
November	530	4.69	123	1.09	88	150
December	808	7.15	292	2.58	260	260
January	768	6.80	259	2.29	260	260
February	760	6.73	309	2.73	260	260
March	613	5.42	272	2.41	260	260
April	421	3.73	219	1.94	260	260
May	212	1.88	122	1.08	195	146
June	113	1.00	69	0.61	108	82
July	60	0.53	37	0.33	62	46
August	38	0.34	26	0.23	37	31
September	40	0.35	24	0.21	31	31

[1] Based on daily data from USGS Chehalis R near Doty station 12-020000; 1939-98; drainage area 113 mi^2
[2] WAC 173-522-020
[3] URO = unit runoff

3.2.3 WATER RIGHTS & WATER USE

Initially, a total of 48 water rights were tabulated in this subbasin; 47 surface water rights, of which two were permits and two were applications. The remaining right was a ground water certificate. The instantaneous amount of water allocated totals 12.47 cfs, with the two largest water rights designated for hydropower and municipal use. The hydropower right was the most senior right listed in the subbasin with a priority date of January 21, 1931.

Of the total allocated amount, 36% was designated for non-consumptive beneficial uses, such as hydropower and fish and wildlife propagation. Irrigation rights represented nearly 44% of the consumptive rights (28% of the total allocation) totaling 3.48 cfs. The associated annual volume limit of 223 acre-feet for irrigation was tabulated, however not all irrigation rights had volume limit entries in the Water Rights Allocation Tracking System (WRATS) database. Of the 375 acres classified for irrigation, 229.5 acres had no associated volume limit (61% of the total acres).

The most junior certificate in this subbasin held a priority date of April 6, 1982; two applications and one permit were junior to this right. The certificates senior to the 1975 base/instream flow represented 12.41 cfs.

The number of registered claims totaled 103; 67 were ground water claims and 35 were surface water claims. One claim was for both surface and ground water abstractions. The majority of these were primarily designated for general domestic use; eight claims have been filed for irrigation rights totaling 158 acres. Many of the claims also listed stock and irrigation as secondary and tertiary beneficial uses.

Table 3.2-2. Subbasin #1: Chehalis River Headwaters
Initial Water Rights Summary by Primary Purpose[1]

Primary Purpose (# rights)	Allocated Amount (cfs)	Volume Limit (acre-feet)	Irrigated Acres
Consumptive Uses			
Commercial/Industrial (1)	0.04	7.7	0
Domestic Use (8)	0.14	13.7	0
Irrigation (24)	3.48	194.4	330
Municipal (4)	3.84[2]	412	0
Stock (7)	0.44	55.5	40
Subtotal	**7.94**	**683.3**	**370**
Non-Consumptive Uses			
Hydropower (2)	4.01	1	0
Fish & Wildlife Propagation (2)	0.52	0	0
Subtotal	**4.53**	**1**	**0**
TOTAL	**12.47**	**272.3**	**370**

(Includes Certificates, Permits, and Applications)
[1]Envirovision and Watershed Professionals Network assume no responsibility for the accuracy of the data provided by the Washington State Department of Ecology.
[2]Town of PeEll Water System Plan indicated that 0.5 cfs for one of the municipal rights will be certificated when 2 rights for 1.34 cfs are relinquished, resulting 2.5 cfs for Town of PeEll.

Residential and Municipal Water Use

The Washington State Department of Health (WDOH) public water system data was obtained in September 1999. Two public water systems were identified in Subbasin #1 from this database; the Town of Pe Ell and a church. WDOH (1999) information for the Town of Pe Ell indicated there were 360 connections serving 600 people and 17 commercial customers.

The Town of Pe Ell held all the municipal water rights in this subbasin (totaling 3.84 cfs). According to the Water System Plan for the Town of Pe Ell (Summers, 1997), the total 1996 water demand, including losses, was 255,100 gallons per day (~0.4 cfs). The water demand for the 22 commercial connections within the municipality was roughly 0.01 cfs, and for the residential customers, the demand was 0.10 cfs. Water losses accounted for 73% of the withdrawals (27% efficiency), or 187,158 gallons per day (0.29 cfs). Future water conservation measures were anticipated to increase the system efficiency to 80% (reduce the water losses to 20% of the total demand), a more reasonable system efficiency than that experienced in 1996.

The investigation into the 3.84 cfs in municipal rights revealed interesting detail. One of the rights that Pe Ell held was a permit for 0.5 cfs that was issued on July 2, 1991. This permit gave the Town of Pe Ell the right to divert Chehalis River water (priority date - 1934) with the condition that two supplemental rights on Crim and Mahaffey Creeks totaling 1.34 cfs be relinquished, since the intakes were never constructed. The WRATS database did not reflect the potential relinquishment of these rights. In essence, the effective municipal rights totaled 2.5 cfs with seasonal restrictions. Under the remaining right for 2 cfs, diversion of water was restricted from May through October. Thus, the new 0.5 cfs right constituted the sole legal entitlement to divert water in the dry season of the year. The 0.5 cfs amount, while less than the relinquished 1.34 cfs, was still higher than the average current withdrawal of 0.4 cfs. Anticipating increased system efficiencies, future withdrawals were projected to be 0.15 cfs by the year 2003.

The census data indicated the population of this subbasin was approximately 1,316 people in 1990. Using the Lewis County 17% average projected increase in growth from 1990 to the year 2000, the current population was estimated at 1,540. Subtracting those served by the Town of Pe Ell resulted in a total of 940 self-supplied water users. According to the WRATS database, there were eight rights designated for single domestic use and three rights listed as multiple domestic use, although the latter were not listed as the primary beneficial use. In this subbasin, WDOE assigned a rate of 0.01 cfs or 0.02 cfs, and a volume limit typically of 0.5 to 1 acre foot to a single domestic water right. The multiple domestic rights had a combined rate of 0.06 cfs, a portion of which was allocated for irrigation and/or stock watering. For purposes of this analysis, the total amount was assumed to be for domestic use. To estimate the number of households potentially served by these three rights, the rate of 0.02 cfs per household was used as recommended by WDOE (Fisher, C. Pers. Comm.). The multiple rights were assumed to serve roughly 3 homes. For the 8 single domestic rights, one water right was assumed to provide a supply to one household. Adding these to the 3 homes under the multiple domestic rights, resulted in 11 households, or 29 people (assuming 2.6 people/household), withdrawing water under a legal entitlement. The remaining 911 people were either covered under a claim or an exempt well. Using the average of 79 gallons per capita per day (gcd) (as computed for the Town of Pe Ell [Summers, 1997]), an estimated 0.11 cfs of water was used for domestic purposes under either a claim or an exempt well. For comparison, using the WDOH (1999) method for determining the daily water demand per residential unit and the Lewis County data for the number of people per household, the estimated water demand was 118 gcd (assuming most of the population resided in the area in which precipitation was about 75 inches); the 911 people would use an estimated 0.17 cfs for domestic supply.

Based on the WDOH method, the total current population of 1,540 required about 0.28 cfs or about 11% of the allocated water under the municipal and domestic water rights (using the amount of 2.5 cfs for the Town of Pe Ell). In other words, the allocation exceeds the estimated actual water use by 89%.

Commercial and Industrial Water Use

In addition to the 17 commercial connections identified within the Pe Ell water service area, there was one water right held by Weyerhaeuser for commercial and industrial purposes. This right was for 20 gpm or 7.7 acre feet. Weyerhaeuser was also supplied water from the Town of Pe Ell (Gibbs & Olson, 1997). The remaining 16 connections could be serving all or a portion of the 50 parcels categorized in the Lewis County Assessor's database as retail or service. It is possible that some of the parcels were served by wells with claims or without the benefit of a water right. Exempt wells can use up to 5000 gallons per day for industrial water; however, there is no provision for commercial use of exempt wells listed in the Revised Code of Washington (RCW).

Irrigation

Irrigation rights represented nearly 44% of the consumptive rights (3.48 cfs), with a volume limit of 250 acre-feet. Under these existing water rights, 370 acres of land can legally be irrigated. The computation of irrigation water requirements involves estimating crop consumptive use, effective precipitation, conveyance losses, and on-farm efficiencies.

At this Level 1 assessment, there were insufficient data to estimate the actual water use for irrigated croplands; the actual number of irrigated acres was unknown. It was possible, however, to examine the crop water requirements for the water righted acreage using regional climatic data and estimating efficiencies. Pasture/turf was used in this analysis since the crop water requirement was higher than most other crops grown in this area resulting in a higher estimate of the water use impact on the streamflows. This approach established an upper bound by assuming all the water-righted acres were currently irrigated.

The estimated average annual precipitation over Subbasin #1 was 89 inches (WDNR, 1991). Most of the irrigated lands likely occur at the lower end of the subbasin where the precipitation is less, on the order of 75 inches. By proximity, Centralia is relatively close to subbasin #1; however, the average annual precipitation at the Centralia climate station was only 46 inches. Since the precipitation in Subbasin #1 was substantially higher than at Centralia, the data from the Aberdeen climate station, mean annual precipitation 83 inches, was used to examine the crop consumptive use for subbasin #1.

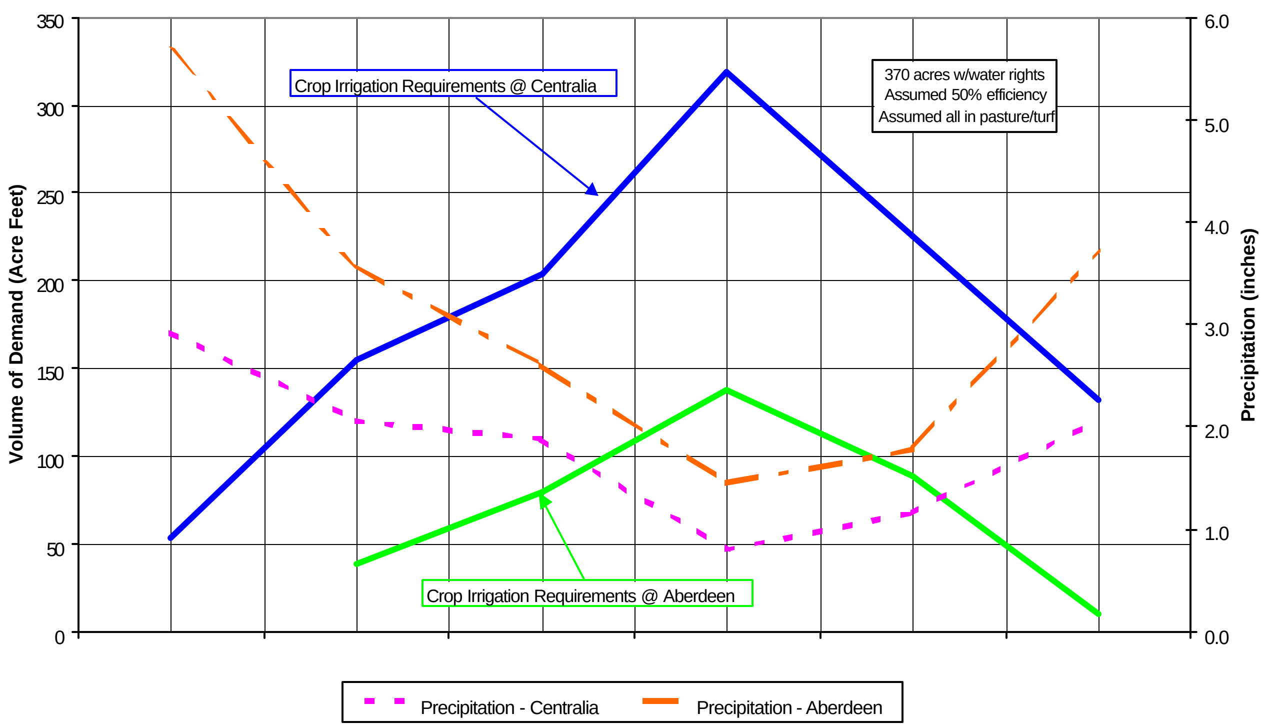

Figure 3.2-2. Subbasin #1: Chehalis River Headwaters Monthly Irrigation Water Demand For Pasture/ Turf

Source: WSU Cooperative Extension, *Irrigation Requirements for Washington – Estimates and Methodology*. Education Bulletin #1513

Figure 3.2-2 demonstrates the difference in crop irrigation requirements for the different precipitation amounts at Centralia and Aberdeen, assuming 370 acres pasture/turf irrigated with an efficiency of 50% (Bainbridge, R. Pers. Comm.). Over the irrigation season (from April or May to September), the total volume (area under the curve) of irrigation water demand using the Aberdeen climate data (424 acre feet) was closer to the volume limit (250 acre feet) associated with the irrigation rights than the Centralia climate data (1,088 acre feet). Note, however, that the annual volume limit tallied from the WRATS database did not include a value for all rights and, therefore, does not account for the total volume of irrigation water that has been allocated.

Comparison of Streamflow and Allocated Water

Figure 3.2-3 compares the flows (50% and 90% exceedance) with the instream flows and the total allocated water for consumptive uses. In addition, the graph includes a line depicting the combined instream flow plus the instantaneous water right allocation (adjusted for the restrictions specified in the new permit issued to the Town of Pe Ell).

The 50% exceedance flow, or median flow, ranged from a low of 38 cfs in August to a high of 808 cfs in December. This means that, in August, 50% of the flows were higher than 38 cfs and the other half of the flows were less than 38 cfs. The 90% exceedance flows were lowest in September and highest in February, i.e. 90% of the flows were 24 cfs or greater and 309 cfs or greater, respectively. The instream flows used on this graph represent the average of the bimonthly base/instream flow values. The monthly average of the instream flows are lowest in August (34 cfs) September (31 cfs) and October (44 cfs).

Examining flows in August,

50% Exceedance Streamflow	= 38 cfs
90% Exceedance Streamflow	= 26 cfs
Instream Flow	= 34 cfs
Instantaneous Water Right Allocation for all consumptive uses (adjusted for the Town of Pe Ell 1991 permit)	= 6.60 cfs

While the water right allocation for human uses was a seemingly small amount of water, in most months streamflows were insufficient in this subbasin to supply all the needs for the fisheries resource as well as allow the full allocation of water for human uses. The 6.60 cfs total allocated amounts for consumptive uses includes both surface water and ground water abstractions and represented about 17% and 25% of the August median and 90% exceedance flows, respectively. Comparing the total of the surface and ground water allocated amounts to the streamflow painted the worst-case scenario because 100% hydraulic continuity was assumed. In this basin, however, there was only one ground water right so the totals were not too overstated.

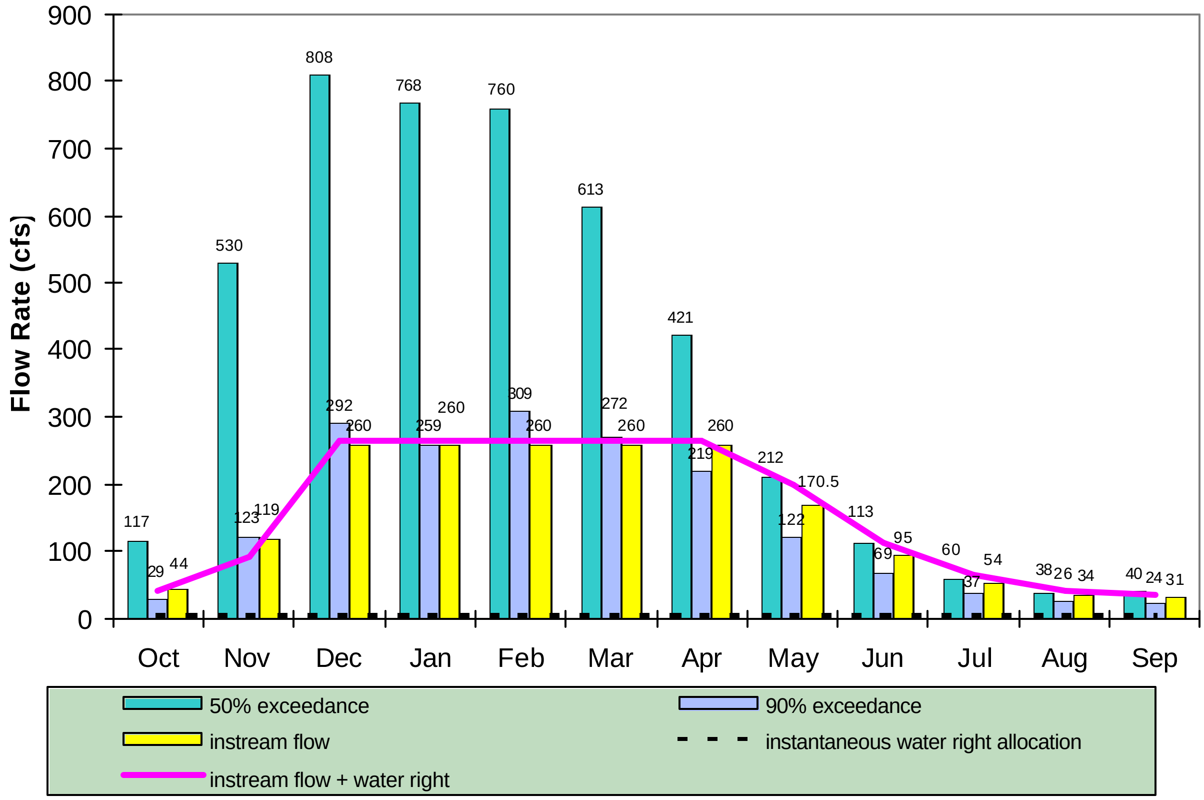

Figure 3.2-3. Subbasin #1: Chehalis River Headwaters
Comparison of Streamflow and Allocated Water

The flows at the 90% exceedance level were greater than the instream flows in November, December, February, and March. The instream flows were within 10% of the median flows (50% exceedance level) in the months of May, June, July, August, and September. In the absence of any withdrawals of water for human use, the 50% exceedance flows were insufficient to meet instream flow in 5 months of the year.

The consumptive portion of the allocated rights was about 25% to 28% of the two lowest monthly 90% exceedance flows. If half of the water were returned to the system, the effective consumptive portion of these rights would then be 12% to 14% of these same two low flows. (Note: A return flow of 50% is not uncommon for irrigation rights, but would be considered low for domestic/municipal rights which have return flows closer to 70%.) Given that streamflow measurements are usually accurate to within 10% of the true value of the flow, up to 4% could be conserved and "measured" in this subbasin. Due to this, the potential for streamflow enhancement by changing withdrawals/diversion patterns was determined to be limited in this subbasin compared to some of the other subbasins described in later sections.

Table 3.2-3.
Summary Comparison of Water Rights and Water Use for Chehalis Headwaters.

Beneficial Use	Estimated Current Water Use (cfs)	Water Rights Allocation (cfs)
Domestic (water rights)	0.003 - 0.005	0.14
Domestic (exempt wells)	0.11 - 0.17	3.5 [2]
Municipal	0.4	2.5
Commercial/Industrial	Unknown	0.04
Irrigation	~424 acre feet[1]	250 acre feet

[1] Based on 370 legally irrigated acres of pasture/turf
[2]Exempt wells are entitled to withdraw up to 5000 gpd or ~0.01 cfs. There were roughly 350 homes being served by exempt wells or 350*0.01 cfs = 3.5 cfs.

Summary of Water Allocation for Chehalis Headwaters

- Domestic use, as defined by with water rights, represents 4% of the water rights allocation.
- Municipal water use is 16 % of the water rights allocation.
- Irrigation of the acreage allotment under existing rights may require a higher annual volume than currently allocated. However, not all irrigation rights had annual volumes associated with them.
- Consumptive rights were 25 to 28 % of the lowest median monthly streamflows.
- An estimated 4 % could be conserved on "paper", therefore, the potential for flow enhancement is limited
- This is not a high priority subbasin for further analysis.

3.2.4 WATER QUALITY

Since a long-term ambient monitoring station is located in this subbasin, the water quality data record is very good. Although there have been occasional high temperatures measured, water quality is not considered to be in violation of any standards, and there are no 303(d) listings. However, the wet season TSS yield was the highest calculated, and close to three times higher than in other locations on the mainstem. TP and IN yields were near average.

3.2.5 FISH HABITAT/CHANNEL MODIFICATIONS/STOCKS

Fish Habitat

The United States Department of Fish and Wildlife (USFWS) and the Washington State Department of Fish and Wildlife (WDFW) have completed two fish habitat surveys within this subbasin: A total of 28 stream miles were surveyed in *"Upper Chehalis"* subbasin. In this case, the Upper Chehalis included the upper Chehalis mainstem, upstream of the Rogers Creek confluence, the East and West Forks, and Thrash and Cinnabar Creeks. The most important problems identified were: stream canopy and streambank vegetation loss from forest practices (8 points and 13.9 miles) (West Fork, East Fork, and mainstem Chehalis), bank erosion (56 points and 7.8 miles) (Cinnabar Creek, EF Chehalis River), and debris torrent inputs to stream channels

(6 points). Few beaver dams were found at the time of the survey. Three water withdrawals were noted (Wampler et al., 1993).

A total of 42 miles were surveyed in "*Crim-Rock*" subbasin, which included the mainstem Chehalis from Rogers Creek downstream to Rainbow Falls, Crim, Big, Rock, and McCormick Creeks. The most important problems identified were: bank erosion (124 points and 19.6 miles) (lower Chehalis, McCormick Creek, Rock Creek, upper Crim Creek), streamside vegetation loss from agriculture and unknown causes (39 points and 12.1 miles) (lower Chehalis River, lower Rock Creek, lower McCormick Creek, mid-Crim Creek), and streamside canopy reduction from forest practices (7 points and 6.3 miles) (Crim Creek, Big Creek, upper Chehalis River). Beaver dams were noted in upper Rock and McCormick Creeks. A total of ten water withdrawals were noted as well as 3 miscellaneous pollution input sources (Wampler et al., 1993).

A portion of this subbasin was included in the *Chehalis Headwaters Watershed Analysis* (Weyerhaeuser, 1994). The analysis area included 44,920 acres in the Chehalis River headwaters, upstream of the Town of Pe Ell (Weyerhaeuser Co. 1994). Prior to 1930, splash dams were operated on the mainstem Chehalis above Fisk Falls, and below Crim Creek (Wendler and Deschamps, 1955). Between the 1960's and the 1970's, stream-cleaning operations removed Large Woody Debris (LWD) from most of the larger streams in this subbasin, except Cinnabar Creek (Weyerhaeuser Co., 1994).

Habitat concerns identified in the watershed analysis include the potential for warm summer temperatures to create adverse conditions for holding spring chinook in the mainstem Chehalis, as well as the potential for legal and illegal fishing to reduce numbers of adult chinook in the same reach, waiting to spawn. Warm summer temperatures also reduce the quality of summer rearing habitat for juvenile fish. Nearly half of the stream channels (47%) had canopy closures lower than that estimated to protect water temperature, including all of the mainstem Chehalis River, and portions of the East Fork, West Fork, and reaches of Crim, Thrash, and Cinnabar Creeks. The lower mainstem is wide enough to limit the degree to which riparian canopy can contribute to thermal reduction.

Riparian conditions were fairly good over most of the watershed, with mature, dense stands of mixed conifers and hardwoods present over much of the basin. At this time, tree sizes along some of the larger streams are too small to function effectively as LWD, although, long-term prospects are good. There is a general lack of in-channel LWD in this subbasin, which limits refuge habitat, holding pool frequency, and depth. This was identified as a problem in areas used by chinook as well as in areas used by coho and steelhead (Weyerhaeuser Co., 1994).

Channel Modifications

The subbasin has a long history of commercial timber harvest by both railroad and truck systems. Channel impacts associated with these activities included splash dams operated prior to 1930 on the mainstem Chehalis above Fisk Falls, and below Crim Creek. In addition, stream-cleaning operations during the 1960's and the 1970's removed large woody debris (LWD) from most of the larger streams in this subbasin, except Cinnabar Creek (Weyerhaeuser, 1994).

Since that time, the number of activities directly altering channel form has been reduced. Current activities, which affect channel form, revolve around loss of riparian vegetation and channel armoring. USFWS/WDFW extensive surveys indicate that of 70 miles of channel surveyed, roughly 31 percent of the surveyed reach had a reduction in riparian canopy density associated with logging. Approximately 39 percent of the reach length surveyed exhibited erosion, and 3,800 feet of bank protection/riprap were observed. Approximately 3% of stream channel surveyed showed bank vegetation removal associated with agricultural activities, and an additional 19% of stream channel was reported with bank vegetation removal from unknown causes. Livestock had access to about 6 percent of the surveyed channel length (Wampler et al., 1993).

Approximately 4.7 miles of channel were evaluated on the 1990 orthophotos. Assessment of channel conditions included the urban/agricultural areas along the mainstem from 2 miles above Pe Ell to about 2 miles downstream from Pe Ell. The channel is bound by low hills on the west and level agricultural fields and town on the east. Table 3.2-4 presents the results of assessment of riparian conditions along this section of the river.

Table 3.2-4
Aerial photo evaluation of riparian disturbance for portions of 5 subbasins.

Subbasin	Channel distance evaluated (mi)	Riparian area intact (%)	Riparian area altered (%)	Riparian area absent (%)
Upper Chehalis-1	4.7	31	66	3
South Fork Newaukum-7	24.8	24	50	26
Cloquallum-Wildcat Creek-14	7	17	71	12
Middle Chehalis River-19	13.6	9	45	28
Humptulips River- 25	9.9	36	55	9

As expected, riparian conditions on the right or east bank have been more severely affected by land use activities. In the area photo evaluated, 98 percent of the right bank possessed an altered riparian zone that commonly consists of a one to three tree wide strip. Clumps of trees, as well as barren areas, are also scattered in the reach assessed. The strip is often bordered by pasture, although the Town of Pe Ell borders approximately 3,000 feet of altered riparian zone.

Bank protection efforts in the Town of Pe Ell exist, but their extent cannot be determined from the photos. Spot bank protection within the town was noted in the USFWS/WDFW data summaries (Wampler et al., 1993). Two bridges cross the river in the area assessed, but they are both located in straight reaches and are not likely to have a significant affect on channel morphology.

Fish Stocks

Detailed information of the fish stocks within the Chehalis headwaters subbasin is not available. General information of the fish stocks within the entire Chehalis watershed can be found in Appendix D: Technical Report for Fish Habitat/ Channel Modifications/ Stocks.

3.3 SUBBASIN 7: LOWER NEWAUKUM RIVER

For purposes of examining water use, water allocation and comparing to streamflow, data from the two upstream subbasins #5, South Fork Newaukum, and #6, North Fork Newaukum, were included in this subbasin discussion.

3.3.1 GENERAL DESCRIPTION

The Newaukum River subbasin encompasses nearly 156 mi^2 from steep hills, up to 3,800 feet, and narrow valleys down to its confluence with the Chehalis River at 160 feet. The mean basin elevation is 960 feet. Mean annual precipitation is 52 inches over the three subbasins (WDNR, 1991). Mean annual discharge, measured at the USGS streamflow gage #12-025000, Newaukum River, was 502 cfs. This translated into a unit runoff of approximately 5 cfs/mi^2; winter unit runoff averaged 8 cfs/mi^2, while summer unit runoff was approximately 1 cfs/mi^2. The primary land use for this subbasin was forestry; the secondary uses of agriculture (17%) and residential (1%) occurred along the river valley (Figure 3.3-1) (WDNR, 1990).

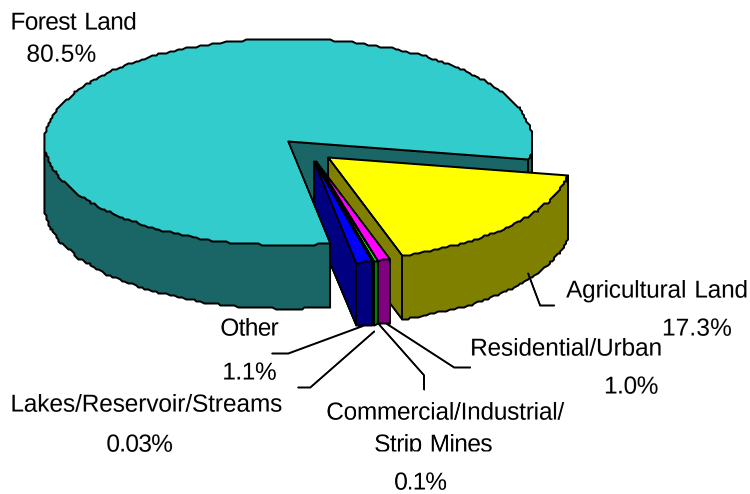

Figure 3.3-1. Subbasin #5, 6, &7: Newaukum River Land Use/Land Cover Summary
Source: WDNR, 1990

3.3.2 GEOLOGY AND HYDROLOGY

Geology

The majority of the basin is underlain by glacial outwash from pre-Fraser glaciations (Logan Hill formation). This formation can exceed 150 feet in depth. Significant deposits of recent alluvium exist in the valley bottom of the South Fork. The depth of these deposits decreases with distance upstream.

Ground Water Hydrology

The Logan Hill formation can hold significant amounts of groundwater, usually under confined conditions in the lower portions of the formation. It is generally not considered a surface aquifer (Garrigues et al., 1998). The aquifer associated with valley alluvial material is within 30 feet of the ground surface.

Surface Water Hydrology

The Newaukum River has been gaged in three locations: South Fork Newaukum River near Onalaska (12024000; 1944-49 and 1957-72), North Fork Newaukum River near Forest (12024500; 1961-66), and Newaukum River mainstem (12025000; 1929-31, 1942-81, and 1983-98) 4.1 miles upstream from its confluence with the Chehalis River. Prior to using these streamflow records to generate summary statistics, two factors were investigated: 1) climate variability over the period of record, and 2) the extent of upstream regulation and abstraction of water.

The mainstem Newaukum gage is located in Subbasin #7 and covers a longer period of record (1942-81 and 1983-98) than the gages on the forks. This period included 28 years for which the flows were above the long-term annual average and 27 years with below normal flows, based on a trend analysis of the longer record at the Satsop near Satsop gage (1929-98). In addition, the 1942-1998 period included almost equal years within each type of Pacific Decadal Oscillation phase (warm/dry, cool/wet). Therefore, the available streamflow data reflected the natural climate variability experienced in this region.

Since the early 1900's, the Cities of Chehalis and Centralia have diverted water from the North Fork Newaukum for municipal supply. Several sources noted municipal diversions in the Newaukum River system [USGS station remarks, WDOE (Sinclair and Pitz, 1999), and the Chehalis River Basin Action plan (Lewis County Conservation District, 1992)], however, the reported amount varied (5cfs, 7cfs, and 15cfs) among sources. Based on discussion with staff from both the City of Chehalis (Petrie, M. Pers. Comm.) and the City of Centralia (Clary, T. Pers. Comm.), and the 1997 Water System Plan (page II-2) for the City of Chehalis (Chehalis Public Works Department, 1997), the following information was ascertained:

Table 3.3-1
Entities Diverting Above Gage on Mainstem Newaukum River (Subbasin #7)

City	NF Newaukum River Withdrawal Amount	Effective Dates
City of Chehalis	3.31 MGD (3.1 cfs)[1]	1914/15 to present
City of Centralia	3.5 MGD (3.4 cfs)[2]	1920/25 to Sept 1993

[1]Capacity of the gravity line (without pumping) from the River
[2]Limited by maximum pipeline capacity

Both diversion structures are located approximately 100 feet apart on the North Fork Newaukum River. The Cities have not kept systematic records of the daily diversion amount, therefore, the assumption was made to set withdrawals equal to the current maximum pipe capacity. This blanket assumption masks several cases, including periods when: 1) the pipelines may have been reconfigured, 2) the Cities have not diverted to the maximum pipe capacity, or 3) the river was too low to withdraw the full pipe capacity; this detail was not accounted for at this level of analysis. Since September 1993, the City of Centralia has not used the North Fork Newaukum River for water supply but has relied entirely on production from the City's well fields (Clary, T. Pers. Comm.). In addition to the North Fork Newaukum River water source, the City of Chehalis has rights to use the Chehalis River as a supplemental source.

The WDOE GIS layer of dams in Washington identified one dam upstream of the gaging station in Sub-basin #7. This dam, located on Gheer Creek, a tributary to the South Fork Newaukum River near the Town of Onalaska, forms Carlisle Lake. The Washington Department of Wildlife (WDFW) built the dam in 1920 for recreational purposes. Neither the WDOE (Sinclair and Pitz, 1999) nor the USGS's station remarks noted regulation upstream of the Newaukum gage due to this dam. Beyond the municipal diversions previously discussed, both USGS's station remarks and WDOE (Sinclair and Pitz, 1999) rated the diversion degree as low. The USFWS cited 26 water withdrawal pumps and 3 suspected withdrawals during their 1992 habitat inventory (Wampler et. al., 1993). These pumps were primarily located along the mainstem and North Fork. The degree of settlement and the predominance of agricultural land usage along the Newaukum River Valley, however, lead to a concern regarding the cumulative effect of the minor diversions. This concern should lead to caution in the use of these flow numbers to represent "undepleted flow", particularly during summer irrigation months.

The daily streamflows recorded downstream of the diversions were adjusted by adding the municipal diversions (based on pipeline capacity) to the flows for the effective time periods noted above. For this Level 1 analysis, the Newaukum River flows and the addition of the easily quantifiable municipal diversions were assumed to be a first estimate of "undepleted flows". Monthly flow exceedance values were generated based on the deregulated daily flow values for this station; the 50%, and 90% exceedance values are listed in Table 3.3-2 along with the instream flows for the Newaukum River control point coincident with the gage location.

Table 3.3-2
Flow Exceedance Values for Subbasin #7

Month	Flow Exceedance Values[1] USGS Gage #12-025000, Newaukum River near Chehalis				WDOE 1975 Base / Instream flow	
	50% Exceedance (cfs)	50% URO[2] cfs/mi^2	90% Exceedance (cfs)	90% URO[2] cfs/mi^2	1st-14th (cfs)	15th to month end (cfs)
October	95	0.61	48	0.31	43	54
November	451	2.91	104	0.67	91	150
December	746	4.81	284	1.83	250	250
January	781	5.04	293	1.89	250	250
February	745	4.81	335	2.16	250	250
March	612	3.95	300	1.94	250	250
April	444	2.86	247	1.59	250	250
May	244	1.57	141	0.91	210	160
June	151	0.97	92	0.59	118	90
July	84	0.54	54	0.35	68	52
August	56	0.36	40	0.26	38	35
September	59	0.38	39	0.25	35	35

[1] Based on deregulation (municipal diversion added back in) of daily data from the USGS station #12-025000 Newaukum R near Chehalis; 1929-31,42-81,82-98; drainage area 155 mi^2
[2] URO = unit runoff

3.3.3 WATER RIGHTS & WATER USE

According to the WRATS database, 234 water rights have been issued in subbasins #5, 6, and 7. The majority of the rights on file were designated as surface water withdrawals. The largest and most senior surface water entitlement was a 10 cfs right for municipal and commercial purposes. The next largest was a 5 cfs right for fish propagation. The two largest ground water rights were both for 600 gpm or 1.3 cfs; commercial and fish propagation were the primary beneficial uses for these rights.

The total amount of allocated water was 86.43 cfs, of which about 18.27 cfs was non-consumptive. Over 60% of the consumptive portion of the allocation has been designated for irrigation purposes. A total of 4,972 acres were associated with the water rights in this subbasin. The 42.06 cfs of irrigation rights were associated with 3,988 acres for which irrigation was designated the primary beneficial use; 984 acres were associated with rights (both consumptive and non-consumptive) for which irrigation was listed as a secondary or tertiary use.

Table 3.3-3 Subbasins #5, 6, 7: Newaukum River Water Rights Summary by Primary Purpose[1]

Primary Purpose (#rights)	Allocated Amount (cfs)	Volume Limit (acre feet)	Irrigated Land Acres
Consumptive Uses			
Commercial/Industrial (3)	1.90	213	0
Domestic (31)	2.42	303	0
Irrigation (143)	42.06	5215	3988
Municipal (7)	11.75	210	20
Stock (34)	10.03	1103	934
Subtotal	**68.16**	**7,044**	**4,942**
Non-Consumptive Uses			
Hydropower (1)	0.07	0	1
Recreation (3)	0.41	11	5
Fish & Wildlife Propagation (12)	17.79	2963	24.5
Subtotal	**18.27**	**2,974**	**30.5**
TOTAL	**86.43**	**10,018**	**4972.5**

(Includes Certificates, Permits, and Applications)
[1]Envirovision and Watershed Professionals Network assume no responsibility for the accuracy of the data provided by the Washington Department of Ecology.

There were also 789 registered claims, most of which were assigned general domestic use from wells. Of the 718 ground water claims, 168 pre-date the 1945 ground water code; 11 of the 76 surface water claims pre-date the 1917 surface water code. However, 227 claims had no priority date listed in the database.

Residential and Municipal Water Use

There were 48 water systems that had points of diversion within the subbasin boundaries serving a total of 22,259. The two largest systems were the City of Centralia, which serves 14,000 people, and the City of Chehalis, which serves 7,100 people; Centralia is located entirely outside of this subbasin and the majority of the residential areas of Chehalis are outside the boundary. There was one water right in the database in the name of the City of Chehalis for 10 cfs. The other six municipal rights were held by Thurston County, Town of Napavine, or Lewis County Water District #2. The City of Centralia did not appear to have a water right in this subbasin, however, Centralia's point of withdrawal on the WDOH database was listed in the subbasin, probably coinciding with a common law claim (dated 1912) for 4.8 mgd (7.44 cfs) from the NF Newaukum River (Summers, 1997). Under the City of Centralia in the WRATS database, one permit listed has been cancelled and one application has been rejected.

A small portion of Chehalis lies within Subbasin #7 but the majority lies within subbasins 8, 9, and 10. The Town of Napavine straddles subbasin 7 and 4, yet the point of diversion has been located in subbasin 4; Napavine supplies a population of 1,240.

The 1990 census data reported in the Chehalis Basin Action Plan (Lewis Conservation District, 1992) notes a population of about 10,000 living within the Newaukum River basin. Assuming the same anticipated average growth of 17% as in the rest of Lewis County (Census Data), the 2000 population should be about 11,700. Census data for 1990 obtained digitally from the Census Bureau was overlain with the subbasin boundaries and a substantially lower population of 6,240 was calculated for the Newaukum (the year 2000 estimate was 7,300). At this level of analysis, the conflict in the different data sources was not resolved. For 11,700 people, an estimate of demand, based on annual precipitation (WDOH, 1999) and assuming 2.6 people per household (Lewis County data), was calculated at 136 gcd or a total of 2.47 cfs. For 7,300 people, the demand was estimated at 1.54 cfs.

Estimating the population served by exempt wells in this subbasin was not attainable since there were 19 water rights for multiple domestic use and 46 public water systems which would need to be examined in detail to determine if any of the multiple rights were not associated with a public water system and, therefore, self-supplied. Instead, an estimate was determined of the number of self- supplied water users that either have an exempt well or may be under a multiple domestic right in subbasins 5, 6, and 7. The population supplied by public water systems and those under single domestic water rights were subtracted from the general population data. As mentioned previously, assumptions on public water system service area were made. It was assumed that all the connections for both the City of Centralia and Chehalis water systems were outside of the Newaukum River subbasin leaving an estimated 1,159 people in the basin served by small public water systems (with points of diversion within the subbasin). In addition, it was assumed that the service area for the 1,240 people served by one public water system (Town of Napavine) was within the subbasin boundary, even though the point of diversion was located outside the subbasin. Subtracting the public water system numbers from the 11,700 general population number resulted in roughly 9,300 people residing in the subbasin that either must have water rights or were using wells under the exempt status. There were 12 single domestic rights serving approximately 31 people. Subtracting from the 9,300 self supplied water users resulted in 9,269 people self-supplied under a multiple domestic right or under an exempt well. Based on the 136 gcd, this population would use approximately 1.95 cfs.

For purposes of comparison, this was bracketed by using the population of 7,300 obtained directly from the GIS census data. The latter resulted in 7,269 (~1.5 cfs). These estimates of use were based on residential water use and not on small non-commercial farms that have higher water use. Assuming all the withdrawals were hydraulically connected to the river system, exempt wells and the population that may be under multiple domestic rights in the Newaukum subbasin appeared to be cumulatively withdrawing less than 7% of the 90% exceedance flow and 5% of the median flow in September. The total residential demand in the basin was estimated between 1.5 cfs to 2.5 cfs, the latter of which was about 3% of the total allocated water and about 18% of the water allocated for municipal and domestic use.

Commercial/Industrial

There were three water rights designated specifically for commercial and industrial use for which the allocated amount was 1.9 cfs with a volume limit of 213 acre-feet/year. An additional two rights listed commercial/industrial as a secondary use; the allocated amount was 0.43 cfs and 20.5 acre-feet annual limit. There were also 92 commercial/industrial connections served by public water systems, and 114 parcels with a designated land use code for commercial/industrial purposes. These two data sources compared favorably. It was possible that one non-residential public water system connection was supplying water to more than one commercial/industrial parcel.

Irrigation

A total of 4,972 acres for potential irrigation were covered under 173 water rights in this subbasin. The volume limit of supply was 6,384 acre-feet, not all of which was allocated for these acres; some rights had other beneficial uses. In addition, 57 water rights listed no annual volume limitation. There were 1,100 parcels designated agricultural use in the Lewis County assessor's database covering about 14,263 acres of which roughly 24% were classified as "not cultivated." The WDNR reported 17,217 acres in agricultural use, for a difference of more than 20% compared to the assessor's information. According to the Lewis County Conservation District (Bainbridge, Rich, Pers. Comm.), peas and corn used to be grown in this basin, but the cannery will not be processing these crops after 2000. Most of the current irrigated land is now in pasture with efficiencies at 50% or lower (Bainbridge, Rich, Pers. Comm.). The number of acres that were actually being irrigated within this subbasin was unknown.

Assuming all 4,972 acres were irrigated in pasture/turf (the highest use), and using the climate and crop consumptive use data from Centralia, Washington, the total crop water demand was estimated at 14,629 acre feet at an efficiency of 50% (Figure 3.3-2). This was nearly 230% higher than the 6,384 acre-feet volume associated with the water rights. The assumption was that all irrigated acres in pasture resulted in an over-allocation of the volume limit. To keep within the legal annual volume limits of the water rights, a portion of the irrigated acres would have to be attributed to a crop type with significantly less consumptive use and/or better on-farm efficiencies than 50%.

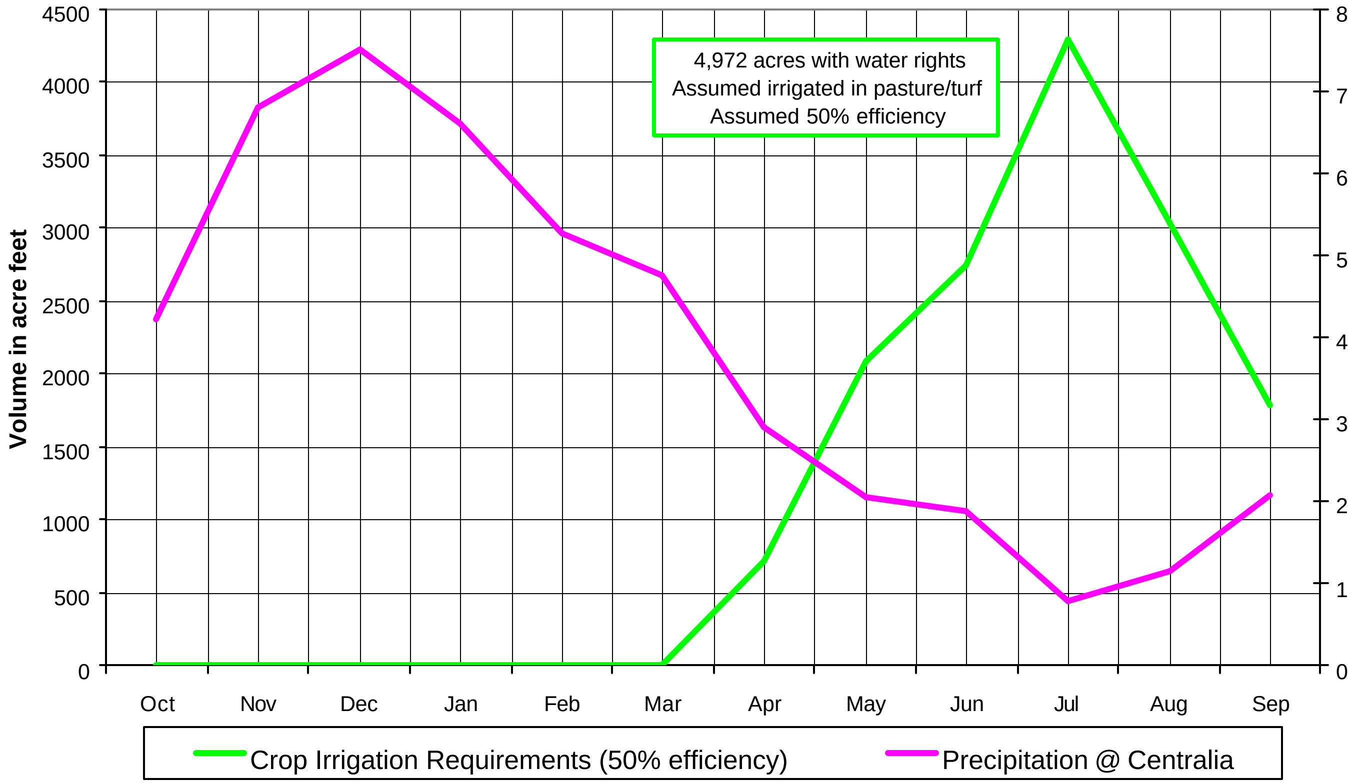

Figure 3.3-2. Subbasins #5, 6, and 7: Newaukum River Monthly Irrigation Water Demand

Source: WSU Cooperative Extension, *Irrigation Requirements for Washington – Estimates and Methodology*. Education Bulletin #1513

Actual irrigation water use probably is lower than the allocated amount. An intensive field and aerial photo survey would be required to determine this. The above exercise, while incorporating several assumptions, was intended to provide an overview of the potential seasonal distribution of irrigation water use.

Stock Watering

Based on farm plans from the NRCS (2000), there were approximately 830 dairy cows within this subbasin. The water needs for a dairy cow is about 20 gallons per day (WDOH, 1999), or 0.05 cfs for the 830 cows. The number of beef cattle was also estimated at 830 (NRCS, 2000). However, beef cattle use less water resulting in an estimated rate of ~.02 cfs. There were three large poultry farms in the Newaukum basin processing about 5 million chickens per year, resulting in an estimated use of .02 cfs. The number of other farm animals was not known. The total of these water uses was estimated at 0.09 cfs, which was less than 1% of the total allocated amount for stock watering. However, there were 934 acres that could be irrigated under the water rights listed for stock watering as a primary beneficial use.

Comparison of Streamflow and Allocated Water

Figure 3.3-3 is a comparison of flows (50% and 90% exceedance), instream flows, and the total allocated water for consumptive uses. In addition, the graph includes a line depicting the combined instream flow plus the instantaneous water right allocation.

The 50% exceedance flow or median flow ranged from a low of 56 cfs in August to a high of 781 cfs in January. This means that in September, 50% of the flows were higher than 56 cfs and the other half of the flows were less than 56 cfs. The 90% exceedance flows were lowest in September and highest in February, i.e. 90% of the daily flows were 39 cfs or greater and 335 cfs or greater, respectively. The instream flows used on this graph represent the average of the bimonthly base/instream flow values. The monthly average of the instream flows are lowest in August (36.5 cfs), September (35 cfs), and October (48.5 cfs).

Examining flows in September,

50% Exceedance Streamflow	= 59 cfs
90% Exceedance Streamflow	= 39 cfs
Instream Flow	= 35 cfs
Instantaneous Water Right Allocation for all consumptive uses	= 68.16 cfs

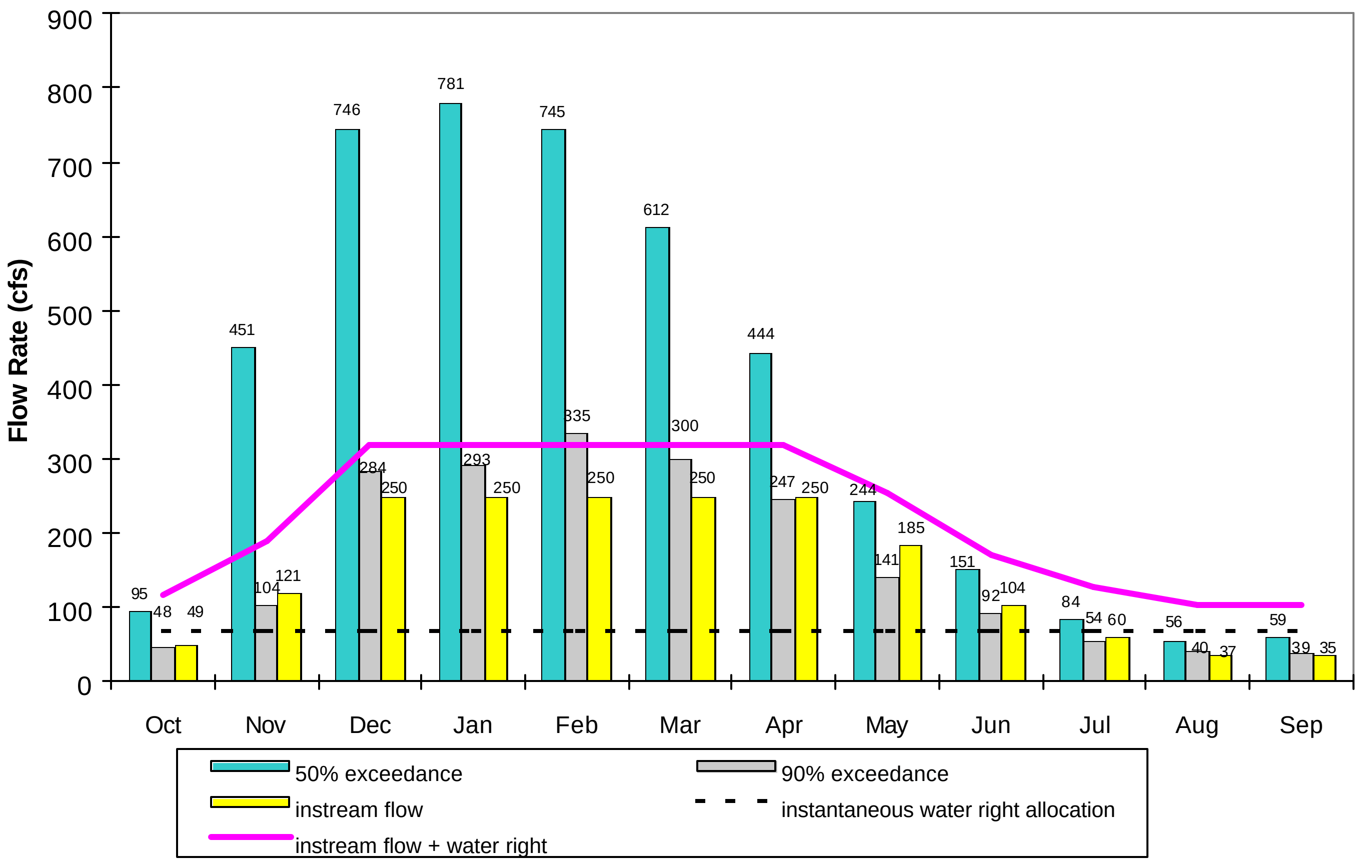

Figure 3.3-3. Subbasin #5, 6, & 7: Newaukum River Comparison of Streamflow and Allocated Water

Based on the median streamflows, this subbasin was over-allocated (combined water rights and instream flows) from May through October. At the 90% exceedance levels, the streamflows were insufficient to meet the water right allocation in four months of the year (July through October) with the maximum deficiency nearly 30 cfs. The combined instream flow and water rights allocation could only be supplied in one month (February) at the 90% exceedance level.

In the absence of water withdrawals/diversions, the deregulated flows (adjusted by adding the municipal diversions) were sufficient to meet the instream flows at the 50% exceedance levels throughout the year. At the 90% exceedance level, instream flows could not be met four months of the year and were very close in another four months.

The 68.16 cfs total allocated amounts for consumptive uses included both surface water and ground water abstractions. Direct comparison of the total allocated amounts to the streamflow represented the "worst case" scenario because 100% hydraulic continuity was assumed. Withdrawals under the 81 ground water rights in this basin would impact the flows in the Newaukum River to differing degrees dependent on depth of well, distance from the stream, and geology.

The consumptive portion of the allocated rights was over 120% of the lowest median streamflow. If half of the water were returned to the system, the effective consumptive portion of these rights would then be 60% of the lowest median flow. (Note: Return flows of 50% is not uncommon for irrigation rights, but would be considered low for domestic/municipal rights for which return flows are closer to 75%). The potential for streamflow enhancement exists in this basin since the water right allocation was substantial (45% to 121% of the median flows between June and October). A detailed mapping of the water rights to determine the rights actually being used and those that have been retired would bring the water rights allocation closer to the actual water use in the subbasin. In addition, an in-depth analysis of the ground water would help to determine the extent of the ground water right impacts on streamflows.

Table 3.3-4.
Summary Comparison of Water Rights and Water Use for the Newaukum River.

Beneficial Use	Estimated Current Water Use (cfs)	Water Rights Allocation (cfs)
Domestic	1.54 to 1.96	2.42
Municipal	Unknown[1]	11.75
Commercial/Industrial	Unknown	1.90
Irrigation	>14,000 acre feet[2]	6,384 acre feet

[1]Due to out of basin transfers to Centralia and Chehalis and in-basin transfers from Napavine
2 Based on 4,972 legally irrigated acres in pasture/turf

Summary of Water Allocation for Newaukum River

- Domestic use is as much as 81% of the water rights allocation.
- Irrigation has the potential to be very high and exceed the allocation, depending on the type of crops grown.
- Irrigation demand estimates need improvement in a Level 2 analysis.

- Potential for "paper" improvement is high since water right allocation is high relative to streamflows (45 - 120 % of median flows from June through October).
- This subbasin needs detailed mapping of water rights, field verification, and better knowledge of groundwater impacts, i.e. hydraulic continuity.

3.3.4 WATER QUALITY

A fair data record exists for this subbasin. There is no long term ambient monitoring station, but there has been recent monitoring covering a full year with some upstream data for comparison. This subbasin has violated both temperature and fecal coliform standards, and thus is included in the 303(d) list for these parameters. Average annual yields for TP and TSS were the lowest calculated, but IN yield was the second highest in the Chehalis, and similar to the highest yield measured in a comparison study of Puget Sound basins.

3.3.5 FISH HABITAT/ CHANNEL MODIFICATIONS/ STOCKS

Fish Habitat

USFWS/WDFW extensive survey.

A total of 125 stream miles were surveyed for fish habitat conditions in the USFWS/WDFW "*Newaukum*" subbasin, which included Newaukum Creek; South Fork Newaukum, Lost, Kearney, Beaver, Bernier, and Frase Creeks; the Middle Fork Newaukum; the North Fork Newaukum, Lucas, and Mitchell Creeks. The most important habitat problems identified were:

- streamside vegetation loss from unknown causes (5 points and 42.9 miles)(Newaukum NF Newaukum, Lucas Creek, SF Newaukum),
- bank erosion (302 points and 28.8 miles) (Newaukum, MF Newaukum, NF Newaukum, SF Newaukum),
- stream canopy reduction and bank vegetation loss from forest practices (28 points and 17.23 miles) (upper NF Newaukum tributaries, Lucas Creek, SF Newaukum tributaries), and
- bank vegetation reduction and other damage from livestock (78 points and 13.9 miles) (SF Newaukum tributaries, MF Newaukum, lower North Fork Newaukum, Allen Creek).

Beaver dams were noted in Lucas Creek, portions of the middle Fork, and in some South Fork tributaries, but were not common in other subbasin streams at the time of the survey. A total of 33 known or suspected water withdrawals were noted, as well as 11 miscellaneous pollution input sources (Wampler et al., 1993).

A portion of this subbasin was included in ***The Upper North Fork and Upper South Fork Newaukum Watershed Analysis:*** (Weyerhaeuser Co, 1999). Analysis area included: the upper North Fork and upper South Fork Newaukum Rivers (50,235 acres). Low amounts of in-channel LWD were noted, primarily due to past management practices. Current shading levels were found to be on target for protection of water temperatures, except for the agricultural areas in the lower North Fork subbasin. Thirteen potential fish passage barriers at culverts were identified, as well as natural passage barriers in steeper sections of the main stems and their tributaries. Lack of in-channel LWD in some stream reaches has produced lowered pool depths and frequency, and lack of cover. Future recruitment potential for LWD was good over much of these basins, and was identified as a problem in 20% of the riparian areas. Pool filling and deposition of fine sediments was noted in some channel types, and much of the watershed has fine sediments delivered from road erosion, and potentially delivered from areas with high hazard ratings for landslides.

Channel Modifications

Historic channel modification activities include operation of splash dams prior to 1925 in the mainstem (one), the North Fork (two), and South Fork (two) (Wendler and Deschamps, 1955). By the mid 1940's, most of the subbasin had been logged and the valley bottom cleared for agricultural uses (Weyerhaeuser, 1999). In 1975, gravel mining operations in and near the stream channels in the Newaukum watershed were found to affect virtually every spawning reach (for chinook and chum) in the South Fork below the Town of Onalaska, as well as other parts of the North Fork and mainstem Newaukum (Phinney et al., 1975).

The primary impacts noted today are; loss of riparian vegetation associated with logging and agricultural uses, and channel erosion. The USFWS/WDFW extensive survey data summary for the subbasin covers 125 miles of stream and are tallied with subbasins 5 and 6 (North Fork and Upper Newaukum River). Of this distance, 12 percent was reported with a reduction in riparian density associated with logging, and 12 percent reported riparian vegetation loss associated with agriculture. A total of 34 percent of the surveyed area was classified as riparian vegetation loss due to unknown causes. Livestock had access to about 9 percent of the surveyed channel length. Channel erosion was reported over 23 percent of the surveyed reach, and riprap was reported over 4 percent of the area surveyed (Wampler et al., 1993).

Approximately 25 miles of channel were evaluated on the 1990 orthophotos. Assessment of channel conditions included the urban/agricultural areas along the mainstem South Fork from the mouth to just above Lost Creek. Table 3.2-4 presents the results of assessment of riparian conditions along this section of the river. Alteration usually involved clearing nearly to the channel edge for agricultural purposes, leaving a thin strip of vegetation. Approximately 24 percent of the channel length was bordered by a relatively intact riparian corridor. A total of ten bridges, including Interstate 5, cross the channel and roads run immediately adjacent to the channel for approximately 1 mile. It is probable that riprap exists in these areas. It appears that in general, the riparian corridor is more intact than that shown in 1944 photos of the area. Channel position does not appear to have changed a great deal since that time.

Fish Stocks

Detailed information on the status of fish stocks within the South Fork Newaukum subbasin is not available. General information on the status of stocks within the entire Chehalis watershed is provided in Appendix D: Technical Report for Fish Habitat/ Channel Modifications/ Stocks.

3.4 SUBBASIN 14: CLOQUALLUM – WILDCAT CREEK

3.4.1 GENERAL DESCRIPTION

The Cloquallum River Subbasin (#14) covers 70.3 mi^2 from the foothills near Lost Lake to its confluence with the Chehalis River in the Town of Elma. The elevation ranges from 16 feet to a high of 1,580 feet; mean basin elevation is 422 feet. The mean annual precipitation is about 68 inches (WDNR, 1991). Mean annual discharge measured at the USGS streamflow gage #12-032500, Cloquallum River at Elma, was 274 cfs which translated into a unit runoff of approximately 4 cfs/mi^2; winter unit runoff averaged 9 cfs/mi^2, while summer unit runoff was 1 cfs/mi^2. The primary land use for this subbasin was forestry with some agricultural and residential land uses along the river valley (Figure 3.4-1) (WDNR, 1990).

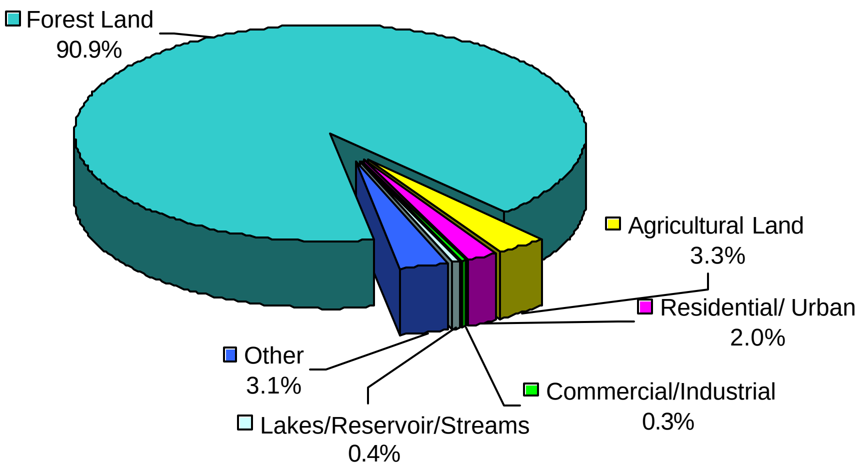

Figure 3.4-1. Subbasin #14: Cloquallum River
Land Use/Land Cover Summary
Source: WDNR, 1990

3.4.2 GEOLOGY AND HYDROLOGY

Geology

The upper two thirds of the basin are underlain by a mix of Vashon glacial deposits and marine sedimentary rocks. The glacial deposits consist primarily of till and are concentrated in the headwaters of the basin. The lower third of the basin is a mix of glacial deposits and recent alluvium.

Ground Water Hydrology

A significant amount of groundwater is likely present in the lower portion of the basin associated with the Chehalis River valley. This aquifer is located within 20 feet of the ground surface. Groundwater conditions in the upper portion of the basin are less known.

Surface Water Hydrology

The USGS collected mean daily discharge at the Cloquallum River at Elma (station #12032500) from 1942 to 1973. The station was located at river mile 1.9. While these records cover a few decades, record extension techniques were employed in an attempt to cover a period of record similar to the other basins and sufficient to reflect natural climate variability.

The Cloquallum River record was extended to cover the 1929-1998 period using long-term daily data from the adjacent basin gage, #12035000 Satsop River near Satsop, and monthly correlation equations.

The USGS station remarks for the Cloquallum River gaging station indicated that there were small diversions on minor tributaries and some regulation by a log pond on Wildcat Creek. In addition, Cloquallum Creek flows through Stump Lake, which may be providing some in-channel retention. Regulation from this lake and the log pond could be investigated in a Level 2 analysis. The WDOE rated the Cloquallum River record low in terms of the degree of regulation and diversions (Sinclair and Pitz, 1999). Based on the WDOE's GIS layer that spatially displays dams in Washington State, no dams were identified in the Cloquallum basin.

Monthly flow exceedance values were generated for this station based on the combined actual and synthetic daily streamflow values; the 50% and 90% exceedance values are listed in Table 3.4-1 along with the instream flows for the Cloquallum control point at the gage location. (These flows were considered estimates of undepleted flow that may require refinement in a Level 2 effort.)

Table 3.4-1
Flow Exceedance Values for Cloquallum River, Subbasin #14

Month	Flow Exceedance Values[1] Gage #12-032500: Cloquallum R. at Elma				WDOE 1975 Base / Instream flow	
	50% Exceedance (cfs)	50% URO[2] cfs/mi[2]	90% Exceedance (cfs)	90% URO[2] cfs/mi[2]	1st-14th (cfs)	15th to month end (cfs)
October	53	0.81	24	0.36	27	30
November	238	3.62	60	0.91	52	88
December	421	6.40	173	2.63	150	150
January	449	6.82	200	3.04	150	150
February	417	6.34	205	3.12	150	150
March	322	4.89	176	2.67	150	150
April	209	3.18	125	1.90	150	150
May	112	1.70	74	1.12	118	92
June	69	1.05	50	0.76	70	55
July	41	0.62	34	0.52	43	34
August	30	0.46	24	0.36	29	24
September	29	0.44	23	0.35	24	24

[1] Based on 38 years of synthetic + 31 years of actual daily data from
USGS station #12-032500: Cloquallum R at Elma; 1929-98; drainage area = 63.8 mi^2

[2] URO = unit runoff

3.4.3 WATER RIGHTS & WATER USE

There were 80 water rights on record for the Cloquallum River (Subbasin #14): 51 surface water rights and 29 ground water rights. Over half were designated for irrigation and another 28% were designated for domestic use. The municipal rights were all certificates assigned to the Town of McCleary. The total diversion/withdrawal rate of these municipal rights was 2.45 cfs, with a combined volume limitation of 1,633 acre-feet. All of the water rights listed in the WRATs database for this subbasin involved some degree of consumptive water usage; none were totally non-consumptive, i.e. hydropower, fish propagation etc.

The most senior water right held a priority date of August 19, 1930 for irrigation and domestic use purposes; the most junior water right certificate in the subbasin was dated September 22, 1989. Four applications were junior to this 1989 certificate. Twenty-five rights were junior to the 1975 base/instream flows set by the WDOE. The total instantaneous withdrawal rate associated with these rights was 9.8 cfs.

Of the 282 registered claims on file, 263 were associated with general domestic use, 7 each for irrigation and stock watering, and 5 had no associated purpose of use listed in the database. The irrigation claims cover 363 acres of land. The majority of the claims were intended for ground water withdrawals (82%).

Table 3.4-2. Subbasin 14: Cloquallum Creek Water Rights Summary by Primary Purpose[1]

Primary Purpose (# rights)	Allocated Amount (cfs)	Volume Limit (acre feet)	Irrigated Land Acres
Commercial/Industrial (4)	2.47	189.7	0
Domestic (22)	3.07	356.93	0
Fire Protection (1)	0.22	3	0
Irrigation (45)	8.52	617	659.5
Municipal (3)	2.45	1633	0
Stock (5)	0.55	76.6	39
TOTAL	**17.28**	**2876.23**	**698.5**

(Includes Certificates, Permits, and Applications)
[1]Envirovision and Watershed Professionals Network assume no responsibility for the accuracy of the data provided by the Washington State Department of Ecology.

Residential and Municipal Water Use

The points of withdrawal for twenty public water systems were located in the Cloquallum River subbasin with a total of 972 connections or 2,083 people. The City of McCleary was listed as the largest purveyor of water serving 1,500. Outside of McCleary, there appeared to be 12 mobile home parks or other small residential systems. The remaining public water systems (7) served primarily commercial or industrial users with some associated residential use.

According to the Chehalis River Basin Action Plan (1992), the 1990 population in the Cloquallum River subbasin was approximately 3,000. The average projected rate of growth between 1990 and 2000 was 11% leading to an estimated year 2000 population of 3,330. As of September 1999, the public water systems in the subbasin supplied a population of 2,083; the difference of 1,247 was assumed to be self-supplied water users some of whom may have water rights. There were six single domestic rights providing water for about 15 people. The difference of 1,232 self-supplied water users (total self-supplied users less those covered under single domestic rights) were estimated to use about 0.24 cfs (127 gcd calculated using WDOH (1999)). An estimate of actual water use for the total population (applying 127 gcd) was approximately 0.66 cfs. The combined municipal and domestic water rights totaled 5.52 cfs, which means the estimated actual water use was about 12% of the total allocated water for this sector.

Commercial and Industrial Water Use

Four commercial/industrial water rights were listed in the WRATS database with a total withdrawal rate of 2.47 cfs. Seven of the public water systems may be associated with this water use sector. In the Grays Harbor Assessor's database, 75 parcels covering roughly 309 acres of land were identified as commercial or industrial by land use code. Without knowledge of the specific enterprises, it is difficult to determine an estimate of actual water use.

Irrigation

The total withdrawal/diversion rate of the irrigation water rights was 8.52 cfs; the associated volume limit and acreage covered was 617 acre feet and 660 acres, respectively. There were three additional rights with stock watering as the primary beneficial use and irrigation as a secondary use: volume limit of 76 acre-feet and 39 irrigated acres.

The Grays Harbor County assessor's database listed 17 parcels totaling 553.68 acres associated with agriculture. Additional irrigated acreage may be located in Mason County. Orthophotographs (WDNR, 1995) of the Mason County portion of the subbasin were reviewed and a few additional farms were noted. The Chehalis River Basin Action Plan states that the water righted acreage was around 400 and that about one-fourth were actually being irrigated (1992).

Assuming all 659.5 acres were irrigated in pasture/turf (the highest use) and using the climate and crop consumptive use data from Elma, Washington, the total crop water demand was estimated at 1,030 acre feet at an efficiency of 50%. This value is 47% higher than the 699 acre-feet volume associated with the water rights. Using field corn as the primary crop (lower consumptive use) for all the acres, the total crop water requirement was 580 acre-feet at 50% efficiency. The crop water requirements of pasture/turf and field corn bracket the high and lower end consumptive uses, as well as the water righted volume. Some vegetables such as peas, green beans, cucumbers, etc. have lower rates of crop consumptive use, however, according to the Lewis County Conservation District (Bainbridge, Rich, Pers. Comm.), the only irrigated crops in Grays Harbor County were corn and pasture.

Based on the estimate that one-fourth (165 acres) of the water righted acreage is actually irrigated, the crop irrigation requirement would be significantly less ranging from 145 acre feet (field corn @ 50% efficiency) to 258 acre feet (pasture @ 50% efficiency) (Figure 3.4-2). The efficiency of 50% is an assumed value based on discussions with Lewis Conservation District staff (Bainbridge, Rich, Pers.Comm.).

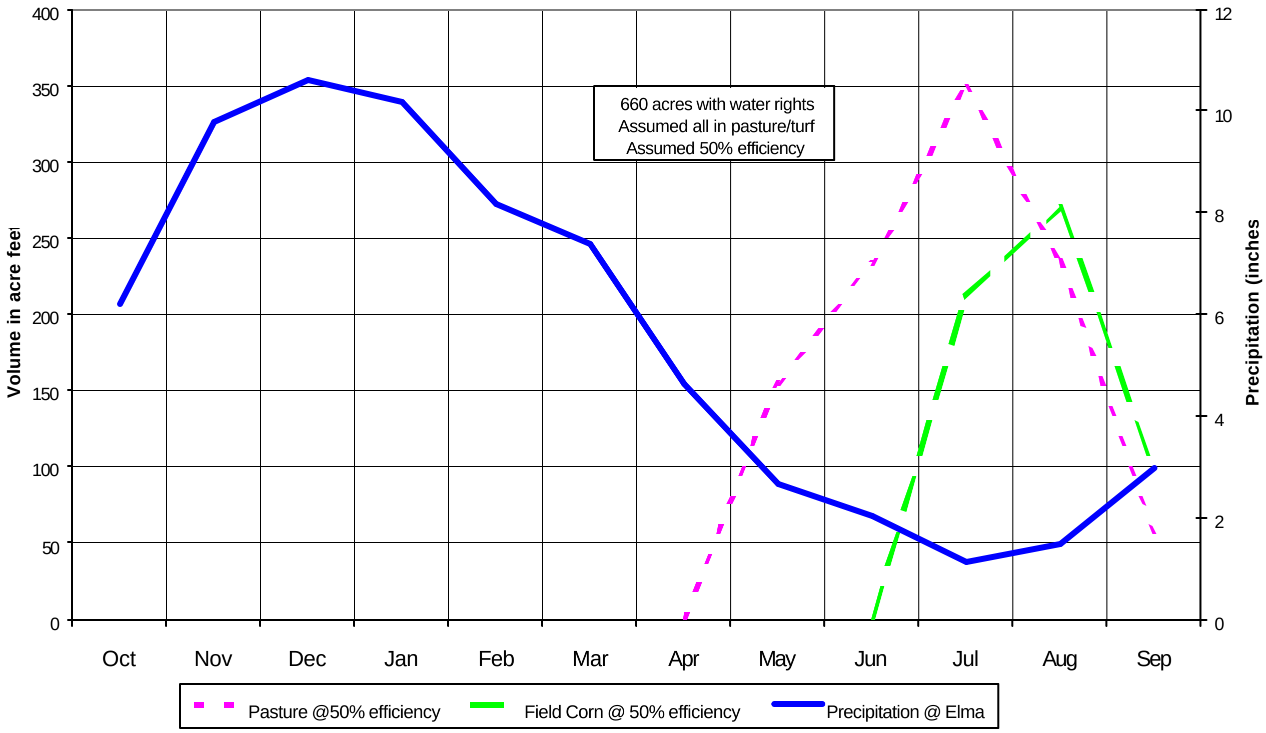

Figure 3.4-2. Subbasin #14: Cloquallum Creek Monthly Irrigation Water Demand

Source: WSU Cooperative Extension, *Irrigation Requirements for Washington – Estimates and Methodology*. Education Bulletin #1513

Comparison of Streamflow and Allocated Water

Figure 3.4-3 compares the streamflow (50% and 90% exceedance) with the instream flows and the total allocated water for consumptive uses. In addition, the graph includes a line depicting the combined instream flow plus the instantaneous water right allocation.

The 50% exceedance flow or median flow ranges from a low of 29 cfs in September, to a high of 449 cfs in January. This means that, in September, 50% of the flows were higher than 29 cfs and the other half of the flows were less than 29 cfs. The 90% exceedance flows were lowest in September and highest in February, i.e. 90% of the flows were 23 cfs or greater and 205 cfs or greater, respectively. The instream flows used on this graph represent the average of the bimonthly base/instream flow values. The monthly average of the instream flows are lowest in August (26.5 cfs), September (24 cfs), and October (28.5 cfs).

Examining flows in September,

50% Exceedance Streamflow	= 29 cfs
90% Exceedance Streamflow	= 23 cfs
Instream Flow	= 24 cfs
Instantaneous Water Right Allocation for all consumptive uses	= 17.28 cfs

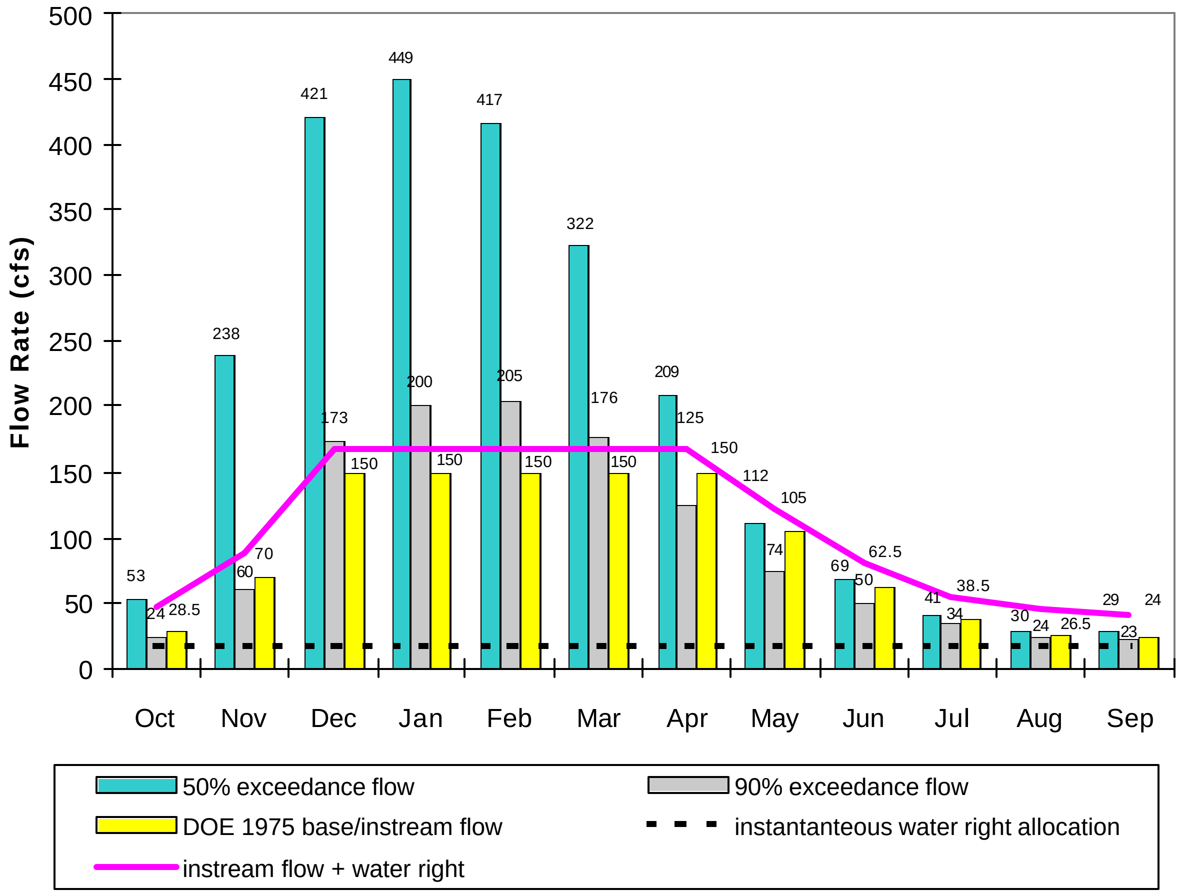

Figure 3.4-3. Subbasin #14: Cloquallum Creek
Comparison of Streamflow and Allocated Water

The median streamflow was insufficient to meet the water right allocation plus the instream flow in five months of the year, while the 90% exceedance flows were insufficient in eight months of the year. In the absence of human water use, the flows were sufficient to meet the instream flows at the 50% exceedance levels throughout the year; at the 90% exceedance level, instream flows could not be met eight months of the year.

The 17.28 cfs total allocated amount for consumptive use included both surface water and ground water abstractions. Direct comparison of the total allocated amounts to the streamflow represented the "worst case" scenario because 100% hydraulic continuity was assumed. Withdrawals under the 29 ground water rights in this basin impact the flows in the Cloquallum River to differing degrees dependent on depth of well, distance from the stream, and geology. The extent of the impact of ground water rights should be investigated further in the Level 2 Assessment.

The consumptive portion of the allocated rights was nearly 60% of the lowest median streamflow. If half of the water were returned to the system, the effective consumptive portion of these rights would then be 30% of the lowest instream flow. (Note: Return flows of 50% is not uncommon for irrigation rights, but would be considered low for domestic/municipal rights for which return flows are closer to 75%). The potential for streamflow enhancement exists in this basin since the water right allocation was substantial (25% to 60% of the median flows between June and October). A detailed mapping of the water rights to determine the rights actually being used and those that have been retired would bring the water rights allocation closer to the actual water use in the subbasin. In addition, an in-depth analysis of the ground water would help to determine the extent of the ground water right impacts on streamflows.

Table 3.4-3.
Summary Comparison of Water Rights and Water Use for Cloquallum Creek.

Beneficial Use	Estimated Current Water Use (cfs)	Water Rights Allocation (cfs)
Domestic	0.36	3.07
Municipal	0.3	2.45
Commercial/Industrial	Unknown	2.47
Irrigation	145-258 acre feet[1]	617 acre feet

[1]Based on NRCS estimate that 1/4th of water righted acreage (165 acres) are actually being irrigated.

Summary of Water Allocation for Cloquallum Creek

- Domestic use is 12 % of the water rights allocation.
- Municipal water use is 12 % of the water rights allocation.
- More than half the population is self-supplied.
- Consumptive water rights are 25 to 60 % of the lowest median streamflows.
- Potential for "paper" improvement is high since the allocation is high relative to streamflow and the estimated actual use is relatively low.
- Detailed mapping of water rights, field verification, and an investigation of hydraulic continuity is recommended for this subbasin.

3.4.4 WATER QUALITY

No monitoring of this subbasin has occurred since the 1970's. At that time there were no water quality violations noted.

3.4.5 FISH HABITAT/ CHANNEL MODIFICATIONS/ STOCKS

Fish Habitat

A total of 94 stream miles were surveyed for fish habitat conditions in the *USFWS/WDFW extensive survey for* in their "*Newman – Cloquallum*" subbasin, including Newman, Vance, Cloquallum, Wildcat, Bush, Mox-Chehalis, and Sand Creeks. The most important habitat problems identified were: streamside vegetation loss from unknown causes (1 point and 41.8 miles) (widespread), excessive instream sediments (12 points and 16 miles) (Vance, Sand, Bush and upper Newman Creeks), bank erosion (173 points and 10.5 miles) (Cloquallum, Mox Chehalis and Wildcat Creeks), and bank riprap/artificial protection or dumping (108 points and 2.2 miles) (Wildcat, lower and mid-Cloquallum and Vance Creeks). Beaver dams were present in the basin in moderate numbers at the time of the survey. A total of 22 known and suspected water withdrawals were noted, as well as 2 wastewater outfalls and 22 miscellaneous pollution input sources (Wampler et al., 1993). (Newman and Vance Creeks results are described in Subbasin #19.)

Channel Modifications

Early historical activities that can affect the form of the current channel included two splash dams, each operated prior to 1935 in Wildcat Creek and Rock Creek (Wendler and Deschamps, 1955).

The USFWS/WDFW extensive surveys present data summaries for the Mox Chehalis, Vance Creek, and Cloquallum Creek subbasins together. These data indicate that of the 94 miles of channel surveyed in the three streams, 5 percent was reported with a reduction in riparian density associated with logging, and 4 percent reported riparian vegetation loss associated with agriculture. A total of 44 percent of the surveyed area was classified as riparian vegetation loss due to unknown causes. Livestock had access to about 9 percent of the surveyed channel length. Channel erosion was reported over 23 percent of the surveyed reach, and riprap was reported over 4 percent of the area surveyed (Wampler et al., 1993).

1988 photos were evaluated from the mouth of Cloquallum Creek up Wildcat Creek to below McCleary (approximately 7 miles). Wildcat Creek was selected for evaluation rather than the main stem of Cloquallum Creek due to a greater variety of land uses. The combination of Highway 8 and the Elma McCleary road have resulted in riparian clearing and bank protection efforts for much of the length of Wildcat Creek. In some cases, the roads appear to limit meander movement.

These roads, as well as landowner clearing, have resulted in a significant loss of riparian vegetation. Table 3.2-4 presents the results of riparian disturbance as assessed from the 1988 aerial photos.

Fish Stocks

Detailed information on the status of fish stocks within the Cloquallum-Wildcat Creek subbasin is not available. General information on the status of stocks within the entire Chehalis watershed is provided in Appendix D: Technical Report for Fish Habitat/ Channel Modifications/ Stocks.

3.5 SUBBASIN 19: LOWER REACH 1 CHEHALIS RIVER

3.5.1 GENERAL DESCRIPTION

The Chehalis River Mainstem (Lower Reach 1) (Subbasin #19) covers 94 mi^2 along the mainstem between Porter Creek and the Satsop River and passing through the Town of Elma. The elevation ranges from 10 feet to 1,814 feet with a mean basin elevation of 309 feet. Mean annual precipitation over the subbasin is 59 inches. Mean annual discharge for the short-term record measured at the USGS streamflow gage #12-033000, Chehalis River at South Elma was 5,057 cfs. This translated into a unit runoff of approximately 4 cfs/mi^2; winter unit runoff averaged 7 cfs/mi^2, while summer unit runoff was <1 cfs/mi^2. The primary land use for this subbasin was forestry with some agricultural and residential land uses along the river valley (Figure 3.5-1) (WDNR, 1990). Although this subbasin does not represent an entire watershed or subwatershed, it was selected to represent mainstem water use/water rights activities.

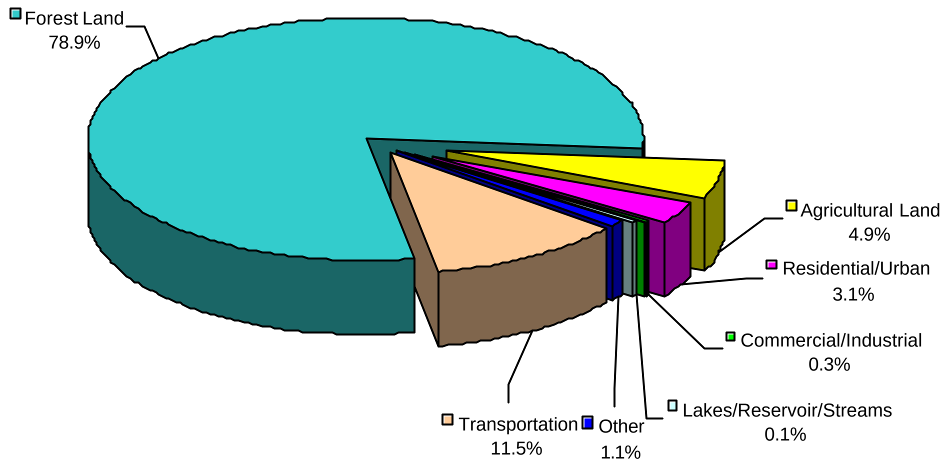

Figure 3.5-1. Subbasin #19: Mainstem Chehalis River – Lower Reach 1 Land Use/Land Cover Summary
Source: WDNR, 1990

3.5.2 GEOLOGY AND HYDROLOGY

Geology

The Chehalis River valley floor is primarily alluvial material with pockets of glacial outwash. Hillslopes of the tributary streams are underlain by marine sedimentary rocks of the Lincoln Creek and Astoria formations. Alluvial material is mapped in the valley floor of Sand Creek.

Ground Water Hydrology

The Chehalis valley aquifer is well developed and in direct hydraulic connection with the river. Water is usually found within 10 to 20 feet of the ground surface. A smaller valley aquifer is also likely in the Sand Creek basin. Groundwater conditions in the sedimentary rock units are not well understood.

Surface Water Hydrology

Subbasin #19 encompasses a reach of the mainstem Chehalis River and, as such, required slightly different treatment than the other four subbasins. Due to the complexity of regulation and extent of diversions upstream of the subbasin, undepleted streamflow estimates for this subbasin were not produced. Instead, the streamflow measured at the upstream end of the subbasin (Chehalis at Porter, 12031000) was used as inflow to the subbasin; water use upstream has depleted these flow values. Daily streamflow values for Cloquallum Creek and the Satsop River were added to the Chehalis River at Porter values to create a time series of all gaged flows draining to the Chehalis River just below Satsop confluence. These recorded flows were then adjusted to account for the ungaged accretion flow generated within the subbasin boundaries in order to allow comparison to the in-basin water use. While the flows used in this analysis do not represent an undepleted value, they do represent the amount that has over time come into the subbasin and is "available" for instream and out-of-stream uses in this subbasin.

Accretion flow from the 94 mi^2 of ungaged drainage in Subbasin #19 (plus the 5.1 mi^2 below the gage on Cloquallum Creek) was estimated using a combination of unit runoff values and the relationship of flows at the USGS Gage #12-031000 (Chehalis at Porter). Mean monthly unit runoff values were generated from the 8 years of gage records available at the historic Chehalis River at south Elma station located mid-basin (USGS Gage #12-033000). These monthly unit values compared favorably to values from the longer-term base gages and therefore were used. Using a ratio of the mean monthly flow to the 50% and 90% exceedance flows at the Porter gage, exceedance values for the ungaged area in Subbasin #19 were derived. These values were then added to the appropriate calculated values from the gaged flow time series to represent flows available at the downstream end of Subbasin #19.

Table 3.5-1
Flow Exceedance Values for Chehalis River Lower Reach 1

	Estimated Flow Exceedance Values[1] Downstream end of Subbasin #19				DOE 1975 Base / Instream flow	
Month	50% Exceedance (cfs)	50% URO[2] cfs/mi^2	90% Exceedance (cfs)	90% URO[2] cfs/mi^2	1st-14th (cfs)	15th to month end (cfs)
October	1,520	0.87	681	0.39	640	750
November	6,499	3.70	1,860	1.06	1305	2220
December	10,749	6.12	4,587	2.61	3800	3800
January	11,147	6.34	4,267	2.43	3800	3800
February	10,664	6.074	5,081	2.89	3800	3800
March	8,585	4.89	4,272	2.43	3800	3800
April	5,794	3.30	3,242	1.85	3800	3800
May	3,040	1.73	1,893	1.08	2910	2300
June	1,715	0.98	1,167	0.66	1750	1360
July	1,056	0.60	743	0.42	1085	860
August	736	0.42	548	0.31	680	550
September	796	0.45	555	0.32	550	550

[1] based on the addition of daily data from three gages USGS station #12-031000: Chehalis R. at Porter , Cloquallum #12-032500 and the Satsop R #12-035000 for coinciding record years 1955-72 and 75-99 + accretion flow to #19 outlet; drainage area = 1,757 mi^2

[2] URO = unit runoff

In addition to the unknown numerous water withdrawals, the streamflow records from the mainstem stations downstream of Skookumchuck River confluence (#12-027500 and #12-031000) were all affected by regulation from the Skookumchuck Reservoir, which was completed in 1971. This reservoir has a normal storage of 35,000 acre-feet and maximum storage of 60,000 acre-feet. Level 2 efforts may need to investigate the operating scheme of the Skookumchuck dam and impacts on downstream streamflow records. For example, to what extent are releases in summer months augmenting low flows in Skookumchuck River itself and further downstream? How significant is the effect further downstream on the mainstem Chehalis River?

3.5.3 WATER RIGHTS & WATER USE

Of the 162 water rights that have been issued by WDOE in this subbasin, 51% (82 rights) listed the source of supply as surface water. The allocated amounts, however, were mostly associated with ground water withdrawals (51.4 cfs) compared to 20.2 cfs connected with the surface water rights. One small storage right (6 acre-feet) for fish propagation was listed in this subbasin. By number, 70% of the rights (114) were designated for irrigation, 17% for domestic use, and 7% for stock watering. By volume, 72% were allocated for irrigation while the allocation to municipal and stock watering beneficial uses was about 9% each.

The largest water right for this subbasin was a ground water application for irrigation in the amount of 1,600 gpm, or ~3.6 cfs. The largest surface water right was a certificate for 1.33 cfs, also for irrigation. The single commercial water right was the second largest right for 1,200 gpm, or ~2.7 cfs.

The most senior water right in the basin was dated January 1, 1910 for 150 gpm; the beneficial use assigned to this right was *right of way* and *general domestic*. A *municipal* right was the next most senior right dated March 1, 1912 for 260 gpm. There were 27 rights junior to the 1975 base/instream flows set by the WDOE; 17 certificates, 1 permit and 9 applications.

Table 3.5-2. Mainstem Chehalis River – Lower Reach 1
Water Rights Summary by Primary Purpose

Primary Purpose (# rights)	Allocated Amount (cfs)	Volume Limit (acre feet)	Irrigated Land (acres)
Consumptive Uses			
Commercial/Industrial (1)	2.78	480	0
Domestic (27)	3.61	1,679.6	0
Irrigation (114)	51.12	6,716.95	4,793.25
Municipal (4)	6.70	1,654	0
Recreation (1)	0.25	0	12
Right of Way (1)	0.33	9.34	0
Stock (12)	6.12	857.8	646
Subtotal	***70.91***	***11,397.69***	***5,453.25***
Non-Consumptive Uses			
Fish Propagation (1)	0.30	7	0
Storage for FP (1)	0	6	0
Subtotal	***0.30***	***13***	***0***
TOTAL	**71.22**	**11,410.69**	**5,453.25**

(Includes Certificates, Permits, and Applications)
[1]Envirovision and Watershed Professionals Network assume no responsibility for the accuracy of the data provided by the Washington State Department of Ecology.

The four municipal rights were in the name of the Town of Elma: 3 certificates (2,010 gpm or ~4.5 cfs) and 1 application (1,000 gpm or ~2.2 cfs). The annual volume limit for the certificates was 1,654 acre-feet.

There were 416 registered claims in this subbasin, 84% of which were designated for ground water withdrawals. The majority of the claims (368) were for general domestic purposes with the remaining claims split almost evenly between irrigation and stock water use. Of the claims to which a priority date was entered into the database, 97 ground water rights preceded the 1945 ground water code and 16 surface water rights held priority dates preceding the 1917 surface water code.

Residential and Municipal Water Use

An estimation of the population and subsequent actual water use estimates in subbasin #19 was not possible at this level of analysis. Population data could not be extracted from the 1992 Chehalis Basin Action Plan since subbasin #19 was part of a larger subbasin in that report entitled "Lower Chehalis Basin." Also, population data in GIS format from Grays Harbor County were not available. Instead, population was roughly estimated from the assessors' databases to the extent possible. A partial estimate of water use was done based on the information that was available, including the WDOH public water system information and the assessors' parcel data.

There were 15 public water systems with their points of withdrawal within subbasin #19. The largest system was the City of Elma, serving 1,200 residential connections, supplying water to 3,000 people. There were an additional 122 residential connections serving 314 people. The per capita daily water use in this subbasin was estimated at 134 gallons using the precipitation-based method developed by the WDOH (1999). The estimated water use for the public water system population was roughly 0.7 cfs. The total allocation for municipal and multiple domestic rights was 9.94 cfs; the public water system use was roughly 7% of the total allocation.

Investigating the Grays Harbor and Thurston County assessors' databases, there were 1,765 single-family residential parcels that would house approximately 4,413 people. An additional 380 parcels were identified in the residential category, 50 in the 2 to 4 unit category (about 375 people), 16 multi-unit households (5+), and 6 mobile home parks. At this level, the number of units within each parcel for the latter two categories was unknown. Another 308 parcels were categorized as "other residential", which may include bare land or sheds etc. In summary, the parcel based method leads to an estimate of 2,145 parcels listing some type of residential designation.

There were 20 single domestic water rights for 0.37 cfs; the allocation for each was either 0.01 cfs or 0.02 cfs, with two exceptions; one right was for 0.03 cfs and the other for 0.07 cfs. Six multiple domestic rights totaled 3.23 cfs for the instantaneous diversion/withdrawal rate. The Washington Public Power Supply System held the largest of these for 1,007 gpm (~2.2 cfs) designated general domestic; this right was associated with the Satsop power plant. According to Energy Northwest, this right was reduced to 300 gpm in 1996 and redesignated for construction, restoration, domestic, and fire protection services, however, the WDOE database did not reflect this change at the time the data were obtained. The remaining 0.99 cfs in multiple domestic rights may cover some or all of the 15 public water systems.

Assuming 20 of the 1,765 residential parcels were supplied water under a single domestic right, the remaining 1,745 households were served either by a public water system and/or a multiple domestic right, or by a claim or an exempt well.

The average number of people per household in Grays Harbor and Thurston County was 2.5 and 2.55, respectively, or an estimated population of 4,457 living in single-family homes. Based on the public water system data, the mobile home parks were assumed to provide water to 113 people. The multi-unit household population was much more difficult to obtain; a very rough estimate of 250 people was calculated from the building values of single-family homes and multi-family units. This number was generated solely to provide a very rough estimate of exempt wells and should be refined using actual population data when it becomes available. Assuming the population residing in the multi-unit buildings and mobile home parks were served by a public water system and/or under a multiple domestic water right, it was possible to estimate the number of exempt wells as follows:

 4,457 people in single-family homes and 2 to 4 unit dwellings
\+ 738 people served by mobile homes and multi-unit residences
 5,195 total population estimate (water use ~ 1 cfs)

-3,314 people served by a public water system
1,881 people were self-supplied under a water right, claim or exempt well
- 50 people were self-supplied with a single domestic water right
1,831 people self-supplied under a multiple domestic right, claim or exempt well
(1,831 people = 725 households using ~ 0.4 cfs)

Further analysis using the parcel-based method described in Section 3 can separate out the multiple domestic water users from the exempt wells or claims.

Commercial/Industrial

There were 13 commercial connections served by public water systems in the WDOH database. Weyerhaeuser Company held the only commercial/industrial water right (1250 gpm or ~2.8 cfs) in this subbasin. Briggs Nursery, a commercial enterprise, had water rights under irrigation rather than commercial/industrial, therefore, it is addressed below.

Irrigation

Water rights covered a total of 5,453 acres for irrigation. Nearly 12% of these were associated with water rights that listed stock water as a primary beneficial use. Of those rights with irrigation as the primary beneficial use, the instantaneous withdrawal/diversion rate was 51.12 cfs and the annual volume limit was 6,716.95 acre-feet. There were 114 irrigation rights with an average rate of 0.45 cfs. These small numerous irrigation rights were located throughout this subbasin.

Briggs Nursery, a public water system, may be the largest single user of irrigation water in this subbasin. The nursery held 13 water rights, four of which were applications. Two of the nine certificates listed stock water as the primary beneficial use with irrigation secondary; the point of diversion for one of these did not fall within Subbasin #19. Of the 12 water rights within Subbasin #19, the total instantaneous withdrawal rate was 5,105 gpm (~11.4 cfs), with an annual volume limit of 1,758.4 acre-feet. The acreage associated with these rights totaled 665 acres. There were three change documents for these rights, however, it was not possible to discern the nature of these changes by viewing the database alone. Examination of the actual water right documents would be necessary to clarify the current allocations for the nursery.

Figure 3.5-2 depicts estimated monthly water demand for the subbasin. Assuming all 5,453 acres with water rights were irrigated in pasture/turf and using the climate and crop consumptive use data from Elma, Washington, the total crop irrigation requirement, assuming a 50% efficiency, was estimated at ~16,000 acre feet, about half of which is needed in July and August. The remaining amount was spread over April, May, June, and September. Field corn would require about 30% the amount of water (4,800 acre feet) in the months of July, August, and September. The annual volume limit associated with the irrigated acreage was about 7,575 acre feet. This being less than half the 16,000 acre feet demand for pasture grass at 50% efficiency indicated that either large areas of crops with lower consumptive use and/or higher efficiencies would have to be used to keep within the volume limitation for the given number of acres.

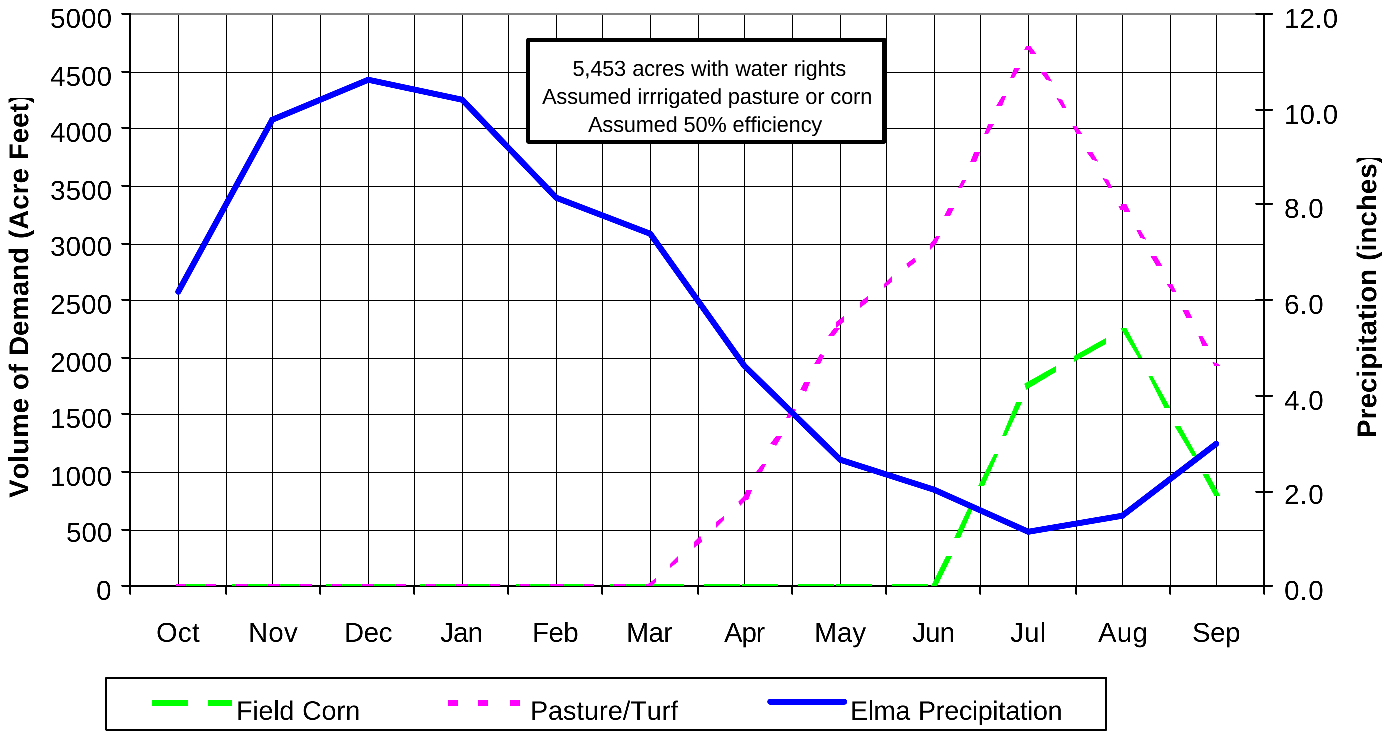

Figure 3.5-2. Subbasin #19: Chehalis River Mainstem – Lower Reach 1 Monthly Irrigation Water Demand

Source: WSU Cooperative Extension, *Irrigation Requirements for Washington – Estimates and Methodology*. Education Bulletin #1513

Comparison of Streamflow and Allocated Water

Figure 3.5-3 is a comparison of the inflow to the basin (USGS Gage #12-031000) plus the accretion within the basin, at the 50% and 90% exceedance levels, instream flows, and the total allocated water for consumptive uses. In addition, the graph includes a line depicting combined instream flow plus the instantaneous water right allocation.

The 50% exceedance flow, or median flow, ranged from a low of 736 cfs in August, to a high of 11,147 cfs in January. This means that, in August, 50% of the flows were higher than 736 cfs and the other half of the flows were less than 736 cfs. The 90% exceedance flows were lowest in August and highest in February, i.e. 90% of the flows were 548 cfs or greater and 5,081 cfs or greater, respectively. The instream flows used on this graph represent the average of the bimonthly base/instream flow values. The instream flows are lowest in August (615 cfs), September (550 cfs), and October (695 cfs).

Examining flows in August,

50% Exceedance Streamflow	= 736 cfs
90% Exceedance Streamflow	= 548 cfs
Instream Flow	= 615 cfs

Instantaneous Water Right Allocation for all consumptive uses = ~71cfs

The combined water right allocation and instream flow were equal to or greater than the 90% exceedance flows in five months. By contrast, sufficient water was available to meet the water rights allocation and instream flows year-round at the 50% exceedance level. In the absence of human water use, instream flows cannot be met seven months of the year at the 90% exceedance level.

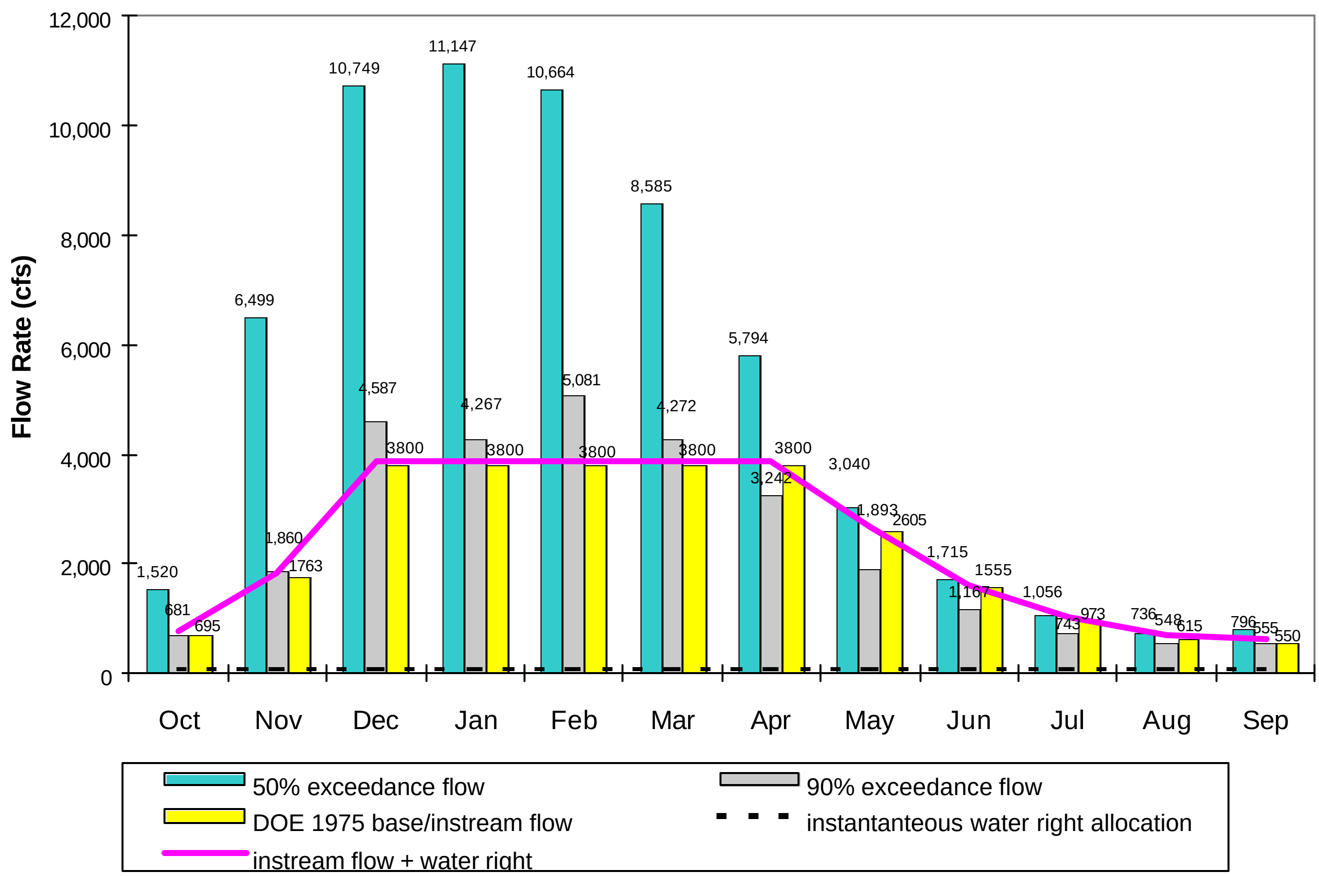

Figure 3.5-3. Subbasin #19: Chehalis River Mainstem - Lower Reach 1 Comparison of Streamflow and Allocated Water

The 71 cfs total allocated amounts for consumptive use included both surface water and ground water abstractions. Direct comparison of the total allocated amounts to the streamflow represents the "worst case" scenario because it assumes 100% hydraulic continuity. Withdrawals under the 29 ground water rights in this basin impact the flows in the Chehalis River around Elma to differing degrees, depending on depth of well, distance from the stream, and geology.

The consumptive portion of the allocated rights was 10% of the median and 13% of the 90% exceedance flows in August, the lowest flow month. If half of the water were returned to the system, the effective consumptive portion of these rights would then be 5% and 6.5%, respectively. (Note: A 50% return efficiency is not uncommon for irrigation rights, but would be considered low for domestic/municipal rights which have return efficiencies closer to 75%.)

Given that streamflow measurements are usually accurate to within 10% of the true value of the flow, conservation efforts would not result in measurable increases in streamflow in this subbasin. Due to this, the potential for streamflow enhancement by changing withdrawal/diversion patterns was determined to be limited in this subbasin compared other subbasins described in this report.

Table 3.5-3.
Summary Comparison of Water Rights and Water Use for the Chehalis River Mainstem.

Beneficial Use	Estimated Current Water Use (cfs)	Water Rights Allocation (cfs)
Domestic	0.46 [1]	3.61
Municipal	0.62	6.7
Commercial/Industrial	Unknown	2.78
Irrigation	4,800 to 16,000 acre feet	7,575 acre feet

[1]Estimated domestic use includes those that fall within exempt well category

Summary of Water Allocation for Chehalis River Mainstem

- Domestic water use is approximately 13 % of the water rights allocation.
- Municipal use is approximately 9 % of the water rights allocation.
- Many small irrigation rights are distributed throughout this subbasin.
- Consumptive portion of rights is approximately 10 % of lowest median flows.
- Conservation efforts are not likely to result in measurable streamflow increases in this subbasin.
- This subbasin is not a priority for further analysis.

3.5.4 WATER QUALITY

No monitoring station exists within this subbasin. Data from the Montesano station located approximately 7 miles downstream was used for the analysis. The water quality data set for the Montesano station is fairly complete and extends from October 1977 through September 1992. It is listed for temperature and fecal coliform violations. Yields (based on extrapolations of flow data) were low for TP and TSS, but the highest measured for IN in the Chehalis. For perspective, the IN yield was second only to the Samish River in the 21 stream and river basins studies in a Puget Sound wide study.

3.5.5 FISH HABITAT/ CHANNEL MODIFICATIONS/ STOCKS

Fish Habitat

This subbasin includes the mainstem Chehalis River between the Satsop River and Porter Creek, including Workman Delezene, Newman, and Vance Creeks. USFWS extensive survey data for the mainstem Chehalis River is presented in Appendix D.

USFWS/WDFW extensive survey. A total of 42 stream miles were surveyed in their "*Workman Delezene*" subbasin, including portions of Workman, Delezene, and Eaton Creeks, and two unnamed tributary creeks. The most important habitat problems identified included:

- stream canopy reduction from forest practices (1 point and 23.3 miles) (Workman, Delezene, Eaton Creeks),
- excessive sediments in streambed (1 point and 16.2 miles) (Workman, mid- and lower Delezene, upper Eaton Creeks),
- stream canopy reduction from agriculture (9 points and 3.3 miles) (upper Eaton, lower Delezene, lower Workman), and
- bank erosion (53 points and 0.3 miles) (Workman and Delezene Creeks).

Beaver dams were fairly widespread across this subbasin at the time of the survey. A total of 4 known or suspected water withdrawals and 6 known or suspected pollution input sources were also noted (Wampler et al., 1993).

Habitat survey results for Vance and Newman Creeks were summarized with Cloquallum Creek, our (Subbasin #14).

Channel Modifications

This subbasin comprises the Chehalis River mainstem from the Satsop River confluence upstream to the Porter Creek confluence. Also included are Workman, Delezene, Mox Chehalis, and Sand Creeks.

USFWS/WDFW extensive surveys summarize results for 110 miles of the Chehalis River mainstem surveyed, from the mouth to about the confluence with the Black River. The data indicate that about 5 percent of the length surveyed had reduced stream canopy due to logging and 73 percent had a reduction due to agriculture. Livestock had access to about 7 percent of the channel network. Erosion was noted over 22 percent of the surveyed area, and 7 percent of the channel was protected by some measure (usually riprap) (Wampler et al., 1993).

Approximately 13.6 miles of channel from Porter to the mouth of the Satsop River were assessed using 1988 photos. Table 3.2-4 presents the results of assessment of riparian conditions along this section of the river. Not surprisingly, the riparian forest in this area has been considerably altered over the long course of human activities. The channel is spanned by 4 bridges in this reach and is closely paralleled by roads or railroad grades for approximately 7,000 feet.

These features, as well as agricultural activities, can limit meander movement and isolate side channels or sloughs. An investigation of the mainstem Chehalis between the Satsop and Wynoochee Rivers found 28 sites where former off-channel areas, sloughs, and side channels were still in existence, but had been isolated from the main river channel by past land use actions (Ralph et al., 1994). This type of land use action has likely occurred in this reach of the Chehalis, but to determine the degree of alteration and the strength of the connection between land use and channel alteration would require a more detailed study than that associated with Level 1.

Fish Stocks

Detailed information on the status of fish stocks within the Middle Chehalis River subbasin is not available. General information on the status of stocks within the entire Chehalis watershed is provided in Appendix D: Technical Report for Fish Habitat/ Channel Modifications/ Stocks.

3.6 Subbasin 25: Humptulips River

3.6.1 GENERAL DESCRIPTION

The Humptulips River Subbasin (#25) covers 244 mi^2, from the headwaters of the Humptulips River to the confluence with Grays Harbor. The elevation ranges from sea level to a high of 4,397 feet in the Olympic Mountains; mean basin elevation is 722 feet. The mean annual precipitation is about 127 inches (WDNR, 1991). Mean annual discharge measured at the USGS stream gage (#12039000, Humptulips River near Humptulips), was 1,337 cfs. This translated into a unit runoff of approximately 10 cfs/mi^2; winter unit runoff averaged 18 cfs/mi^2, while summer unit runoff was 3 cfs/mi^2. The primary land use for this subbasin was forestry with some agricultural and residential land uses along the river valley (Figure 3.6-1) (WDNR, 1990).

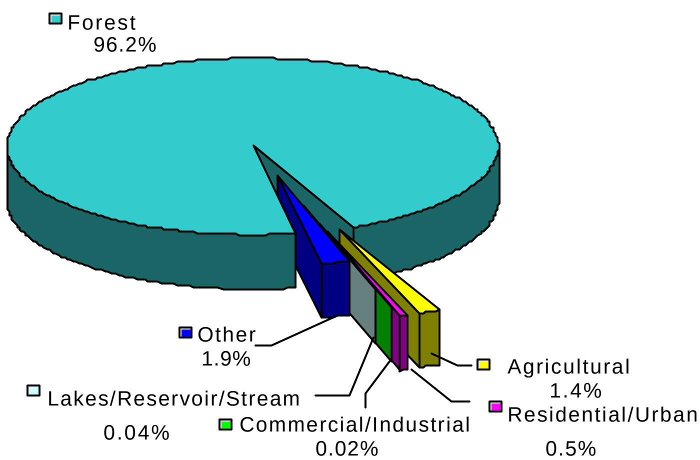

Figure 3.6-1. Subbasin #25: Humptulips River Land Use/Land Cover Summary
Source: WDNR, 1990

3.6.2 GEOLOGY AND HYDROLOGY

Geology

The upper portion of the basin above the community of Humptulips is underlain by Eocene epoch volcanic rocks of the Crescent formation. In the lower portion of the basin, old glacial deposits and alluvial material of varying age can be found.

Groundwater Hydrology

Little groundwater information is available for the Humptulips, but a well developed aquifer is likely present in the glacial and alluvial material in the lower portion of the basin.

Surface Water Hydrology

The USGS collected mean daily discharge at the Humptulips station (#12039000) from 1933 to 1935 and 1942 to 1979. The station was located mid-way up the Humptulips at river mile 24.8. While these records covered numerous years, record extension techniques were employed in attempt to cover a period of record similar to the other basins and representative of natural climate variability.

The Humptulips River record was extended using the Wynoochee River (#12035500) gage records to fill in the seven years from 1935 to 1942. The Humptulips River record could not be extended to cover the 1980 to 1998 period using the Wynoochee River data because this later period was influenced by regulation of the Wynoochee reservoir (completed in 1972).

The majority of years (32 of the 46) within the 1933-1979 period experienced the conditions of a cool/wet Pacific Decadal Oscillation (PDO) phase, however, the cyclical phases can have both above normal and below normal years. Based on the longer record at the Satsop near Satsop gage (1929-98), the 1933-79 period included 23 years of flows above the long-term annual average and 25 years below normal. Therefore, the available streamflow data reflected both wet and dry conditions even though they occur during a predominantly cool/wet PDO phase.

Since land use was predominantly forestry (primarily National Forest ownership), with no development in the watershed above the gage, and the USGS (station remarks) and WDOE (Sinclair and Pitz, 1999) both reported no regulation or diversions upstream of the gage, the extended records were representative of "undepleted flows".

Monthly flow exceedance values were generated for this station based on the actual and synthetic daily streamflow values; the 50% and 90% exceedance values are listed in Table 3.6-1 along with the instream flows for the Humptulips control point coincident with the gage location.

Table 3.6-1
Flow Exceedance Values for Humptulips River Subbasin #25

Month	Flow Exceedance Values[1] Gage #12-039000: Humptulips R. near Humptulips				WDOE 1975 Base/Instream Flow	
	50% Exceedance (cfs)	50% URO cfs/mi^2	90% Exceedance (cfs)	90% URO cfs/mi^2	1st-14th (cfs)	15th to month end (cfs)
October	575	4.42	169	1.30	205	250
November	1,490	11.46	506	3.89	390	600
December	2,055	15.81	906	6.97	600	600
January	1,700	13.08	676	5.20	600	600
February	1,621	12.47	759	5.84	600	600
March	1,380	10.62	682	5.25	600	600
April	1,000	7.69	605	4.65	600	600
May	683	5.25	420	3.23	600	500
June	400	3.08	247	1.90	400	325
July	256	1.97	157	1.21	265	215
August	187	1.44	119	0.92	170	170
September	216	1.66	129	0.99	170	170

[1]Based on 7 years synthetic data and 39 years daily data from USGS station #12-039000, Humptulips R near Humptulips; 1933-79 drainage area was 130 mi^2

3.6.3 WATER RIGHTS & WATER USE

Water Rights

A total of 30 water rights were tabulated in this subbasin: 17 surface water rights; 11 ground water rights; and 2 storage rights. Of the surface water rights, there were 15 certificates, 1 permit, and 1 application. The City of Ocean Shores holds a permit for the largest diversion from the Humptulips River (20 cfs); this right would constitute an out-of-basin diversion and thereby a 100% loss to the system. A private individual holds the only surface water application on record, which is intended for fish propagation. Ten of the eleven ground water rights were certificates; the remaining one was an application for general domestic use by the Washington State Baptist Convention.

The instantaneous amount of water allocated totals 86.55 cfs, of which 57.14 cfs was for non-consumptive uses (fish propagation). Five of the six surface water right certificates for fish propagation were held by the WDFW. The two storage rights for 469 acre-feet were also for fish and wildlife propagation.

The most senior water right (priority date of July 20, 1923) was designated for power and commercial/industrial use in the amount of 2.25 cfs, filed by the Oriental Lumber Company. The portion allocated for power could not be determined from the WRATS database. The most junior certificate in this subbasin had a priority date of July 24, 1979; two applications were junior to this right. The certificates senior to the 1975 base/instream flow represented 86 cfs (29 cfs of the consumptive rights).

Of the five largest water rights in the Humptulips River subbasin, three were for fish propagation (55 cfs total). The second largest right was for 20 cfs of multiple domestic use by the City of Ocean Shores. The fifth right was the most senior right discussed above.

Of the total allocated amount, 66% was designated for non-consumptive beneficial uses (fish and wildlife propagation). Irrigation rights represented nearly 14% of the consumptive rights (5% of the total allocation) totaling 3.99 cfs with an annual volume limit of 486.25 acre-feet. Of the 308.75 acres classified for irrigation, 54 acres were not assigned a volume limit in the WRATS database (WDOE 2000).

The number of registered claims in the Humptulips subbasin totaled 242, of which 211 were ground water claims and 31 were surface water claims. Only 8 claims were designated for irrigation purposes, 6 for stock watering, 4 unknown uses, and the remaining 224 indicated the primary beneficial use as general domestic. The largest claim in terms of irrigated land was for 730 acres; the total irrigated acres under the registered claims equaled 2,012. Many of these claims also listed stock and irrigation as secondary and tertiary beneficial uses.

Table 3.6-2. Subbasin #25: Humptulips River Water Rights Summary by Primary Purpose[1]

Primary Purpose (# Rights)	Allocated Amount (cfs)	Volume Limit (acre feet)	Irrigated Land (acres)
Consumptive Uses			
Domestic (7)	20.64	47.5	0
Fire Protection (1)	2.22	0	0
Irrigation (12)	3.99	486.25	308.75
Power/Commercial/Industrial (1)	2.25	0	0
Right of Way (1)	0.22	93	0
Stock (1)	0.09	6.4	0
Subtotal	**29.41**	**633.15**	**308.75**
Non –Consumptive Uses			
Fish Propagation (7)	57.14	394	0
Storage for Wildlife & Fish Propagation		469	0
Subtotal	**57.14**	**863**	**0**
TOTAL	**86.55**	**1,496.15**	**308.75**

(Includes Certificates, Permits, and Applications)
[1]Envirovision and Watershed Professionals Network assume no responsibility for the accuracy of the data provided by the Washington State Department of Ecology.

Residential and Municipal Water Use

There were ten public water systems with points of withdrawal in the Humptulips River subbasin, all of which were relatively small. The residential population served by these systems was 80, with 34 residential connections. Fifty-eight of the 80 people lived within mobile home parks and the remaining 22 people were associated with commercial enterprises.

In this subbasin, there were seven domestic rights for 20.64 cfs. The largest was a 20 cfs multiple domestic right allocated to the City of Ocean Shores, an out-of-basin diversion. Of the remaining six rights (0.64 cfs), one was a single domestic water right for 0.02 cfs and the other five were multiple domestic water rights. One of the five smaller multiple domestic rights was held by the Olympic National Forest for 0.1 cfs and was most likely associated with the Campbell Tree Grove Campground. This campground was listed as federally owned in the WDOH public water system list and served 1 non-residential connection.

Of the remaining four multiple domestic rights, with a total withdrawal rate of 0.52 cfs, three were tied reasonably well to the following public water systems: Timberview Mobile Home Park (population 25, residential connections 12); Warren Dahl (population 33, residential connections 11); and Riverview Recreation Area with 15 non-residential connections. At this level of analysis, the latter was an assumption since the only information available was the location of the system withdrawal in Township 20 North Range 10 West Section 7, which coincided with an irrigation/general domestic water right in the same section. The fourth multiple domestic right, Copalis Water Fund Inc., could not be specifically identified with a public water system since there were none that identified a point of withdrawal in the same section.

According to the county assessor's database, there were 308 single-family parcels, 1 unit of 2 to 4 households, and 3 mobile home parks. At least two of the mobile home parks appeared to be covered by water rights. The third mobile home park was not identified as a public water system, however, the water right in the name of the Copalis Water Fund Inc. may cover this use. Assuming this was the third mobile home park, the parcels that appeared to have no water rights totaled 310 (307 of the single-family households and an assumed 3 unit household (2-4 unit category)). These 310 households appeared to be covered by claims or exempt wells. Applying the Grays Harbor average people per household of 2.5, there were 775 people using water under exempt wells or claims. Assuming 119 gcd (WDOH, 1999) for self-supplied water users, the total water use for this population was estimated at roughly 0.14 cfs.

An alternative approach was to use the population data from to the Chehalis Basin Action Plan (1992). The reported 1990 population in the Humptulips River subbasin from that document was approximately 3,600 with 1,200 units from Ocean Shores. Assuming the county average of 2.5 people per household, the 1,200 units housed 3,000 people. The remaining 600 people would be the 1990 population within subbasin #24. The average projected rate of growth between 1990 and 2000 was 11%, leading to an average projected year 2000 population of 666. As of September 1999, the public water systems in the subbasin supplied a population of 80; the difference of 586 was assumed to be self-supplied water users, some of whom may have water rights. There were six single domestic rights providing water for about 15 people. The difference of 571 self-supplied water users (total self-supplied users less those covered under single domestic rights) was estimated to use about 0.11 cfs (119 gcd calculated using WDOH (1999)). An estimate of actual water use for the total population (applying 119 gcd) was approximately 0.12 cfs. The combined municipal and domestic water rights total 3.52 cfs (excluding the 20 cfs out-of-basin allocation), which means the estimated actual water use was about 3% of the total allocated water for this sector. Using the first approach, the actual use was about 4% of the total allocated water for residential use.

Commercial and Industrial Water Use

By water right, there were three commercial/industrial water users in this subbasin: Graham Shake Company, Oriental Lumber Company, and Polson Logging Company. Based on the public water system information, there were three stores (two were grocers), one restaurant, and two campgrounds. There were no records of actual use of any of these entities, however, the water right amount associated with the three forest products industries total 4.69 cfs; 4.47 cfs for which volume limits were not indicated. The continuous use of 4.47 cfs was calculated to be 3,236 acre-feet per year. Adding the 93 acre-feet restriction on the remaining 100 gpm water right, the total legal entitlement was 3,329 acre feet/year for commercial/industrial use.

One of the campgrounds, Campbell Tree Grove Campground, was noted as federally owned. WDOH listed it as a public water system with 1 connection; a water right of 0.1 cfs was on file with WDOE. The campground is located in Olympic National Forest (T23N R8W S15).

Irrigation

Irrigation rights represented nearly 14% of the consumptive rights, or 3.99 cfs with a volume limit of 486.25 acre-feet. Under these existing water rights, 309 acres of land can legally be irrigated (the assessor's database indicated 479 acres in agricultural land). The computation of irrigation water requirements involves estimating crop consumptive use, effective precipitation, conveyance losses, and on-farm efficiencies.

At this assessment level, there was insufficient data to estimate the actual water use for irrigated croplands; the actual number of irrigated acres was unknown. It was possible, however, to examine the crop water requirements for the water righted acreage using regional climatic data and estimating efficiencies. Pasture/turf was used in this analysis since the crop water requirement was higher than most other crops grown in this area resulting in a higher estimate of the water use impact on the streamflows. Using this approach, an upper bound was established given that all the water righted acres were irrigated.

Aberdeen was the closest climate station for which crop consumptive use has been estimated (Washington Irrigation Guide, 1991). While the Humptulips subbasin mean annual precipitation was significantly higher than the 83 inches at Aberdeen, most of the irrigated agriculture was likely to occur at the lower end of the basin where precipitation levels would more closely approximate those measured in Aberdeen.

Figure 3.6-2 demonstrates the estimated differences in irrigation water requirements, assuming 50% and 60% efficiency for the 309 acres of irrigated pasture. The total volume of the irrigation water demand from April to September (area under the curve) from the river (using the Aberdeen climate data,) ranged from 295 acre-feet/year to 354 acre-feet/year depending on the efficiency assumed. The annual volume limit associated with the irrigation rights totaled 486.25 acre-feet, or over 132 acre-feet per year more than the total demand of pasture/turf at 50% efficiency.

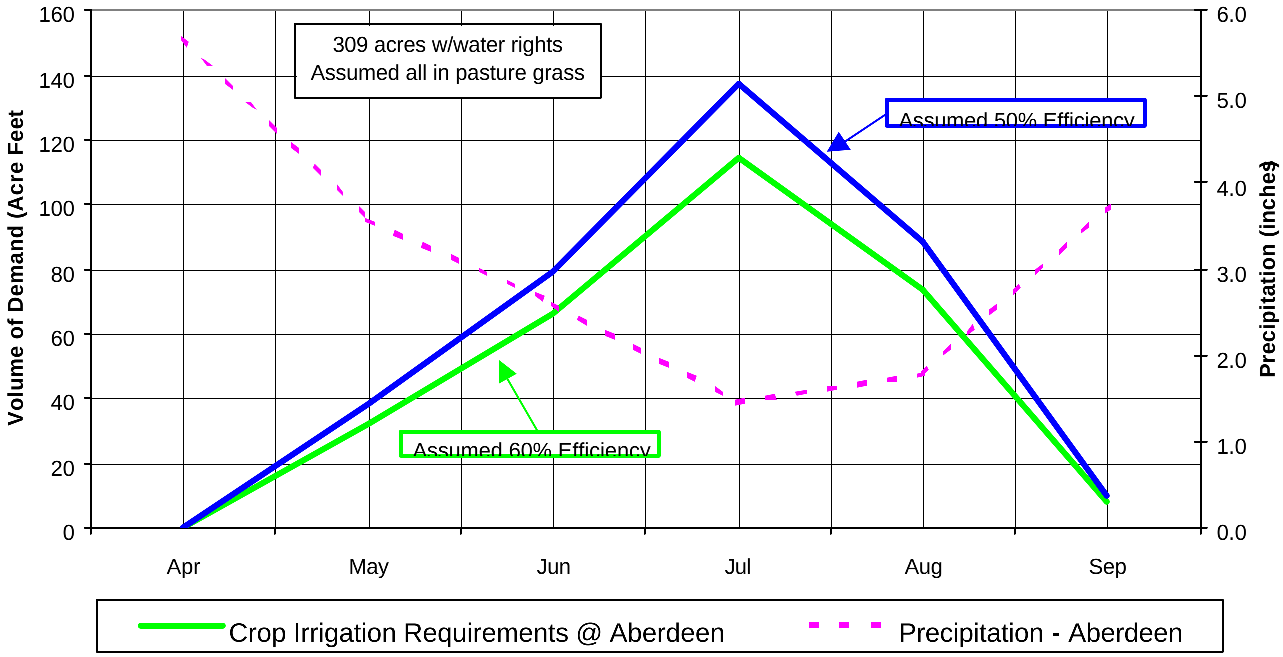

Figure 3.6-2. Subbasin #25: Humptulips River
Monthly Irrigation Water Demand for Pasture/Turf
Source: WSU Cooperative Extension, *Irrigation Requirements for Washington – Estimates and Methodology*. Education Bulletin #1513

Comparison of Streamflow and Allocated Water

Figure 3.6-3 is a comparison of flows (50% and 90% exceedance), instream flows, and the total allocated water for consumptive uses. In addition, the graph includes a line depicting combined instream flow plus the instantaneous water right allocation.

The 50% exceedance flow, or median flow, ranged from a low of 187 cfs in August to a high of 2,055 cfs in December. This means that in August, 50% of the flows were higher than 187 cfs and the other half the flows were less than 187 cfs. The 90% exceedance flows were also lowest in August and highest in December, i.e. 90% of the flows were 119 cfs or greater and 906 cfs or greater, respectively. The instream flows used on this graph represented the average of the bimonthly base/instream flow values. The monthly average of the instream flows are lowest in August (170 cfs) September (170 cfs) and October (average of 230 cfs).

Examining flows in August,

50% Exceedance Streamflow	= 187 cfs
90% Exceedance Streamflow	= 119 cfs
Instream Flow	= 170 cfs
Instantaneous Water Right Allocation for all consumptive uses	= 29.4 cfs

At the 50% exceedance level, the streamflow was sufficient to meet the combined water right allocation and instream flows in all but two months, July and August. There was insufficient water available at the 90% exceedance flows to supply all of the water right allocations and the instream flow needs in eight months of the year, April through November. Without the water rights allocations, instream flows were met year-round at the 50% exceedance level and in six months of the year at the 90% exceedance level.

The median flows (at the 50% exceedance level) were greater than the instream flows in the winter/ spring months (November through April). For the summer and fall months, the instream flows were much closer to the median of the flows (July and August were within 10%). In these months, even absent of withdrawals of water for human use, the flows were insufficient to meet the instream flow.

The 29.4 cfs total allocated amount for consumptive uses included both surface water (17 rights) and ground water rights (11). Direct comparison of the total allocated amounts to the streamflow represented the "worst case" scenario because 100% hydraulic continuity was assumed. Withdrawals under the 11 ground water rights in this basin impact the flows in the Humptulips River to differing degrees dependent on depth of well, distance from the stream, and geology.

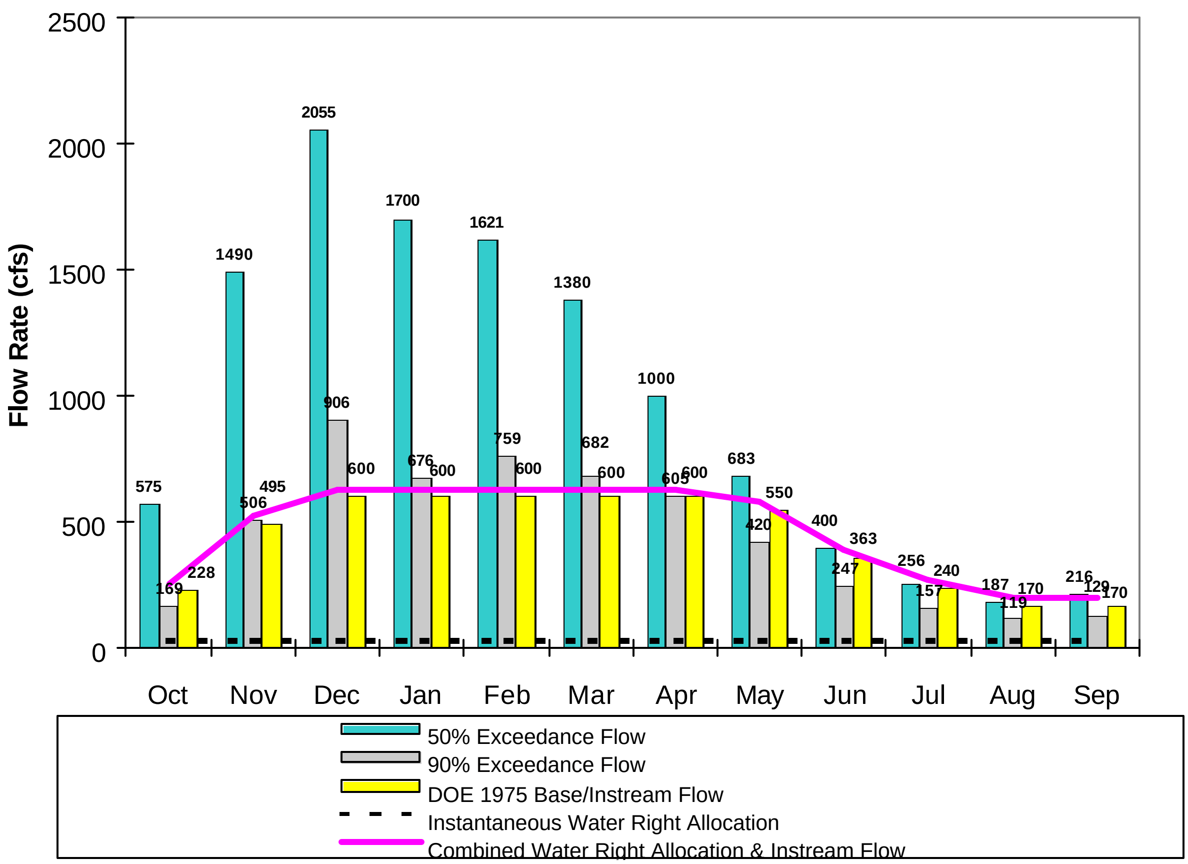

Figure 3.6-3. Subbasin #25: Humptulips River Comparison of Streamflow and Allocated Water

The consumptive portion of the allocated rights (29.41 cfs) was 16% and 25% of the lowest monthly median and 90% exceedance streamflows, respectively. Assuming half of the water was returned to the system, the effective consumptive portion of these rights was then 8% and 12.5% of the median and 90% exceedance flows in the lowest month of August. (Note: A 50% return efficiency is not uncommon for irrigation rights, but would be considered low for domestic/municipal rights which have return efficiencies closer to 75%.)

Since the ground water rights represent 10% of the total number of rights, the effective consumptive use would actually by something less than 12.5%. Given that streamflow measurements are usually accurate to within 10% of the true value of the flow, conservation efforts would not result in measurable increases in streamflow in this subbasin. Due to this, the potential for streamflow enhancement by changing withdrawals/diversion patterns was determined to be limited in this subbasin compared to subbasins #7 and #14, and therefore, further analysis here should be given a lower priority.

Table 3.6-3.
Summary Comparison of Water Rights and Water Use for the Humptulips River.

Beneficial Use	Estimated Current Water Use (cfs)	Water Rights Allocation (cfs)
Domestic	0.12 to 0.14	0.64
Ocean Shores	0	20
Commercial/Industrial	Unknown	2.25
Irrigation	295 to 354 acre feet	486.3 acre feet

Summary of Water Allocation for Humptulips River

- Domestic use is approximately 20 % of the water rights allocation.
- Irrigation rights represent approximately 14 % of the consumptive rights.
- The consumptive portion of rights is 16 to 25 % of the lowest median flows.
- Conservation efforts are not likely to result in measurable streamflow increases.
- This subbasin is not a priority for further analysis.

3.6.4 WATER QUALITY

The water quality station in the Humptulips is located nearly 24 miles upstream of the mouth. The record for this station extends back to the 1970's. Temperature and fecal coliform standards have been exceeded at this station, thus it is included in the 303(d) list for these problems. The average annual TP and TSS yields were the highest measured in this study, while the IN yield was lowest. As noted in the hydrology analysis, this subbasin has the highest unit runoff at least two times higher than what was estimated at the other four subbasins described above. Since TP and TSS are closely associated with runoff, the high yields calculated may be an artifact of this characteristic.

3.6.5 FISH HABITAT/ CHANNEL MODIFICATIONS/ STOCKS

Fish Habitat

Fish habitat has been assessed in the East Fork and WF Humptulips Rivers upstream of their confluence as part of the *East/West Humptulips watershed analysis* (Dieu and Martin, 2000; Martin and McConnell, 2000). Spawning gravels were found in adequate amounts in the anadromous zones. Substrate embeddedness was found to be high in O'Brien Creek and the West Fork Humptulips. The relative amount of pool habitat available for summer rearing was high in both upper mainstems and in several tributaries with anadromous fish. Amounts of instream LWD were adequate in many tributaries, especially those upstream of historic splash dam locations. Instream LWD amounts were found to be low in portions of the West Fork and larger portions of the East Fork. Loss of LWD-associated habitat as a result of channel flushing and reduced inputs of LWD was identified as a concern for the lower portions of the channel network. A reduction in the rate of bank erosion was also identified as a key objective in areas where the river channel is confined by terraces. Summer water temperatures were determined to cause risk to juvenile steelhead and chinook, especially in the lower reaches of the East and West Forks.

Collins and Dunne (1986) estimated that gravel removal in the Humptulips River between RM 16 and RM 28, between the late 1950's and 1985, caused the river bed to lower, with an estimated rate of 0.1 foot/year. Harvest rates in Grays Harbor County were adjusted after 1986, and the current gravel harvest rate is lower than the rate during that period. Also, WDFW now encourages gravel pit location outside of active stream channels. Current gravel harvest rates, and currently acceptable instream locations, are not known.

Channel Modifications

The Humptulips has an extensive history of splash dams, with over thirty dams reported in operation between 1900 and the 1930's. Stream channels were scoured of both gravel and instream LWD as a result of dam operations, and severe bank erosion of downstream areas converted to orchards and farmland was common (Van Syckle, 1981). In conjunction with dam operations, the liberal use of dynamite altered channel conditions by removing boulders and bedrock obstructions (Wendler and Deschamps, 1955).

Following dam removal, stream cleaning, gravel mining, and riparian vegetation loss have also affected channel conditions. Gravel mining occurred on at least 24 gravel bars on the mainstem Humptulips between 1955 and 1983. Gravel harvest rate exceeded the replenishment rate during this period (Collins and Dunne, 1986).

Although shifts in general channel position likely did not occur, changes in channel form have been documented. Maps made of the river in the mid 19^{th} century display a river that is wider and less sinuous (15%) than today (Collins and Dunne, 1986). Collins and Dunne surmise that this is consistent with a river in transition from a gravel rich braided system to a more meandering river with less gravel. This transition is aided by land use changes within the riparian corridor. Historical changes in the size of the channel migration zone (CMZ) have also been quantified (Martin et al., 1998). Over the past 47 years, the CMZ was largest for both forks of the river in the 1950 or 1968 photos (Martin et al 1998). This tends to follow the pattern of many western Washington channels, which were altered in the 1940 into the 1960's but are now moving toward a pre- alteration condition. Bank erosion, however, is still prevalent in mainstem reaches in the lower river where the river cuts into confining glacial terraces (Martin et al., 1998).

More recent channel modifications include 0.95 miles of dike, which affects natural meander patterns along the mainstem at river mile 7. The dike is associated with the Ocean Beach Road Bridge. Sections of riprap along the mainstem include 5,300 feet of rock downstream of the Highway 101 bridge, and 300 feet near river mile 23.3.

There is no USFWS/WDFW extensive survey for this watershed, as discussed for the other selected subbasins. Analysis of 9.9 miles of channel from the Highway 109 bridge to near Copalis Crossing and about one and one half miles above and below the Community of Humptulips was undertaken using 1988 photos. No changes in channel position due to modifications was noted, however for approximately 2 miles, the river runs immediately adjacent to roadways or railroad tracks. These features may impact meander patterns or exacerbate erosion downstream. In general, riparian impacts are more associated with silvicultural rather than agricultural practices due to the lack of agricultural activity in the subbasin. Table 3.2-4 presents the results of assessment of riparian conditions along this section of the river.

Fish Stocks

Detailed information on the status of fish stocks within the Middle Chehalis River subbasin is not available. General information on the status of stocks within the entire Chehalis watershed is provided in Appendix D: Technical Report for Fish Habitat/ Channel Modifications/ Stocks.

3.7 CONCLUSIONS

If there is a conclusion that can be drawn from detailed assessment of these five subbasins, it is that generalizations of water quantity, quality, and fisheries should not be made across the entire basin. Assessment by subbasin is the appropriate scale. However, this analysis provided a few general considerations that may be extrapolated to the remainder of the basin.

- In subbasins where agricultural use is high, over allocation of water supplies may be more common. However, agricultural land also represents the area where the differences between allocated water and actual water use are likely to be high, and where this difference is most difficult to estimate. However, from a water quality and fisheries perspective these subbasins can also be problematic in terms of oxygen and temperature. Due to the relationship between these water quality parameters and flow, addressing water quality issues should be the first priority, since water "found" through an analysis of actual use would still be required for instream use to prevent further water quality degradation.
- Subbasins undergoing rapid development that also have high agricultural use should be prioritized for detailed water rights analysis. This should include quantifying actual water use in agricultural areas and quantifying exempt wells and setting up a method for tracking this use over the long term.

- The analysis of subbasins that were predominately forest indicates that instream flow targets for some basins should be re-examined since these targets are not met, or just barely met, by the naturally existing streamflows.
- The comparison of flows to the consumptive portion of allocated flows in the subbasins revealed where potential exists for streamflow enhancement by changing withdrawal/diversion patterns. Potential for streamflow enhancement exists in subbasins where the water right allocation was substantial. These basins would benefit from a detailed mapping of water rights to identify alternatives for streamflow enhancement water management strategies.

SECTION 4: DATA GAPS/RECOMMENDATIONS

4.1 INTRODUCTION

Eventually a plan for long term protection or restoration of water quantity, quality, and fish habitat will be developed for the Chehalis Basin watershed. This will require; assessing water resources with respect to projected growth and use in the basin, managing groundwater withdrawals, evaluating the potential for flow augmentation, and selecting areas to target for water quality or fish habitat improvement. It will also require prioritizing amongst and between these issues.

To make these decisions, the CBP will need to understand on a subbasin level; the interaction of groundwater and surface water, the relationship among water rights and existing and predicted water use, and the relationships between water quality, quantity, and fish habitat and their priority in each subbasin. This Level 1 Assessment provides a synthesis of available information and preliminary analysis. The next step will be to prioritize subbasins for further assessment and define the data gaps or recommendations that are critical to that subbasin. Then a more rigorous and focused assessment of the key issue(s) can be completed at a scale more appropriate for decision making.

The following is a summary of the key data gaps and recommendations identified during the Chehalis Basin Level 1 Assessment. Recommendations for Level 2 Assessment are generally based on an identified data gap. However, not all data gaps identified have been listed as a recommendation for a Level 2 Assessment. As described at the conclusion of the previous chapter, assessment at the subbasin scale is much more appropriate for the Chehalis Basin. Likewise, the importance or priority given to a data gap or recommendation is highly dependent upon the subbasin being described. As a consequence the following is general in nature. Terms such as “may” or “could” are used because the significance of the data gap will vary widely by subbasin.

4.2 GEOLOGY AND HYDROLOGY

4.2.1 DATA GAPS

Geology

In the Chehalis Basin there is an increasing human reliance on groundwater and a growing recognition of the importance of groundwater in supporting stream flow. Information on groundwater and surface water interactions in the Chehalis would greatly increase our knowledge of the potential impacts of ground water withdrawals at the subbasin or basin scale. These interactions have been documented in portions of the Black and Middle Chehalis Rivers, and Scatter Creek, but not elsewhere in the Chehalis Basin. Due to the discontinuous nature of confining lenses within the glacial/alluvial deposits found in valley bottoms, interaction between surface and shallow groundwater bodies is variable. The nature of the surface deposits in the major river valleys suggests a high degree of ground/surface water continuity throughout the basin but much diversity, with respect to discharge/recharge timing, volumes and relative contribution to surface flows, between and within these valleys.

Hydrology

Hydrologic analyses rely heavily on time series of streamflow data and the Chehalis Basin is fortunate to have numerous streamflow stations distributed throughout the basin. However, 5 of the 30 subbasins do not have any record of streamflow in the basin and several others have only a few years of record. Hydrologic analyses can be undertaken in Level 2 to estimate flows in these ungaged subbasins in the absence of collecting new data. Future management decisions however, would be facilitated if streamflow gages were installed or re-instated coincident with the instream flow control points of primary fishery concern.

Insufficient streamflow data existed on the South Bay tributaries (Johns, Elk, Charley) to determine representative unit runoff ranges in the Level 1 assessment. If fishery concerns exist on the South Bay tributaries, more streamflow data would be helpful.

4.2.2 LEVEL 2 RECOMMENDATIONS

Geology

- Investigate the interaction of groundwater with surface water in portions of the basin that have not been studied. Develop a hydrologic water balance for each subbasin to screen areas for issues related to groundwater and stream flow interactions.

- The use of three-dimensional modeling may be required on a subset of subbasins. Modeling should focus on subbasins which have: significant groundwater withdrawals, aquifer/geologic systems with some information available, and, which after additional fisheries work, are identified as flow limiting from a habitat perspective.

Hydrology

- Estimates of undepleted streamflow were developed for 4 of the 30 subbasins; Level 2 efforts should continue developing undepleted streamflows for the remaining 25 subbasins to allow comparison of flow to allocated water. Subbasins should be prioritized for this analysis according to where low flows have been identified as a limiting factor for fish or where instream flows are difficult to meet.

- Estimates of undepleted flow may require additional investigation into the influence of regulation by upstream dams on the streamflow records, and documentation of the amount of upstream diversions.

- The analysis of subbasins that were predominately forest indicates that instream flow targets for some basins should be re-examined since these targets are not met, or just barely met, by the naturally existing streamflows.

- More detailed investigation of hydrologic change as affected by land use changes would be beneficial. This investigation should assess the changes in land use and watershed conditions over the length of the gage records as well as against historic (pre-gage) conditions.

4.3 WATER RIGHTS/ WATER USE

4.3.1 DATA GAPS

Information regarding water rights in the Chehalis Basin were derived from the WDOE's WRATS and GEOWRATS databases. Short of reviewing each and every water right document, these databases contain WDOE's current state of information on water rights. However, the databases do not contain some critical information on allocated amounts and withdrawal locations, and, if results from other basins in Washington State are an indicator, the database can be incomplete (i.e. does not contain some water rights that exist on paper). Additionally, locating water right diversions/withdrawals based on the Q/4-Q/4 section (as in the WDOE databases) is inexact and actual withdrawal or diversion locations are sometimes undefined. In subbasins where allocation amounts are high (e.g. Newaukum), it may be prudent to conduct a detailed mapping of the water rights, including point of diversion and place of use based on the detailed legal description recorded on the actual water right documents.

There is also a lack of information pertaining to actual water use; actual use numbers are generally not available and therefore, the estimates used in this document were based on numerous assumptions, which yielded coarse-scale estimates. This may be especially important for the larger rights holders or those that have been identified as having unusually high allocated or unused amounts, such as irrigators.

An additional data gap is the service area boundaries for the public water systems serving populous within the Chehalis Basin.

4.3.2 LEVEL 2 RECOMMENDATIONS

- Focus the next phase of assessment on subbasins where potential exists for flow augmentation. For example, in areas where agricultural uses are on the decline, there may be some rights that can be relinquished or conservation techniques implemented to save water. In subbasins with storage rights or a reservoir, opportunity may exist to augment low flows downstream of the impoundment.

- Comparison graphs of allocated water (both out-of stream demands and in-stream demands) versus "natural" streamflow are a good tool for prioritizing future efforts. These were completed for the five selected subbasins and revealed that some warrant further investigation (e.g. Newaukum), while others may not require further study (e.g. Chehalis headwaters, and the Humptulips). Comparison of consumptive allocated amounts to monthly exceedance values should be completed for the remaining subbasins to determine the potential for flow enhancement.

- Refine estimates of actual water use versus water rights. Prioritize by largest rights or those representing 90% of the allocated water. Determine the status of the rights that potentially have not been developed.
- Obtain service area boundaries for public water systems and plot to determine subbasin location for place of use. Obtain actual use records, if available.
- Determine the actual irrigated area in each WRIA and in each subbasin by engaging the partnership to assist in developing communication with the farm community. This may require an intensive field and aerial photo survey.
- Investigate the status of larger rights to understand the actual and consumptive use of the water withdrawn.
- Conduct additional mapping of water rights for subbasins with larger allocations (e.g. Newaukum).
- Subbasins undergoing rapid development that also have high agricultural use should be prioritized for detailed water rights analysis. This should include quantifying actual water use in agricultural area, and quantifying exempt well use.
- Update and revise the WRATS database.

4.4 WATER QUALITY

4.4.1 DATA GAPS

While the Chehalis River watershed is one of the more highly sampled basins in Washington, water quality data (including data that meets the needs for long-term trend analysis) is not available for all subbasins. Due to the diversity of conditions across the basin, water quality in un-monitored subbasins cannot necessarily be extrapolated. Thus, water quality cannot be adequately characterized in many of the subbasins, particularly those in the outer harbor.

The water quality data collected is primarily in the form of "grab" samples that represent one point in time and not necessarily the range of conditions. Data sets with longer periods of record generally compensate for this lack. However, for parameters that experience a critical seasonal or diurnal fluctuation, data may be missing during periods of greatest concern.

The natural impact of the Centralia Reach on downstream water quality and an accurate definition of an expected baseline condition within the reach are currently unknown. Also, monitoring at the Montesano station on the mainstem Chehalis River was interrupted in 1992. This station is particularly critical as it represents the cumulative impacts of activities upriver of most of the tidal influence.

Other data gaps in water quality include; an analysis of Grays Harbor water quality, which was not performed for this Level 1 Assessment, and an analysis of point source loading based on reported discharge characteristics. Also, assessment of additional parameters, such as heavy metals and pesticides, may be beneficial in selected subbasins.

4.4.2 LEVEL 2 RECOMMENDATIONS

- Enhance monitoring of water quality in areas where data does not exist or water quality is degraded. Monitoring the water quality of the subbasins that discharge to the south shore of Grays Harbor and updating the monitoring on the Wynoochee and Wishkah Rivers would ensure that basins with higher pollutant yields specified in this study are appropriately identified and prioritized for action.

- Rank subbasins for prioritization based on level of water quality impairment and relationship with other technical issues.

- A pollutant yield analysis for priority subbasins should be developed based on more detailed hydrologic assessments. This should be used to identify major pollution sources and prioritize improvement actions.

- An outcome of the Grays Harbor bacteria TMDL was recommendations for FC bacteria load reductions in rivers that already have quite low concentrations. These recommendations should be examined against other watershed priorities.

- Prioritize water quality improvement actions and accompany with verification monitoring to demonstrate improvements.

- Establish long-term water quality monitoring stations in one or two places likely to represent a baseline condition that can be used for comparisons.

4.5 FISH HABITAT/CHANNEL MODIFICATIONS/STOCKS

Due to the USFWS/WDFW extensive survey of 1,500 stream miles in the Chehalis watershed, as well as available watershed analysis information for some watersheds, only a small number of data gaps were found. Representatives of the co-managers of the fisheries resources and responsible federal agencies (WDFW, Quinault Indian Nation, Chehalis Tribe, USFWS, NMFS) may have identified research and monitoring needs from a fisheries management perspective that are not summarized here. In addition, the Limiting Factors Analysis process will identify data needs for the Chehalis watershed, and make recommendations for further data collection. This section should be seen as a contribution to those ongoing efforts, not as a summary of them.

4.5.1 DATAGAPS

Smaller scale modifications such as riprap are difficult to detect from aerial photos. Additional field work and historical trends photo analysis would greatly increase knowledge concerning channel processes and conditions.

Little information was found regarding current habitat conditions and trends for the South Bay tributary streams (which include Andrews, Elk and Barlow Creeks, the Johns and Newskah Rivers, O'Leary, Indian, Stafford, Chapin and Charley Creeks), or the Wishkah and Hoquiam Rivers and their tributary streams. Some historic information was available for each of these systems. An initial assessment of current habitat conditions, problems, and opportunities should be made in order to assist in identification and prioritization of restoration efforts.

Information exists regarding formerly connected side channels, wetlands, and sloughs in the lower Chehalis mainstem, Wynoochee and Satsop floodplains. This information has been used to identify and prioritize habitat improvement projects. If a similar survey took place in the mainstem Chehalis, for instance between Satsop and Doty, additional opportunities for reconnecting of formerly connected channels or wetlands, or other habitat improvements, may be identified.

4.5.2 LEVEL 2 RECOMMENDATIONS

- An assessment of current habitat conditions, problems, and opportunities, for the South Bay tributary streams, the Wishkah and Hoquiam Rivers, would be an asset to identification and prioritization of restoration efforts. Data collection should be focused on areas where potential restoration actions are likely.

- An assessment of formerly connected side channels, wetlands, and sloughs in the mainstem Chehalis River valley and floodplain upstream of the existing survey (Ralph et. al. 1994) could be used to identify additional restoration opportunities such as reconnection of wetlands or channels, as well as other habitat improvements. One area for consideration is the reach between Satsop and Doty.

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GLOSSARY

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

Adfluvial: Migrating between spawning areas in streams and rearing areas in lakes or marshes.

Alluvial: deposited by moving water.

Alluvium: Material deposited by running water, including the sediments laid down in riverbeds, flood plains, lakes and estuaries.

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

Annual peak flood: The highest peak discharge in a given year.

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

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

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

BOD: Biochemical Oxygen Demand

Canopy closure: A measurements of amount of shading over the stream. Inverse of view-to-the-sky (percent open sky).

Canopy cover: The overhanging vegetation over a given area.

CFS: Abbreviation for cubic feet per second, a measurement of streamflow volume.

cfu: Coliform Units (refers to the number of fecal coliform bacteria)

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

Channel gradient: see stream gradient.

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

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

Channel structure: see geomorphic structure

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

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

Colluvial: Loose deposits of soil and rock deposited by gravity.

Confinement: A description of how much a channel can move within it's valley before it is stopped by a hillslope or terrace.

Creep, soil: Slow, continual downslope movement of mineral, rock and soil particles under the influence of gravity.

Crown closure: A measure of the amount of tree canopy cover in a given area.

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

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

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

Diurnal: daily, over a daily cycle.

DO: Dissolved Oxygen

Downcutting: when a stream channel deepens over time.

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

Drainage density: see stream density

Earthflow: Deep-seated landslide of broken soil and rock, produces areas of hummocky terrain.

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

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

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

Eocene: an early epoch of the Tertiary geologic period.

Ephemeral (intermittent) stream: A stream that flows only certain times of the year, as it receives water from springs or a surface source.

Estuarine: pertaining to, or in, an estuary.

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

FC: Fecal Coliform

Fish life stage: see life stage

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

Flood desynchronization: When flooding is delayed by temporary water storage in wetlands.

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

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

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

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

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

Geomorphic structure (channel structure): For a stream channel, a description of how the channel is shaped in response to processes like erosion, and by underlying geology.

Hardwood trees: Deciduous trees. For example, bigleaf maple, red alder, flowering dogwood, paper birch, bitter cherry, willow, cottonwood, Oregon ash, and laurel, among others.

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

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

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

Hydrologic Units (HUCs): U.S. Geological Survey Hydrologic Unit Codes, which correspond with specific watersheds, and are expressed in a hierarchical scale.

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

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

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

IN: Inorganic Nitrogen

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

Lag time: The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff. It is the delay between the upstream production of flow and its arrival at a downstream location.

Large Woody Debris (LWD) recruitment: The amount or size of large trees in a riparian area that could potentially fall in (recruit) to the stream channel. Mechanisms for recruitment include small landslides, bank undercutting, windthrow during storms, individual trees dying of age or disease, and transport from upstream reaches.

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

Legacy activities: Past land use practices, which have contributed to current watershed and stream channel conditions.

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

Losing reach: Stream reach where surface water is flowing out of the stream channel to become groundwater.

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

Meandering: When a stream channel moves across laterally it’s valley.

Microhabitat: Specific combination of habitat elements in the place occupied by an organism for a specific purpose (such as feeding, refuge, reproduction).

Miocene: a later epoch of the Tertiary geologic period.

NMFS: National Marine Fisheries Service

ODF: Oregon Dept. of Forestry

ODFW: Oregon Dept. of Fish and Wildlife

Oligocene: an epoch of the Tertiary geologic period, between the Miocene and Eocene epochs.

Orthophotos: A composite photograph compiled from a series of aerial photographs, where displacements from ground relief and slope are removed, and objects are in the same relationship to one another as they would be on a map. Because the photo scale is standardized, measurements of distance and area are much easier using this type of photo.

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

Perennial stream: A stream that flows throughout the year.

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

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

Raindrop splash: Erosion created when a raindrop hits a bare soil surface.

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

Raveling: Erosion caused by gravity. Often seen on steep slopes immediately uphill of roads.

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

Reference reach(es): Stream reaches where past protection (for instance, national parks or wilderness areas) or current land use (for instance, roadless areas) allows condition to be used as a reference to natural or undisturbed conditions. Designation of reference reaches should be done with care; effects of stream channels from past land uses (such as mining) exist in many areas protected today.

Regulation: A governing direction or law.

Resident fish: Non-migratory fish that remain in the same stream network their entire lives.

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

Riparian area: Areas bordering streams and rivers.

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

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

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

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

Seven-day maximum average temperature: An average of seven consecutive days of water temperatures. The maximum of these values is used to determine whether water temperatures meet state standards at a given place.

Sideslope: Hillslope that borders a stream channel.

Snow-water Equivalent (SWE): The depth of water contained in the snowpack, if the snowpack were melted, expressed in inches.

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

Specific heat (of water): The amount of heat required to make a one-degree change in water or air temperatures.

Splash Dam: a type of logging dam, where water and logs were stored upstream of the dam until the dam was opened. Using floodgates or dam destruction, the stored water was used to transport timber to downstream mills.

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

SSGIS: Oregon State Center for GIS

Stade: a substage of a glacial stage, when a glacier advances.

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

Stereographic: For photographs, aerial photographs taken along a parallel flight track so that objects appear to be three-dimensional when viewed through stereoscopic lenses.

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

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

Stream terrace: One of a series of level surfaces in a stream valley, alongside of and mostly parallel to the stream channel. These are remnants of valley floors, floodplains or streambeds that were produced in the past.

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

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

TES: Threatened or endangered species.

Till: A mixture of clay, sand, silt, gravel and boulders deposited by a glacier.

TMDL: Total Maximum Daily Load

TN: Total Nitrogen

TN:TP: Ration of Total Nitrogen to Total Phosphorous

TP: Total Phosphorous

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

TSS: Total Suspended Solids

Tuff: a generic term for consolidated pyroclastic (formed by a volcano) rocks.

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

USFWS: United States Department of Fish and Wildlife Services

USGS: United States Geological Survey

View-to-the-sky (percent open sky): A measurement of amount of shading over the stream. Inverse of canopy closure, expressed in percent (100% - canopy closure).

Water Right Certificate: A *water right certificate* is issued by the Department of Ecology to certify that water users have the authority to use a specific amount of water under certain conditions. These conditions are based on beneficial use of water under your water right permit. The water right certificate is a legal document recorded at your county auditor's office. The certificate completes the process of obtaining your water right. Once a certificate is issued, no expansion is allowed under the water right.

Water Right Claim: A *water right claim* is a statement of claim to a water use that began before the State Water Codes were adopted and is not covered by a permit or certificate. A claim may represent a valid water right if it describes a surface water use that began before 1917 or a ground water use that began before 1945, a water right claim that was filed with the state during an open filing period designated under RCW 90.14 (the Water Rights Claim Registration Act), or is covered by the ground water exemption.

Water Right Permit: A *water right permit* is permission given to water right applicants by the state to develop a water right. Water rights are developed when water right applicants follow the provisions outlined in their permit, using water for the purposes and up to the limits stated in the permit. Water right permits remain in effect until the water right certificate is issued, if all terms of the permit are met, or the permit has been canceled.

Water Year: The water year in North America is the twelve month period beginning October 1 in one year and ending September 30 of the following year. The water year is designated by he calendar year in which it ends.

Watershed: an area of land that drains down slope to the lowest point. Drainage pathways may converge into a stream or river, or may end in a marsh or ancient lakebed.

WDFW: Washington State Department of Fish and Wildlife

WDNR: Washington State Department of Natural Resources

WDOE: Washington State Department of Ecology

WDOH: Washington State Department of Health

WRIA: Water Resources Inventory Area

APPENDIX A: *SURFACE AND GROUND WATER QUANTITY*

INTRODUCTION

Appendix A presents the technical reports for the surface water and ground water quantity portion of the Chehalis Basin Level 1 Watershed Assessment. Information found in the technical summary report is gleaned from the technical depth presented herein.

GROUND WATER HYDROLOGY

The geology and associated hydrogeologic conditions of the Chehalis Basin vary widely and reflect the complex geologic history of the area. The basic geology of the basin can be summarized as older bedrock of both sedimentary and volcanic origin exposed on hillslopes and ridges, with more recent depositions of glacial and alluvial sediments overlying these rock units in the valley bottoms and lowland prairies. Groundwater in substantial quantities is present in the glacial deposits, as well as alluvial sediments in the major river valleys.

GEOLOGY

Bedrock

The bedrock sequence from oldest to youngest in the Chehalis Basin starts with Eocene epoch basalt flows which covered the region. A fluctuating sea level also allowed deposition of sediments over the volcanic material, forming sedimentary rocks belonging to the McIntosh formation. Over time, younger sedimentary rocks known as the Lincoln Creek, Astoria, and Montesano formations were deposited over earlier sediments as well as the volcanic material. These units vary in composition and extent, often existing in interbedded layers and discontinuous beds. These bedrock units underlie the entire basin and define the surficial lithology of most of the upland areas of the basin.

The largest block of volcanics, which have not been covered by sedimentary deposits or inundated by glacial or alluvial material, comprises the Black Hills west of the Black River (Walsh et al., 1987). Two other blocks of old volcanic rocks (Eocene epoch) are located in the Doty Hills, as well as the headwaters of the rivers draining the south slope of the Olympic Mountains (Humptulips, Wynoochee, and Satsop Rivers north of township 20N) (Huntting et al., 1961). These rocks are fine to coarse grain basalt flows and breccia (Crescent formation).

Other volcanic rocks in the basin include andesite flows and associated breccia from this same epoch. These comprise the headwaters of the Skookumchuck and Newaukum Rivers. Subsequent weathering of this bedrock produced unconsolidated material, which filled the valley bottoms and was reworked by streams in the basins.

The other significant bedrock units which have not been inundated by glacial and/or alluvial material are of sedimentary origin. These sedimentary rocks can be roughly divided into two groups based on their age. The older group of sedimentary rocks (McIntosh formation and later the Lincoln Creek formation) are from the Oligocene/Eocene epoch. The older McIntosh formation can be found in the Lincoln Creek and South Fork Chehalis subbasins, while the Lincoln Creek formation occupies the terraces on either side of the Chehalis River west and southwest of the Black Hills. The Lincoln Creek deposits are often basaltic sand and siltstones, approximately 2,000 to 4,000 feet in thickness (Beikman et al., 1967).

The younger sedimentary rocks are from the Miocene epoch (Astoria and Montesano formations) and occupy a north/south running band roughly 12 miles in width between the Wynoochee and Satsop Rivers in the north and the central Willapa Hills in the south. These marine sedimentary units consist of moderately consolidated sand and siltstone (Huntting et al., 1961). Given their distribution, this unit likely underlies the alluvial material in the mainstem Chehalis valley downstream from the confluence of Cloquallum Creek. Sedimentary rocks, which are non-marine in origin, are also present in the Hoquiam River drainage and scattered throughout the Chehalis Basin.

Glacial/Alluvial Sediments

Although the Chehalis Basin is underlain by these bedrock units and associated sediments, the surface features of much of the basin, as well as the prominent aquifer characteristics, are the result of more recent glacial and alluvial processes. The results of these processes are evident in the valley bottoms and prairies, where a number of glacial advances and retreats, as well as redistribution of sediments by meltwater and modern river channels has left a thick layer of sediment. The thickness, composition, and density of these deposits varies greatly, as does the hydrogeologic characteristics of the deposits.

Depending on location, the Chehalis Basin has been glaciated three or four times during the Pleistocene epoch (Crandell, 1964, Moore, 1965). These events include alpine glaciers, which flowed south from the Olympic Mountains, as well as the Vashon Stade of the Fraser glaciation, which filled Puget Sound and the northeast portion of the Chehalis Basin. Sediment deposited from the earlier glaciations has been reworked and often compacted by subsequent glaciations.

The first major glaciation occurred early in the Pleistocene epoch (800,000 to 1,600,000 years ago) and left deposits known as the Logan Hill formation (Garrigues et al., 1998). This formation is likely an outwash plane from alpine glaciers (Weigle and Foxworthy, 1962). This unit is composed of poorly sorted gravels and sand that can exceed 150 feet in thickness. In most areas, it is covered by a thicker layer of more recent sediments. It is, however, mapped as the primary lithology in much of the middle and lower Newaukum River basin (Walsh et al., 1987).

More recent pre-Fraser glacial deposits have been identified as Salmon Springs or Penultimate drift (Sinclair and Hirschey, 1992). The drift is composed of discontinuous till and poorly sorted silt, sand, and gravel. Again, these deposits are mostly inundated by more recent glacial material, but significant surface or near surface deposits occur north of Tenino. Scattered pockets of this material can also be found in terraces along the lower Chehalis River, occupying narrow bands between the bedrock uplands and the alluvial sediments of the mainstem valley floor. Thickness of the deposits likely ranges from 15 to about 60 feet (Drost et al., 1998).

More recent glaciations occurred between 13,000 and 15,000 years ago and consist of the Vashon Stade of the Fraser glaciation and alpine glaciers flowing south from the Olympic Mountains. The Vashon Stade was part of a larger glacial system, which filled Puget Sound and moved south from British Columbia. The glaciers reached their southern extent near Scatter Creek in Thurston County, likely halted by bedrock at the land surface (Drost et al., 1999). To the west, the ice sheet was halted by the volcanic rocks of the Black Hills, but extended around the hills to the East Fork of the Satsop River.

Glacial material, including till, outwash, and undifferentiated materials, was deposited by the Vashon Stade in the lowland areas of Thurston County and Lewis County north of Centralia. Till is composed of a poorly sorted, very compact mix of gravel, sand, and silt which often impedes vertical movement of water. It often overlies more permeable outwash material, and can be discontinuous, thereby allowing surface water to move through to aquifers below. Outwash also consists of a mix of gravel, sand, silt, and clay, but tends to be much more permeable. Outwash can be further differentiated as advance or recessional deposits. Advance deposits are those which have be reworked by the glacier, while recessional deposits have not been reworked and are considerably more porous.

These glacial deposits are discontinuous, often occurring in alternating beds of varying thickness. Local variation in the till/outwash layering sequence is considerable, but some general patterns emerge. For example, the deposits in the Scatter Creek area tend to be permeable outwash gravels. To the north, in the Beaver Creek area, glacial till tends to dominate, while outwash sands are common north of Beaver Creek. Thickness of the deposits in this area range from about 10 to 60 feet (Drost et al., 1998). In the lower Black River, glacial and recent alluvial sediments average about 100 feet in thickness.

As the glacier advanced south, it dammed the Chehalis and Newaukum Rivers near Centralia, forming a large lake (Bretz, 1913). The resultant lacustrine deposits are not exposed at the surface, and consist primarily of sand, silt, clay and some organic matter. Eventually the lake was breached, sending water southwest and west through the valley of the Chehalis. Large volumes of unconsolidated material were moved and deposited in the broad valley of the mainstem and low lying tributary valleys downstream.

Alpine glaciers descended south from the southern Olympic Mountains at least four times during the Pleistocene epoch (Crandell, 1964). These glaciers moved down the major river valleys, depositing a mix of till and outwash material. Glaciers reached their southern extent in the Humptulips Valley near the confluence of the East and West Forks (Crandell, 1964), but outwash from the older of these glaciations is evident south into Township 19 (Walsh et al., 1987). Alpine glaciers also descended into the Wynoochee and Satsop basins, depositing drift as far south as the northern portion of Township 19. Alluvial forces have reworked glacial deposits in the valley floor of all of these basins.

The most recent geologic unit mapped in the Chehalis Basin is alluvial material. This unit consists primarily of unconsolidated sand and gravel along major river and stream courses. The valley floor of the Chehalis, Black, and Newaukum Rivers contain significant deposits. The alluvium is often mixed with glacial outwash material, producing a permeable matrix roughly 100 feet in thickness near the confluence of the Black and the Chehalis Rivers. Downstream in the Chehalis valley, these sediments reach up to 200 feet in depth. Depending on location, this material rests on older glacial deposits or tertiary sedimentary or volcanic bedrock. Alluvial deposits also comprise the valley floor material in the rivers draining the southern Olympics. The depth and composition of these deposits is not well studied, but it can be assumed that they are largely unconsolidated and poorly sorted.

HYDROGEOLOGY

Hydrogeologic conditions within the Chehalis Basin are quite diverse, due in large part to the complex geologic history of the area. Groundwater conditions in the Newaukum, Black, middle Chehalis Rivers, as well as the Scatter Creek area have received considerable study (Drost et al., 1998, Drost et al., 1999, Erickson, 1993, Garrigues et al., 1998, Weigle and Foxworthy, 1962). These areas provide significant quantities of groundwater from a series of aquifers present in the relatively shallow glacial and alluvial deposits. Much less is known about deeper aquifers and groundwater conditions in the older deposits and bedrock elsewhere in the basin. The following discussion parallels the geologic text presented above, starting with information on hydrogeologic conditions in the bedrock units.

Bedrock

As stated above, detailed information on hydrogeolgic conditions in the bedrock underlying the basin is not available. In general, however, bedrock units do not contain significant quantities of water, and are largely impermeable (Garrigues et al., 1998). Water of some quantity exists primarily in fractures and contact zones, often near the top of the bedrock unit. In the upper portions of the Chehalis valley, wells drilled into the tertiary marine sedimentary bedrock have yielded only small quantities of water, while wells tapping the younger, non-marine sedimentary rocks generally produce moderate quantities of water (Van Denburgh and Santos, 1965, Weigle and Foxworthy, 1962). Considerable local variation exists in the quantity of water available from bedrock. In Thurston County, only about 5 percent of 1,100 wells studied are located in this unit (Drost et al., 1999). Wells tapping water in fractures in bedrock zones tend to be over 250 feet in depth.

Glacial/Alluvial Sediments

These sediments contain the principle aquifers within the Chehalis Basin. As expected, these deposits contain a complex mix of compacted glacial material, which confines aquifers, as well as unconsolidated material through which water moves relatively freely. The following discussion follows the geologic discussion presented above, with the older, deeper deposits discussed first.

In many areas of Thurston and Lewis County, pre-Fraser sediments of glacial and non-glacial origin exist between the bedrock and more recent glacial deposits. These older sediments, such as the Logan Hill Formation, possess lenses of unconsolidated deposits which can hold moderate amounts of groundwater. These lenses are often bound by denser layers which form effective aquitards. Groundwater conditions in these deposits have not received as much study as conditions in the overlying, younger deposits which often possess more well developed aquifer systems. Approximately 15 percent of the 1,100 wells studied extensively in Thurston County tap aquifers in these older, deeper deposits (Drost et al., 1998).

Other pre-Fraser glacial deposits which contain groundwater are labeled as the Salmon Springs or Penultimate drift. Depending on location, these deposits can possess large aquifer systems, and contain approximately 35% of the wells studied in the Thurston County area (Drost et al., 1998). In most areas, the aquifer is confined, but where an overlying confining unit is absent, this aquifer merges with aquifers in the more recent deposits, forming a thick productive aquifer. The aquifer is generally about 30 feet in thickness.

Of the most recent series of glaciations in the basin, deposits of the Vashon Stade which cover part of the middle Chehalis Basin (including the Black River and Scatter Creek areas), likely contain the most extensive groundwater bodies. These deposits have been tapped by the greatest number of wells and have received the most study.

The greatest quantity of groundwater exists in the recessional and advance outwash in this area, with lesser amounts present in the till, which acts as a discontinuous confining layer. The aquifer varies in thickness between 10 and about 150 feet, although it may reach 200 feet in places (Weigle and Foxworthy, 1962). Of the 1,100 wells studied in Thurston County, the median well depth is about 105 feet (Drost et al., 1998).

Other aquifers in the Chehalis Basin have received less study and are associated primarily with alluvial deposits in the major river valleys. In the Chehalis river valley upstream of Adna, the surface aquifer is between 4 to 10 feet in thickness. Aquifer thickness increases to about 90 feet downstream in the area northwest of Centralia (Larson, 1994). Depth to groundwater in the valley floor varies considerably, but commonly ranges from 10 to 30 feet (Garrigues et al., 1998).

Downstream from Oakville to Elma, the Chehalis valley is underlain by an aquifer composed of coarse alluvium and reworked glacial material. The aquifer is typically less than 20 feet from the ground surface and highly productive. Further downstream to Grays Harbor, the valley aquifer tends to be thicker due to the increased depth of deposits. Groundwater can typically be found at about 20 feet below the ground surface, with the aquifer extending down approximately 200 feet. The lower 100 feet of the aquifer typically produces water in greater quantity when tapped by wells.

Surficial aquifers can also be found in the tributary stream and river valleys. Depending on the basin, these aquifers are held in glacial and/or alluvial deposits that are thinner and more discontinuous than those associated with the Chehalis River. As these aquifers are not used to the extent of those in the Chehalis and Black River/Scatter Creek valleys, less is known about their characteristics. Typically, groundwater in the Wynoochee and Satsop valleys is within 20 feet of the ground surface, and may extend through the alluvial deposits, which can range up to 30 feet in thickness (Rau, 1967).

Table A-1 contains information concerning the dominant geologic and groundwater conditions for each of the 30 Chehalis subbasins.

Table A-1. Chehalis subbasin geology and groundwater summary

Subbasin no.	Subbasin name	Dominant geology	Groundwater summary
1	Chehalis River Headwaters	The upper three quarters of the basin is Eocene epoch basalt rocks (Crescent formation) and tuff. There is a small area of Eocene marine sedimentary rocks (McIntosh formation) in the southwest corner of the subbasin. The lower quarter of the basin is younger Eocene marine sedimentary rocks (Lincoln Creek formation) with alluvium in valley bottoms.	The upper three quarters of the basin likely contains minimal amounts of groundwater in fractures of dense bedrock. There is likely a limited shallow aquifer in alluvium at the north end of basin.
2	Elk Creek	The north half of the basin is Eocene epoch marine sedimentary rocks (Astoria formation) with alluvium in the valley bottom. The foothills in the south portion of the basin are Miocene Grande Ronde Columbia River basalt. The foothills in the extreme north corner of the subbasin are Eocene basalt (Crescent formation).	Sedimentary rocks in most of the basin are generally thought to provide limited, discontinuous groundwater at considerable depth. A shallow aquifer in alluvium in the valley bottom likely interacts with Elk Creek.
3	South Fork Chehalis River	The majority of the basin is Eocene epoch marine sedimentary rocks (McIntosh formation) with alluvium in the valley bottoms. The hill slopes west of the river are Eocene basalt intrusives.	The bedrock units on hillslopes provide limited quantities of groundwater; there is likely more water present in sedimentary rocks in the east half of basin than in the west half. There are likely increasing quantities of groundwater in the shallow alluvial aquifer as you progress north (downstream). A significant valley bottom aquifer is present in the northern 3 miles of the subbasin.

Table A-1 (Continued). Chehalis subbasin geology and groundwater summary cont.

Subbasin no.	Subbasin name	Dominant geology	Groundwater summary
4	Upper Chehalis River	Numerous units are present; the hillslopes are generally older marine sedimentary rocks (Lincoln Creek formation) with volcanic material along the footslopes. Stillman Creek is underlain by volcanics.	The largest aquifer in the upper basin is likely associated with the mainstem Chehalis valley alluvium. Varied conditions exist elsewhere in the basin.
5	South Fork Newaukum	The lower quarter of the basin is glacial outwash from pre-Fraser glaciations (Logan Hill formation). The upper portion of the basin is Eocene epoch andesite flows with pockets of non-marine sedimentary rocks from the same epoch.	Groundwater in any quantity is likely only in the lower part of the basin as either a surface alluvial or deeper confined aquifer associated with the Logan Hill formation.
6	North Fork Newaukum	The upper two thirds of the basin is Eocene epoch andesite flows. The lower third is a mix of Eocene epoch marine and continental sedimentary rocks, with valley floor alluvium.	Groundwater in any quantity is likely only in the lower part of the basin as a surface alluvial aquifer.
7	Newaukum	The majority of the basin is glacial outwash from pre-Fraser glaciations (Logan Hill formation). Significant deposits of alluvium exist in the river valley (South Fork only) which decrease as you progress upstream.	The Logan Hill formation can produce significant quantities usually under confined conditions; not considered a surface aquifer. Well data indicate the valley surface alluvial aquifer is generally 10-20 feet below the ground surface.

Table A-1 (Continued). Chehalis subbasin geology and groundwater summary cont.

Subbasin no.	Subbasin name	Dominant geology	Groundwater summary
8	Salzer Creek	Eocene epoch marine sedimentary rocks (Lincoln Creek formation) underlie the majority of the basin. Alluvial deposits exist in the lower basin.	Groundwater in any quantity is likely only in the lower part of the basin as a surface alluvial aquifer.
9	Skookumchuck	The upper half of the basin is Eocene epoch andesite flows. The lower half is Eocene epoch continental marine sedimentary rock (Skookumchuck formation) with alluvial deposits in the valley bottoms.	Significant quantities of groundwater are unlikely in the upper basin. Thin aquifers are possible in the sedimentary rocks at depth. In the lower basin, well data indicate water in the alluvial aquifer is at depths of 20-30 feet.
10	Chehalis River	The upper half of the basin (Lincoln Cr.) is underlain primarily by continental sedimentary rocks from the Eocene epoch (Skookumchuck formation). The valley floor is mapped as alluvium. The Chehalis valley is a mix of alluvium and Vashon outwash gravel.	A shallow alluvial aquifer is likely in Lincoln Creek. In the Chehalis valley, alluvial and glacial material is up to 50 thick, with wells tapping a surface aquifer in the 10 to 40 foot depth range.
11	Black River	The majority of the basin is glacial deposits (approximately 100 feet in depth) from the Vashon Stade of the Fraser glaciation. Alluvial material exists along the river channel. The upper portion of Waddell Creek and other west side tributaries are mapped as Eocene epoch basalt (Crescent formation).	A significant, unconfined aquifer is associated with the Vashon glacial outwash. Aquifer located in the 40 to 120 feet of unconsolidated material. Exchange rates between groundwater and the River are available.

Table A-1 (Continued). Chehalis subbasin geology and groundwater summary cont.

Subbasin no.	Subbasin name	Dominant geology	Groundwater summary
12	Cedar Creek	The majority of the basin is Eocene epoch basalt (Crescent formation). Thin bands of marine sedimentary rocks Eocene (Lincoln Creek formation) are mapped near the mouth of the creek. Alluvium is found at the creek mouth.	Minimal aquifer development is likely except that associated with the Chehalis valley system, where water levels are generally 10 to 20 feet below the ground level.
13	Chehalis River	Most of the Scatter Creek basin is underlain by about 100 feet of Vashon outwash gravels. Some sedimentary rock (Skookumchuck formation) is mapped in the hillslopes to the south.	An extensive aquifer is associated with the glacial material. The aquifer is a well studied and productive system.
14	Cloquallum Creek	The upper two thirds of the basin is underlain by Vashon till in the headwaters, with Lincoln Creek formation and younger marine sedimentary rocks at the lower elevations. The bottom third is a mix of glacial and alluvial material.	A surface aquifer associated with the Chehalis valley is likely within 10 to 20 feet of the ground surface.
15	East Fork Satsop	The upper two thirds of the basin is mapped as Vashon till. Hillslopes in the lower basin are mapped as marine sedimentary rocks (Lincoln Creek formation).	Flow data indicate that a very high percentage of total flow is from groundwater input. There is likely a very shallow aquifer associated with the glacial till. There is limited aquifer development in the sedimentary rocks.
16	Decker Creek	The upper two thirds of the basin is mapped as Vashon till. Hillslopes in the lower basin are marine sedimentary rocks (Lincoln Creek formation) and older glacial deposits.	There is likely a very shallow aquifer associated with the glacial till. There is limited aquifer development in the sedimentary rocks. An alluvial aquifer exists in the lower basin.

Table A-1 (Continued). Chehalis subbasin geology and groundwater summary cont.

Subbasin no.	Subbasin name	Dominant geology	Groundwater summary
17	Middle Fork Satsop	Marine sedimentary rocks underlie the hillslopes west of the river, while the east side is pre-Vashon glacial drift.	There is likely a shallow alluvial aquifer with diffuse groundwater patterns in the bedrock.
18	Satsop River	The lower third of the basin is marine sedimentary rocks (Montesano formation). The upper basin is a mix of sedimentary rocks and older glacial material with volcanics (Crescent formation) in the headwaters.	There is likely a shallow alluvial aquifer with diffuse groundwater patterns in the bedrock.
19	Chehalis River	The valley floor is alluvium with some glacial material. Hillslopes south of the valley are mapped as sedimentary rocks. The Sand Creek basin is underlain by a mix of sedimentary rocks (Astoria and Lincoln Creek formations) and old volcanics.	The valley aquifer is well developed in thick alluvium. Water is usually within 10 to 20 feet of the ground surface. There is likely a small alluvial aquifer in Sand Creek.
20	Wynoochee River	The lower third of the basin is mapped as marine sedimentary (Astoria/Montesano formations) rocks and alluvial material. The upper basin is underlain by volcanic rocks of the Crescent formation.	A significant shallow aquifer is likely in the wide valley bottom in the lower basin. Highly variable groundwater conditions exist in the upper basin.

Table A-1 (Continued). Chehalis subbasin geology and groundwater summary cont.

Sub basin no.	Subbasin name	Dominant geology	Groundwater summary
21	Wishkah River	The lower third of the basin is bound by hills underlain by marine sedimentary rocks. The middle third is underlain by older alluvial sediments. The headwaters are a mix of glacial material and sedimentary rock.	A Significant shallow aquifer is likely in the wide valley bottom in the lower basin. Highly variable groundwater conditions exist in the upper basin.
22	Hoquiam River	The majority of the basin is underlain by non-marine sedimentary rocks with alluvium in the valley bottom.	Little information is available for the Hoquiam. There is likely a well developed alluvial aquifer in the lower basin.
23	Middle Fork Hoquiam	The majority of the basin is underlain by non-marine sedimentary rocks with alluvium in the valley bottom.	Little information is available for the Hoquiam. There is likely a well developed alluvial aquifer in the lower basin.
24	East Fork Hoquiam	The majority of the basin is underlain by non-marine sedimentary rocks with alluvium in the valley bottom. Older alluvium is mapped in the headwaters.	Little information is available for the Hoquiam. There is likely a well developed alluvial aquifer in the lower basin.
25	Humptulips River	Alluvium and glacial drift is mapped in the lower portion of basin. Crescent formation volcanics are mapped in the headwaters.	Little information is available for the Humptulips. There is likely a well developed alluvial aquifer in the lower basin.
26	Elks River	The majority of the basin is mapped as unconsolidated to partly consolidated marine terrace deposits. Recent alluvium is mapped in the major river valley bottoms.	The aquifer characteristics of terrace sediments are not well studied; well developed aquifer systems are unlikely. A small alluvial aquifer is likely.
27	Johns River	The majority of the basin is mapped as unconsolidated to partly consolidated marine terrace deposits. Recent alluvium is mapped in the major river valley bottoms.	The aquifer characteristics of terrace sediments are not well studied. Large aquifer systems are unlikely. A small alluvial aquifer is likely.

Table A-1 (Continued). Chehalis subbasin geology and groundwater summary cont.

Sub basin no.	Subbasin name	Dominant geology	Groundwater summary
28	Newskah Creek	The hillslopes in the lower half of the basin are Pliocene epoch unconsolidated to partly consolidated marine terrace deposits. Recent alluvium is mapped in the creek valley bottom and mouth. The hillslopes in the upper half of the basin are Miocene sedimentary rocks (Astoria formation).	Hillslopes likely do not have significant quantities of groundwater present. A small alluvial aquifer is likely.
29	Charley Creek	The hillslopes in the lower half of the basin are Pliocene epoch unconsolidated to partly consolidated marine terrace deposits (Astoria formation). Recent alluvium is mapped in the creek valley bottom and mouth. The hillslopes in the upper half of the basin are Miocene sedimentary rocks.	Hillslopes likely do not have significant quantities of groundwater present. A small alluvial aquifer is likely.
30	Chehalis River	The valley floor is alluvium approximately 100 to 200 feet thick. The footslopes are mapped as glacial outwash and sedimentary rocks (Astoria and Montesano formations).	A well developed unconfined alluvial aquifer exists in the valley floor. Ground/surface water exchange is assumed but unquantified.

WELL WATER LEVEL DATA

There are a number of sources of water level data for wells in the Chehalis Basin. Although numerous, the initial water level reported on the drillers log is a one time measurement with limited value. Although not presented at this level, these data could be accessed and evaluated in a Level 2 analysis.

The two other well level data sets available are from the Washington Department of Ecology (WDOE) and the US Geological Survey (USGS). There is some overlap between these data sets, but the degree of the overlap is not known. The WDOE data evaluated is a download of data for the WRIA and contains water levels for 208 wells, mostly taken within the past 25 years. Number of observations per well varies considerably, and the vast majority (88%) of wells were located in the Scatter Creek and Black River drainages. Table A-13 below presents the WDOE data by subbasin.

Table A-13. Summary of WDOE well water level data for the Chehalis Basin.

Subbasin number	Number of wells with data	Number of observations	Mean water level below ground surface	Median water level below ground surface	Water level range
5	1	82	21.9	22.5	22.1-43.4
7	5	462	31.0	28.9	0.4-98.0
8	1	158	10.4	10.2	5.3-15.7
9	2	21	29.8	31.0	22.1-43.4
10	2	189	6.8	6.7	0.7-11.5
11	46	953	32.5	35.3	0.1-114.0
13	136	4,935	23.7	23.6	0.2-68.7
19	4	71	21.2	20.9	5.3-33.8
26	11	469	15.4	10.7	5.0-36.0

All data in feet

As expected, most wells were drilled in the glacial outwash near the end of the Vashon ice sheet. These wells commonly reported water at depths of between 20 and 50 feet.

The majority of the USGS data set contains one-time water level measurements for wells within the basin. There was no way to request only data from those wells with multiple measurements. Well data for the five selected subbasins covers 411 wells, only 3 of which have more than one observation. These three are covered in the WDOE database. It is likely that the one time measurements are those reported in the drillers log (Fuste, pers. comm.). As stated above, these one time observations are not evaluated in the Level 1 analysis.

HYDRAULIC CONTINUITY-SURFACE/GROUNDWATER INTERACTIONS

The bulk of the groundwater within the Chehalis Basin is from direct infiltration of precipitation. In some cases, recharge from streams, lakes, and wetlands may add to aquifer volumes. The underlying geology of the basin suggests that for all but the deeper, regional aquifers, groundwater basin divides and movement roughly parallels that of surface water.

Commonly, groundwater associated with bedrock units either moves from the hillslopes to the valley floor, or infiltrates into fractures associated with rock folding and deformation. In most cases, groundwater held in bedrock units is too deep to interact directly with surface waters.

Water which moves to the valley floor enters alluvium and glacial drift where unconfined surface aquifers likely interact with the stream or river. The type and degree of this interaction can be complex. Variation with respect to discharge/recharge capabilities varies along the stream network as well as fluctuates seasonally in most basins. This variation is due in part to the stratification of confining and nonconfining layers resulting from glacial and alluvial processes.

While all subbasins in the Chehalis possess surface aquifers which interact with the stream or river, variation exists as to the degree of this interaction. Table A-3 presents the results of a study which attempts to define the contribution of baseflow to the total streamflow. Subbasins have been arranged in order of baseflow as a percentage of mean streamflow.

Table A-3. Chehalis Basin Baseflow Data

Subbasin number	Subbasin name	Median of annual means-baseflow as % of total flow
15	E.F. Satsop	77
11	Black River	75
10	Lincoln Creek	69
13	Porter Creek	68
22	SF Newaukum near Onalaska	67
6	NF Newaukum near Forest	67
13	Rock Creek	66
20	Wynoochee near Montesano	66
2	Elk Creek	65
20	Wynoochee at Oxbow	65
20	Wynoochee below Black Creek	65
14	Cloquallum Creek	64
29	Charley Creek	63
20	Big Creek near Grisdale	63
7	Newaukum near Chehalis	62
9	Skookumchuck near Vail	62
18	Satsop near Satsop	61
20	Anderson Creek near Montesano	61
28	Newshkah Creek	60
9	Skookumchuck below Centralia	60
19	Chehalis at South Elma	60
25	Humptulips near Humptulips	60
8	Salzer Creek	59
1	Chehalis near Doty	57
10	Chehalis near Grand Mound	56
3	SF Chehalis near Boisfort	55
13	Chehalis at Porter	55
3	SF Chehalis at Boisfort	54
	Mean	63
	Median	63

Data source: Sinclair and Pitz, 1999
Subbasin boundaries in Sinclair and Pitz (1999) may not correspond exactly with those mapped for the Chehalis Basin Partnership watershed assessment

Data in the table confirms that subbasins within the Chehalis rely heavily on baseflow contribution to streamflow. It is obvious that subbasins, which possess extensive glacial or alluvial deposits near the surface, support aquifers that interact with surface flows. The Black River, mainstem Chehalis, and lower reaches of the larger rivers all likely possess significant shallow aquifer systems which interact directly with the river. Basins such as the upper South Fork Chehalis and Salzer Creek, which lack significant unconsolidated deposits, likely rely less on groundwater inflow to maintain stream flow.

While the above information links groundwater and surface water flow, only limited study into direct measurement of this connection has occurred. Not surprisingly, surface/ground water interactions of the aquifers associated with the Black River/Scatter Creek and the Middle Chehalis River have received the most study. Surficial aquifers in these basins provide a significant portion of the stream flow during low flow periods. The greatest exchange of ground and surface water occurs in the glacial and alluvial deposits in the Black River/Scatter Creek/Chehalis River area. Lewis and Thurston Counties have recognized the direct link between surface and groundwater, as both counties have mapped the valley floors of the Chehalis and Black Rivers as moderate to severe Critical Aquifer Recharge Areas in terms of aquifer sensitivity. This sensitivity is due to the permeability of glacial and alluvial deposits which extend from the ground surface to the base of the surficial aquifers.

The surficial aquifer of the Chehalis River valley is connected directly to the river, with the river acting as a discharge point for the aquifer. Discharge from the aquifer to the river varies with location and season, but Erickson (1993) has calculated rates between 0.1 and 10.3 cubic feet per second per mile of river (cfs/mi) in the 26 miles of river downstream of the Thurston/Lewis County border. Sinclair and Hirschey (1992) measured inflow rates of 3.1 cfs/mi in this same area. In general, inflows increased as you move downstream due to increased aquifer thickness and greater hydraulic conductivity.

Both the Black River and Scatter Creek are also seasonal discharge points for the valley aquifers. While the Black and Chehalis Rivers receive the bulk of the groundwater discharge, Scatter Creek and a number of smaller creeks also receive inflow (Sinclair and Hirschey, 1992). Data collected over an eight month period indicated that inflows to a 16 mile reach of Scatter Creek varied from near zero to a high of 8.0 cfs/mi. Recharge from the creek to the aquifer during this same period ranged up to 5.6 cfs/mi (Sinclair and Hirschey, 1992). In general, the upper and lower portions of the creek are groundwater discharge points, while the central portion of the creek acts as a groundwater recharge zone. The Black River also receives considerable inflows from groundwater. Inflows measured during a period of low stream flow indicate that over a 5 mile reach, the Black gained an average of 1.8cfs/mi.

These types of interactions likely occur in every subbasin in the Chehalis. As stated earlier, the degree of this interaction elsewhere in the basin is unquantified, but unlikely to be of the magnitude of that observed in the Black River and central Chehalis. Depth and condition of the valley floor sediments dictate to a large degree the interaction between surface and groundwater.

SURFACE WATER HYDROLOGY

The Level 1 assessment of surface water quantity in the Chehalis Basin included several independent analyses which can be summarized under the following four headings:

- the compilation of available data (e.g. streamflow records, climate data, subbasin characteristics, and structural features);
- the analysis of gaged flows;
- the analysis of natural climate variability; and
- undepleted gage flows.

The products presented in this report will serve as building blocks for the Level 2 efforts.

The majority of these analyses were conducted at the basinwide scale, while others produced information by WRIA or are specific to certain subbasins. In many cases, this information will have to be refined at a subbasin level. A notable local example is the Black River Subbasin where the hydrology of the upper basin has been greatly modified. Although Black Lake historically flowed into the Black River, at the present, at least during the dry season, there is no surface water connection from the lake to the river, and the lake flows out of the Chehalis Basin toward Percival Creek (Berg, 1993). Some of the factors believed to be contributing to this change in hydrology include: a ditch built in the 1920s from Black Lake to Percival Creek to prevent flooding; a pipeline installed in the 1960s through wetlands at the southern end of the lake, which has formed a topographical high point; and several dozen beaver dams.

COMPILATION OF AVAILABLE DATA

The Chehalis Basin was fortunate to have a substantial amount of hydrologic and climatic data available for use in assessing watershed processes. Of particular notice, were the several streamflow stations which have been continuously monitored dating back to the early part of the 20th Century. Characteristics of current and historic streamflow and climate data stations located in or near the Chehalis Basin were identified and are presented below.

Streamflow Data

Systematic streamflow records were available at fifty-four locations in the Chehalis Basin with 30 in WRIA 23 and 24 in WRIA 22 (Tables A-1 and A-2). Map 4 displays the spatial location of each of these streamflow gaging stations. Few of these streamflow stations recorded flows unhampered by human uses. The actual flow at some of the stations may be near "natural" or undepleted by withdrawals, while many of the stations recorded flows that were substantially depleted from natural flows due to regulation or withdrawals of water for municipal, irrigation, or other uses.

The final column in Tables A-1 and A-2 provides remarks on the degree of regulation and diversion upstream of each streamflow station. The information portrayed in the final column was obtained primarily from the USGS gaging station remarks; the WDOE Water Supply Bulletin #60 (Sinclair and Pitz, 1999), and the WDOE GIS coverage of the dams in Washington provided some additional information. The diversion information from the USGS and WDOE addressed surface water diversions only; these data sources did not explicitly account for the degree of ground water withdrawals in a basin. Groundwater withdrawals in continuity with surface water sources could be depleting the surface water streamflow.

In addition to systematic streamflow data collection, numerous miscellaneous discharge measurements have been taken in the Chehalis Basin since the turn of the century. Miscellaneous measurements, taken by the USGS, the WDOE, and other local interests, will be useful during level 2 analyses. These data points could provide an excellent source of information for use in extending the period of record at streamflow gaging stations and estimating frequency information at a location without the benefit of continuous streamflow records.

Climate Data

Several climate stations within or near the Chehalis Basin (Table A-3) were reviewed for their usefulness in analyzing local climate trends and the resulting affect on streamflow in the Chehalis Basin. Map 4 displays the spatial location of each of these climate stations. Annual precipitation values were found to be available for the some of the stations (Aberdeen and Centralia stations) for the years where daily records were missing.

Subbasin Characteristics

Drainage area, elevation features, and mean annual precipitation characteristics were compiled for the 30 subbasins defined in the Chehalis Basin (Table A-4).

Structural Features

The investigation of structural features in the Chehalis Basin was limited to the identification of dams. The WDOE has available on its web site a GIS layer portraying attributes and location of the dams in Washington. According to this data source, seventy dams were located within the Chehalis Basin. Map 3 displays the location of these dams by subbasin and Table A-5 provides information on the dams by the map number listed on Map 3. The majority of the dams were concentrated around the City of Aberdeen, and in the Black and Skookumchuck River subbasins.

Table A-1. Streamflow Gaging Stations -- Lower Chehalis WRIA 22

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation (ft)	Remarks on Regulation and Diversions *= USGS Water Supply Bulletin #15 , 1962 Data source for all other Earthinfo 1994 CDRom
12016500	Little North R Cosmospolis	1946-49, 1953	18.6 mi^2	No remarks
12017500	Johns R nr Markham	1942-43	18.9 mi^2	No remarks
12018500	Charley Crk nr Aberdeen	1945-49	5.93 mi^2 20 ft	No remarks
12018000	Newskah Crk nr Aberdeen	1945-49	7.44 mi^2 40 ft	No remarks
12039000	Humptulips R nr Hump	1933-35 1942-79	130 mi^2 120 ft	No diversion above station Slight low flow regulation by fish hatchery on west fork*
12037500	Wynoochee R Blw Black Crk nr Montesano	1942-50	40 ft	No remarks
12037400	Wynoochee R Abv Black Crk nr Montesano	1956 – current	155 mi^2 179 mi^2 * 40 ft	1957-69 unregulated; 1969-72 some regulation from dam construction 1972-current regulated by Wynoochee Dam (45.7 mi upstream) Municipal water supply (City of Aberdeen) Small diversions for domestic and irrigation use
12036650	Anderson Crk nr Montesano	1972-85	2.72 mi^2 150 ft	No remarks
12036500	Wynoochee R nr Montesano	1923-30	112 mi^2	No remarks
12036400	Schafer Crk nr Grisdale	1987-96	12.1 mi^2 280 ft	No regulation or diversions upstream
12036000	Wynoochee R Abv Save Crk nr Aberdeen	1925-52; 1952-current	74.1 mi^2 401 ft	1925-52 unregulated (published as at Oxbow 12035500) 1952-69 unregulated 1969-72 some regulation from dam construction 1972-current regulated by Wynoochee Dam USGS adjusts some of the summary statistics for the change in contents of Wynoochee Lake No diversions upstream of station
12035500	Wynoochee R at Oxbow nr Aberdeen	1925-52	70.7 mi^2	No remarks
12035450	Big Crk nr Grisdale	1972-96	9.57 mi^2 600 ft	No regulation or diversions upstream
12035400	Wynoochee R nr Grisdale	1965-current	41.3 mi^2 630 ft	1965-69 unregulated 1969-72 some regulation from dam construction 1972-current regulated by Wynoochee Dam USGS adjusts some of the summary statistics for the change in contents of Wynoochee Lake No diversions upstream of station
12035380	Wynoochee Lake nr Grisdale	1972-current	41.0 mi^2	Lake created by dam; Useable Capacity 67,288 ac-ft between 690 ft (sluice gate invert) and 800 ft (full pool level)
12035002	Chehalis R nr Satsop	1977-83	1,761 mi^2 2.66 ft	No remarks

Table A-1 (Continued). Streamflow Gaging Stations -- Lower Chehalis WRIA 22

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation (ft)	Remarks on Regulation and Diversions *= USGS Water Supply Bulletin #15 , 1962 Data source for all other Earthinfo 1994 CDRom
12035000	Satsop R nr Satsop	1929-current	299 mi^2 sea level	No regulation or diversion upstream of station
12034200	E Fk Satsop R nr Elma	1957-71	65.8 mi^2 205 ft	No regulation or diversion upstream of station *
12034000	Bingham Cr nr Matlock	1946-49	30 mi^2	No remarks
12033500	E Fk Satsop R nr Matlock	1946-48	23.7 mi^2	No remarks
12033000	Chehalis R at South Elma	1942-45 1947-52	1,417 mi^2 15 ft	No remarks
12032500	Cloquallum R at Elma	1942-73	64.9 mi^2 20 ft	Small diversions on minor tributaries Some regulation by log pond –Wildcat Crk*
12032000	Wildcat Crk nr Elma	1944	19.8 mi^2	No Remarks
12030900	Porter Crk at Porter	1942-49	35.3 mi^2 60 ft	No remarks

Table A-2. Streamflow Gaging Stations -- Upper Chehalis WRIA 23

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation gage (ft)	Remarks on Regulation and Diversions *= USGS Water Supply Bulletin #15 , 1962 Data source for all other Earthinfo 1994 CDRom
12031000	Chehalis R at Porter	1952-72 1975-current	1,294 mi^2 23.64 ft	1952-1971 Unregulated 1971-current Minor regulation Skookumchuck Dam Consumptive Use – 54.5 peak, 30 cfs avg by Centralia Steam Plant Municipal water supply 4cfs (Centralia, Chehalis)
12030500	Cedar R nr Cedarville	1944	38.2 mi^2	No Remarks
12030000	Rock Crk nr Cedarville	1942-71	24.8 mi^2 70 ft	No regulation upstream Some diversion for irrigation*
12029500	Garrard Crk nr Oakville	1944	27.7 mi^2	No remarks
12029000	Black R at Little Rock	1942-50	63.7 mi^2 125 ft	No remarks
12028500	Wadell Crk nr Little Rock	1944	15.9 mi^2	No remarks
12028000	Scatter Crk n Ground Mnd	1944	21.0 mi^2	No remarks
12027500	Chehalis R nr Grand Mound	1928-current	895 mi^2 123.65 ft	1928-1971 Unregulated 1971-current Minor regulation Skookumchuck R Dam Consumptive Use by Centralia Steam Plant Municipal water supply 4cfs (Centralia, Chehalis) Small diversions for domestic and irrigation use

Table A-2 (Continued). Streamflow Gaging Stations -- Upper Chehalis WRIA 23

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation gage (ft)	Remarks on Regulation and Diversions *= USGS Water Supply Bulletin #15 , 1962 Data source for all other Earthinfo 1994 CDRom
12027000	Lincoln Crk nr Rochester	1942-50	19.3 mi^2 190 ft	No remarks
12026500	Hanaford Crk nr Centralia	1944	13.3 mi^2	No remarks
12026400	Skookumchuck R nr Bucoda	1967-current	112 mi^2 198.19 ft	1967-71 Unregulated; 1971-current regulated by Skookumchuck Dam Consumptive Use – by Centralia Steam Plant Minor diversions for domestic and irrigation use
12026150	Skookumchuck R Blw Bldy Rn Cr N Centralia	1929-33 1939-current	65.9 mi^2 301.04 ft	Published as “near Centralia” prior to 1969 1967-71 Unregulated; 1971-current regulated by Skookumchuck Dam No diversions upstream
12026000	Skookumchuck R nr Centralia	1929-34 1939-69	61.7 mi^2 317.34 ft	No regulation No diversions upstream
12025700	Skookumchuck R nr Vail	1967-current	40.0 mi^2 710 ft	No regulation No diversion upstream
12025500	Chehalis R at Centralia	1910-11	653 mi^2	No remarks
12025300	Salzer Crk nr Centralia	1968-72	12.6 mi^2 185 ft	No remarks
12025000	Newaukum R nr Chehalis	1929-31 1942-81 82-current	155 mi^2 (revised) * 190 ft	Municipal diversion of 5 cfs (Chehalis and Centralia) No regulation upstream
12024500	NF Newaukum R nr Forest	1944, 1957-66	31.5 mi^2 380 ft	No regulation upstream Municipal diversion 15 cfs (Chehalis and Centralia) *
12024000	SF Newaukum R nr Onalaska	1944-49 1957-72	42.4 mi^2 540 ft	No regulation or diversion above station *
12023500	Chehalis R nr Chehalis	1929-31	434 mi^2	No remarks
12023000	Stearns Crk nr Adna	1944	27.1 mi^2	No remarks
12022500	Stearns Crk nr Napaville	1945	14.1 mi^2	No remarks
12022000	Bunker Crk nr Adna	1944	20.1 mi^2	No remarks
12021500	Halfway Crk nr Boistfort	1944	13.4 mi^2	No remarks
12021000	SF Chehalis R at Boistfort	1942-50 1961-66	48 mi^2 255 ft	No remarks
12020900	SF Chehalis R nr Boistfort	1961-81	44.9 mi^2 280 ft	No remarks
12020500	Elk Crk nr Doty	1942-50 1968-70	46.7 mi^2 360 ft	No remarks
12020000	Chehalis R nr Doty	1939-current	113 mi^2 302.1 ft	No regulation or diversions upstream 23A160 DOE Ambient Monitoring
12019000	Chehalis R nr Pe Ell	1944	54.7 mi^2	No remarks
12019500	Rock Crk nr Pe Ell	1944	13.4 mi^2	No remarks

Table A-3. Climate Stations in or near the Chehalis Basin

Station Name	Type of Station *	Elevation (ft)	Period of Record	Mean Annual Precipitation (in) +
Aberdeen	Climate Data	10	1931-53,55-63,65-86,88-current	83
Aberdeen 20 NNE	Climate Data Hourly Precip since 1948	435	1931-32,34,36-63,66-current	130
Hoquiam FCWOS AP	Climate Data	12	1954-86,88-current	70
Hoquiam	Climate Data	15	1949-50	82
Humptulips Salmon Hatchery	Climate Data	140	1988-current	109
Montesano 1 S	Hourly Precipitation	25	1949-50	91
Matlock 8 S	Climate Data	110	1986-current	78
Elma	Climate Data	69	1949,51-60,62-92,94-current	67
Oakville	Climate Data	80	1948-94	56
Doty 3 E	Climate Data	260	1979-85,87,90-91	52
Olympia WSO AP	Climate and Hourly Precip	195	1949-current	50
Centralia 1W	Hourly Precipitation	185	1967-current	41
Centralia	Climate Data	185	1931-77,79-81,84-current	46
Chehalis	Climate Data Hourly Precip	180	1951 1948-68	 41
Dryad	Climate Data	312	1964-77	58
Toledo	Climate Data	325	1951-54,62-63,66-71,73-81,83	46
Mayfield Power Plant	Climate Data	280	1981-current	54
Cinebar	Hourly Precipitation	1,040	1948-53,62-94	72
Glenoma 1 W	Climate Data	781 840	1933-64 1968-84,86-88,91-92	62 66

* Climate Data station records daily values for temperature precipitation
Hourly Precipitation records hourly and daily precipitation values
+ summary statistics from Earthinfo (1994) CDRom

Table A-4. Chehalis Sub-basin Characteristics for Upper Chehalis Basin (WRIA 23) and Lower Chehalis Basin (WRIA 22)

Sub-basin No.	Sub-basin Name [Reach Description]	Drainage Area (mi2)	Mean Basin Elevation (ft)	Range in Basin Elevation (ft) Min Max	Mean Annual Precipitation (in)
1	Chehalis River Headwaters [Upper Chehalis above Doty]	116	1,280	293 - 3134	89
2	Elk Creek [Elk Creek mouth to headwaters]	60	871	276 - 2404	73
3	South Fork Chehalis River	50	860	240 - 2621	74
4	Upper Chehalis River [Chehalis above Chehalis below Elk and Doty]	211	642	160 - 2992	56
5	South Fork Newaukum	42	1,486	559 - 3804	63
6	North Fork Newaukum	32	1,323	379 - 2827	57
7	Newaukum	82	548	160 - 2096	45
8	Salzer Creek	19	430	161 - 893	42
9	Skookumchuck River	177	945	140 - 3812	53
10	Chehalis River - Middle Reach 1 [Chehalis above Grand Mound below Chehalis]	102	419	120 - 2475	45
11	Black River	137	358	48 - 2572	48
12	Cedar Creek	39	973	39 - 2656	54
13	Chehalis River – Middle Reach 2 [Chehalis above Porter below Grand Mound] *WRIA 23*	226	509	25 - 2660	51
14	*WRIA 22* Cloquallum Creek	70	422	16 - 1580	68
15	East Fork Satsop River	57	483	223 - 2851	98
16	Decker Creek	48	576	115 - 3013	106
17	Middle Fork Satsop River	57	983	98 - 3325	114
18	Satsop River	137	769	11 - 3876	102
19	Chehalis River – Lower Reach 1 [Chehalis above Satsop below Porter]	94	309	10 - 1814	59
20	Wynoochee River	198	916	5 - 4981	123
21	Wishkah River	104	412	sea level – 1637	106

Table A-4 (Continued). Chehalis Sub-basin Characteristics for Upper Chehalis Basin (WRIA 23) and Lower Chehalis Basin (WRIA 22)

Sub-basin No.	Sub-basin Name [Reach Description]	Drainage Area (mi2)	Mean Basin Elevation (ft)	Range in Basin Elevation (ft) Min Max	Mean Annual Precipitation (in)
Basins Draining to Grays Harbor					
22	Hoquiam River	52	195	sea level - 502	82
23	Middle Fork Hoquiam	10	259	13 - 442	94
24	East Fork Hoquiam	26	288	26 - 868	104
25	Humptulips R.	244	722	sea level - 4,397	127
26	Elks River	18	235	sea level - 575	71
27	Johns River	30	272	sea level - 667	75
28	Newskah Creek	12	314	sea level - 834	88
29	Charley Creek	8	237	5 - 647	87
30	Chehalis River – Lower Reach 2 [from mouth to Satsop R confluence]	60	149	sea level - 823	75

Table A-5: Location of Dams in the Chehalis Basin (Source: WDOE GIS Layer Dams in Washington)

Map Number	*Name of Dam*	*Legal Description* Section Township Range	*County Name*	*Name of Stream*	*Name of Dam Owner*	*Year Dam Completed*
1	Sea Horse Ranch Dike	S15 T18 R11W	GRAYS HARBOR	Tr-Gillis Slough		1961
2	Failor Lake Dam	S30 T19 R10W	GRAYS HARBOR	Deep Creek	Washington Dept. of Wildlife	1956
3	Aberdeen Lake Dam	S12 T17 R9W	GRAYS HARBOR	Van Winkle Creek	City of Aberdeen	1928
4	Sylvia Lake Dam	S31 T18 R7W	GRAYS HARBOR	Sylvia Creek	Washington Parks & Recreation	1918
5	Wishkah Reservoir No. 2 Dam	S33 T21 R8W	GRAYS HARBOR	Wishkah River	City of Aberdeen	1928
6	Surge Pond Dam	S30 T15 R1W	LEWIS	Hanaford Creek	PacifiCorp	1971
7	Skookumchuck Dam	S14 T15 R1E	THURSTON	Skookumchuck River	PacifiCorp	1970
8	Berger Dam	S15 T16 R1W	THURSTON	Tr-Scatter Creek		1970
9	Carlisle Lake Dam	S30 T13 R1E	LEWIS	Tr-South Fork Newaukum River	Washington Dept. of Wildlife	1920
10	PEO Dam No. 1A	S29 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1972
11	PEO Dam No. 5C	S32 T15 R1W	LEWIS	Tr-Packwood Creek	PacifiCorp	1970
12	PEO Dam No. 3A	S32 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1970
13	PEO Dam No. 6B	S32 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1970
14	PEO Dam No. 5	S29 T15 R1W	LEWIS	Tr-Packwood Creek	PacifiCorp	1971
15	PEO Dam No. 8A	S16 T14 R1W	LEWIS	Tr-South Hanaford Creek	PacifiCorp	1972
16	PEO Dam No. 8	S9 T14 R1W	LEWIS	Tr-South Hanaford Creek	PacifiCorp	1972
17	Wynoochee Dam	S20 T22 R7W	GRAYS HARBOR	Wynoochee River	City of Aberdeen	1973
18	Malinowski Dam	S33 T21 R8W	GRAYS HARBOR	Wishkah River	City of Aberdeen	1963
19	French Canyon Dam	S11 T14 R16E	YAKIMA	North Fork Cowiche Creek	Dept. of Interior, Bureau Rec.	1985
20	PEO Dam No. 3B	S32 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1980
21	PEO Dam No. 22	S25 T15 R2W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1973
22	PEO Dam No. 3C - North	S32 T15 R1W	LEWIS	South Hanaford Creek-Offstre	PacifiCorp	1987
23	PEO Dam No. 3C - South	S32 T15 R1W	LEWIS	Tr-Packwood Creek-Offstream	PacifiCorp	1987
24	PEO Dam No. 3C - East	S32 T15 R1W	LEWIS	Tr-Packwood Creek-Offstream	PacifiCorp	1987
25	PEO Dam No. 20B	S24 T15 R2W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1981
26	PEO Dam No. 20C	S19 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1981

Table A-5 (Continued): Location of Dams in the Chehalis Basin (Source: WDOE GIS Layer Dams in Washington)

Map Number	*Name of Dam*	*Legal Description* Section Township Range	*County Name*	*Name of Stream*	*Name of Dam Owner*	*Year Dam Completed*
27	Swano Lake Dam	S16 T17 R9W	GRAYS HARBOR	Tr-Charley Creek	Grays Harbor College	1949
28	Fairview Reservoir No. 1	S5 T17 R9W	GRAYS HARBOR	Wishkah River-Offstream	City of Aberdeen	1917
29	Spoils Pond Dam	S17 T17 R9W	GRAYS HARBOR	Grays Harbor-Offstream	Weyerhaeuser Company	1970
30	Maytown Ski Pond Dam	S16 T16 R2W	THURSTON	Tr-Scatter Creek		1987
31	PEO Dam No. 36	S29 T15 R1W	LEWIS	Hanaford Creek-Offstream	PacifiCorp	1989
32	PEO Dam No. 36A	S29 T15 R1W	LEWIS	Hanaford Creek-Offstream	PacifiCorp	1989
33	PEO Dam No. 3D	S5 T14 R1W	LEWIS	Tr-Packwood Creek	PacifiCorp	1988
34	PEO Dam No. 44	S33 T15 R1W	LEWIS	Tr-Packwood Creek	PacifiCorp	1975
36	PEO Dam No. 19A	S3 T14 R1W	LEWIS	Tr-Packwood Creek	PacifiCorp	1977
37	Seeley Ski Lake	S8 T17 R2W	THURSTON	Tr-Black River		1992
38	PEO Dam No. 32B	S21 T15 R1W	THURSTON	North Hanaford Creek	PacifiCorp	1991
39	Black River Ranch	S22 T16 R3W	THURSTON	Offstream	Black River Ranch	1994
40	College Hill Reservoir	S2 T17 R10W	GRAYS HARBOR	Little Hoquiam R. - offstream		1900
41	Reilly Dam	S21 T15 R5W	LEWIS	Tr-South Fork Garrard Creek		1965
42	Kyte Dam	S20 T15 R2W	THURSTON	Tr-Skookumchuck River		1966
43	Davis Creek Dam	S4 T18 R10W	GRAYS HARBOR	Davis Creek	City of Hoquiam	1966
44	Campbell Slough	S16 T18 R11W	GRAYS HARBOR	Campbell Slough	Washington Dept. of Fisheries	1964
45	Walentiny Dam	S12 T16 R3W	THURSTON	Tr-Black River		1968
46	Borst Lake Dam	S6 T14 R2W	LEWIS	Tr-Skookumchuck River	City of Centralia	1950
47	PEO Dam No. 6	S29 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1971
48	PEO Dam No. 6A	S29 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1970
49	Dunlap Pond Dam	S8 T15 R2W	THURSTON	Tr-Prairie Creek		1930
50	Eagle Creek Dam	S4 T14 R3W	LEWIS	Eagle Creek	Jerguson	1950
51	Monte Vista Poultry Detention Pond	S20 T16 R2W	THURSTON	Offstream	South Sound Soils	1980
52	Wynoochee Fish Barrier Dam	S12 T22 R7W	GRAYS HARBOR	Wynoochee River	City of Aberdeen	1972
53	Stewart Dam	S4 T27 R8W	GRAYS HARBOR	Geissler Creek		1916

Table A-5 (Continued): Location of Dams in the Chehalis Basin (Source: WDOE GIS Layer Dams in Washington)

Map Number	*Name of Dam*	*Legal Description* Section Township Range	*County Name*	*Name of Stream*	*Name of Dam Owner*	*Year Dam Completed*
54	PEO Dam No. 5A	S32 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1971
55	PEO Dam No. 5B	S32 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1982
56	PEO Dam No. 5D	S32 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1983
57	PEO Dam No. 20	S24 T15 R2W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1973
58	PEO Dam No. 45	S10 T14 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1978
59	PEO Dam No. 32	S20 T15 R1W	THURSTON	Tr-Hanaford Creek	PacifiCorp	1986
60	Schoenbachler Dam	S2 T16 R1W	THURSTON	Silver Springs Creek		1960
61	PEO Dam No. 20A	S24 T15 R2W	LEWIS	Tr-North Fork Hanaford Creek	PacifiCorp	1955
62	PEO Pit No. 7 West Sump	S4 T14 R1W	LEWIS	Tr-Packwood Creek	PacifiCorp	1974
63	PEO Dam No. 22	S30 T15 R1W	LEWIS	Tr-Hanaford Creek	PacifiCorp	1973
64	PEO Mendota East Sump	S33 T15 R1W	LEWIS	Tr-Packwood Creek	PacifiCorp	1985
65	Havvaski Waterski Pond	S2 T16 R3W	THURSTON	Tr-Black River		1992
66	Silverado Waterski Pond	S3 T13 R3W	LEWIS	Tr-Chehalis River		1992
67	Fairview Reservoir No. 2	S5 T17 R9W	GRAYS HARBOR	Wishkah River-Offstream	City of Aberdeen	1921
68	Mill Creek Dam	S23 T17 R9W	GRAYS HARBOR	Mill Creek	City of Cosmopolis	1930
69	Beacon Hill Reservoir	S12 T17 R10W	GRAYS HARBOR	Hoquiam River - offstream	City of Hoquiam	1935
70	West Fork Dam	S4 T18 R10W	GRAYS HARBOR	West Fk. Hoquiam River	City of Hoquiam	1956

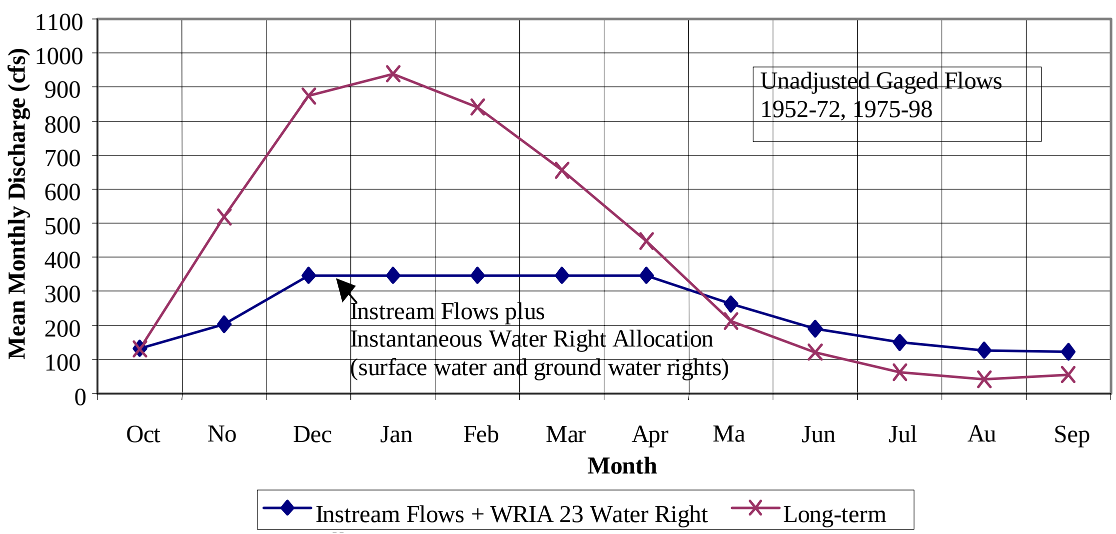
ANALYSIS OF GAGED FLOWS

In order to obtain an understanding of the flows the Chehalis River actually experiences, gaged flows at or near the mouth of each WRIA were examined. Upstream dams and myriad diversions have influenced the gaged flows along the Chehalis River. Dams typically influence the flow regime of a river by reducing the peak flows and augmenting low flows; pre-dam and post-dam data sets can represent two distinct population of flows depending on operating policies. Level 2 analyses may need to investigate the effects of streamflow regulation due to dams in the Chehalis Basin.

The Chehalis River at Porter (#12031000) is located at the downstream end of WRIA 23 and therefore reflects surface water quantity totals for this WRIA. Fifty-four dams were identified within WRIA 23, 14 of which had storage rights listed in WDOEs water rights database (WRATS). The largest dam in WRIA 23 is the Skookumchuck Dam (subbasin 9) completed in 1971. The USGS note minor effects of flow regulation from this dam on the streamflows recorded at the Chehalis River at Porter gage. At this level of analysis, the impact of this and the other dams on the flow in the Chehalis River was unknown.

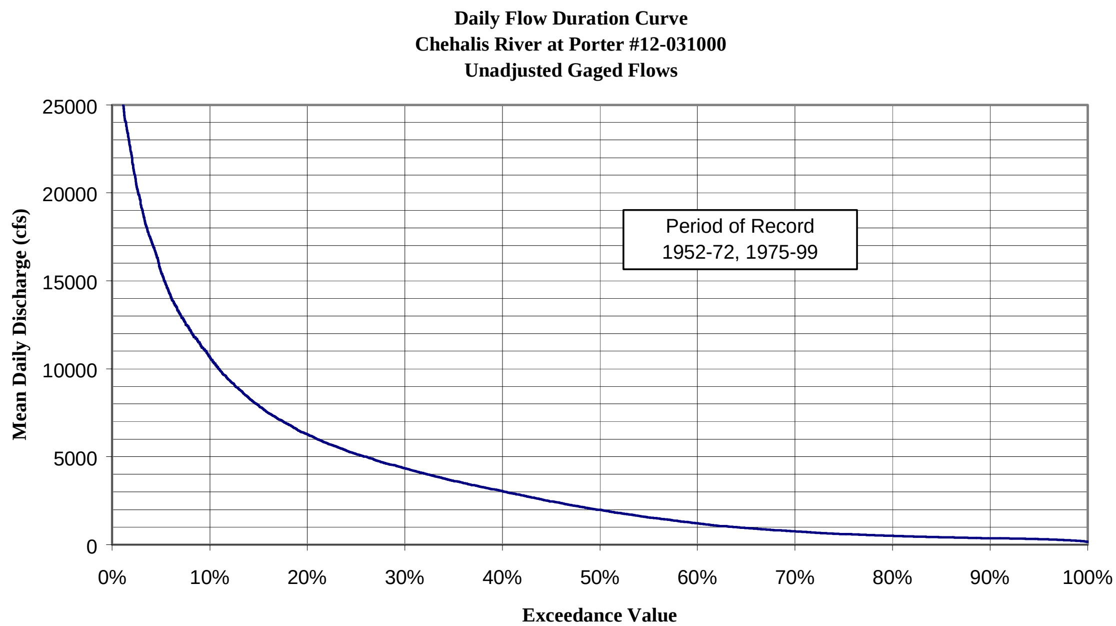
The mean monthly hydrograph for the Chehalis River at Porter (1952-72,1975-98) is displayed in Figure A-1. For perspective, the average bimonthly instream flows at the Porter control point (as set by WAC 173-522-020) were added to the total water right allocation for WRIA 23 (961 cfs) and plotted on Figure A-1. This graph indicates that the combination of the instream flow and the instantaneous water right allocation (which includes both surface water and ground water rights) exceeds the gaged mean monthly flows from May through September.

Figure A-1: Chehalis River at Porter (12-031000) Regulated Mean Monthly Hydrograph



A flow duration curve (Figure A-2) was generated for the Chehalis River at Porter using the unadjusted flows. Flow duration curves provide an indication of the frequency distribution of flows at a station. Since exceedance values are indirectly proportional to the flow, the 90% exceedance values are always less than the 50%, the median flow value of the data series (half of the flows will be less than the 50% exceedance value and half will be greater). Of the mean daily flows recorded at the Porter gage, half have been equal to or greater than 1980 cfs and 90% of the flows have been equal or greater than 370 cfs.

Figure A-2: Chehalis River at Porter (12-031000) Flow Duration Curve



Surface water quantity totals for WRIA 22 were more difficult to estimate since there was no flow data available near the mouth of the Chehalis River. Additionally, WRIA-wide totals would not be hydrologically meaningful since several of the major tributaries in WRIA 22 drain directly to Grays Harbor, not to the Chehalis River. Lower Chehalis River surface water runoff was estimated at Montesano, near the upstream end of the tidally influenced reach.

Flows at Montesano were estimated by adding gaged flows (Chehalis at Porter, Cloquallum, Satsop, and Wynoochee) and incorporating unit runoff estimates for the ungaged portions along the river valley between Porter and Montesano. Accretion flow from the 165 mi^2 of ungaged drainage to the Chehalis River between Montesano and the Porter Creek confluence was estimated using a combination of unit runoff values and the relationship of flows at the Chehalis at Porter gage. Mean monthly unit runoff values were generated from the 8 years of gage records available at the historic Chehalis River at south Elma station located mid-basin. These monthly unit values compared favorably to values from the longer-term base gages and therefore were used. Exceedance values for the ungaged area between Montesano and Porter were derived by using a ratio of the mean monthly to the 50% and 90% exceedance value at the Chehalis River at Porter gage. These exceedance values were then added to the accumulated values of the gaged flows (Porter gage + Cloquallum, Satsop, and Wynoochee) to represent flows available at Montesano.

The Chehalis River at Montesano exceedance values listed in Table A-6 were based on data from 1957-72 and 76-98, the coinciding years of record at the four gages. This period did include both pre- and post-dam years on the Wynoochee and therefore the values do not represent an estimate of natural flow. Instead, the exceedance values were based on the addition of unadjusted gaged flows, which reflect the many unidentified diversions throughout both WRIA's and regulation of the Wynoochee River. There is no instream flow control point on the lower Chehalis River near Montesano.

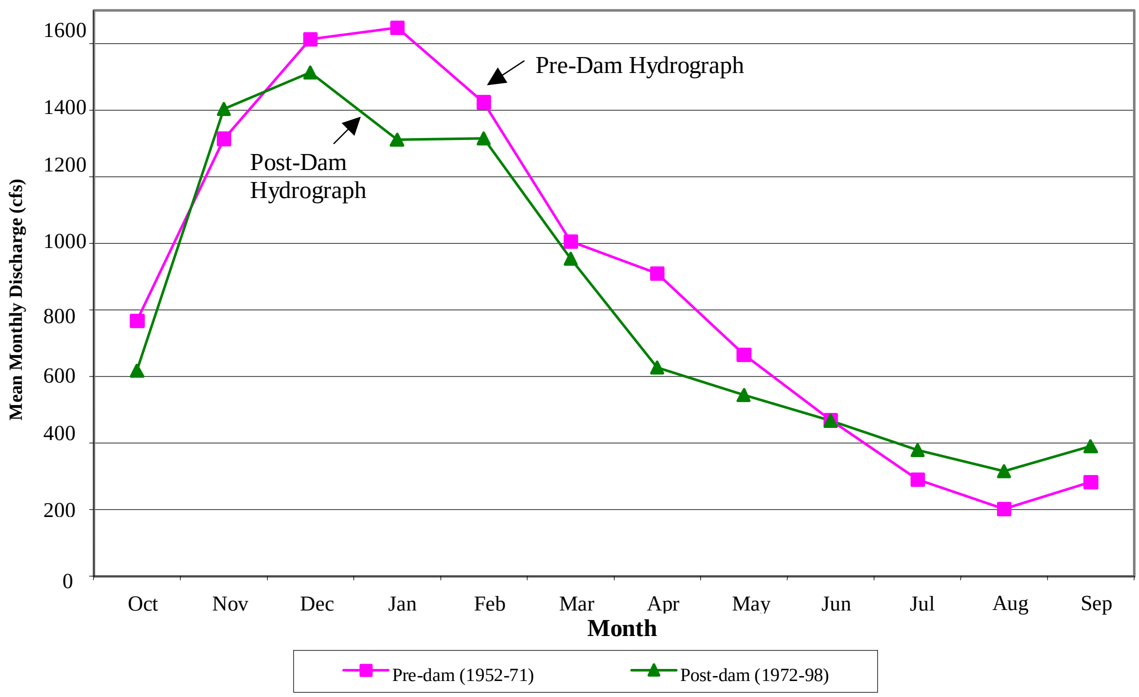
Table A-6
Flow Exceedance Values for Chehalis River at Montesano

Month	Estimated Flow Exceedance Values[1] Chehalis River at Montesano			
	50% Exceedance (cfs)	50% URO[2] cfs/mi^2	90% Exceedance (cfs)	90% URO[2] cfs/mi^2
October	2078	1.05	827	0.42
November	8296	4.19	2424	1.23
December	13144	6.65	5596	2.83
January	13445	6.80	5020	2.54
February	12987	6.57	6026	3.05
March	10260	5.19	5045	2.55
April	6853	3.46	3828	1.94
May	3761	1.90	2336	1.18
June	2124	1.07	1438	0.73
July	1333	0.67	893	0.45
August	915	0.46	611	0.31
September	985	0.50	627	0.32

[1] based on the addition of daily data from four gages USGS station #12-031000, Chehalis R. at Porter, Cloquallum #12-032500, Satsop R #12-035000, and the Wynoochee R. #12- 037400 for coinciding record years 1957-72,76-98 + accretion flow to Montesano; drainage area = 1,978 mi^2
[2] URO = unit runoff

Mean monthly flows at the Wynoochee above Save Creek gage (#12-036000) for the pre-dam years (1952-71) were compared to those for the post-dam years (1972-98) as displayed in Figure A-3. The post-dam hydrograph demonstrates that the dam is effective in dampening the peak flows; post-dam mean monthly flows for December through May were lower than pre-dam flows. Also, the post-dam flows show augmentation during the low flow months (July, August, and September).

Figure A-3: Wynoochee River (12-036000) Pre-and Post-Dam Hydrographs



ANALYSIS OF NATURAL CLIMATE VARIABILITY

In the Pacific Northwest, two primary patterns of climate variability occur: El Nino Southern Oscillation (ENSO) and the Pacific Decadal Oscillation (PDO). The cyclical patterns and physical mechanisms of ENSO have been thoroughly researched and are now fairly well understood. The physical mechanism behind the more recently discovered PDO is not as well studied, however, the cyclical nature of the PDO phases has been characterized. The ENSO effect can be determined on a year-by-year basis, however, for water allocation, planning this is not as useful as a longer-term pattern that includes cycles of dry and wet year extremes. For this study, an understanding of the decadal climate phases was most important, therefore, climatic and hydrologic data from the Chehalis Basin were analyzed and compared to the regionally identified natural climate variability as measured by PDO phases (Mote et.al., 1999).

Regional Patterns of Climate Variability

Mote et.al 1999 have defined time periods for five distinct PDO climate cycles experienced in the Pacific Northwest (Table A-7). The period of record used for water allocation studies should cover both PDO phases to adequately represent the natural variability.

Table A-7: Pacific Northwest Pacific Decadal Oscillation Cycles

Pacific Northwest PDO Climate Cycles	Time Period[1]
Cool/Wet Phase	1890-1924
Warm/Dry Phase	1925-1945
Cool/Wet Phase	1946-1976
Warm/Dry Phase	1977-1995
Cool/Wet Phase	1995 shift speculated

[1] per Mote et.al. 1999

In the Pacific Northwest, the cool PDO phase, experienced in the 1890-1924 and 1946-1976 cycles, resulted in: an average temperature decrease of 0.2 ºF, an average increase in precipitation of 2%, an increase in snow depth of 17%, and a corresponding increase in streamflow of 6% (Mote, 1999). Also, during these cool phases of PDO, an increase of 19% in the annual catch of Washington Coho salmon was observed (Note: only Coho salmon catch was evaluated in Mote, 1999).

The warm PDO phase that occurred throughout the Pacific Northwest from 1925 to 1945 and from 1977 to 1995 was characterized by: an average temperature increase of 0.3 ºF, an average precipitation decrease of 4%, a corresponding decrease in snow depth and streamflow (-15% and -10%, respectively), and a 16% decrease in the Washington Coho salmon catch (Mote, 1999). Scientists have speculated that a shift may have occurred from the warm and dry PDO in 1995; however, the certainty of a shift is not yet known (Mote, 1999).

Climate and Streamflow Patterns in the Chehalis Basin

Statistical techniques were applied to the annual precipitation data for the entire period of record at the Centralia and the lower Aberdeen climate stations to understand the trends in these “local” data and whether they follow the documented regional climate variability cycles.

Patterns of increasing and decreasing values over time are often difficult to discern from time-series graphs because of the variation between values from month to month or year to year. The patterns become more evident by accumulating the values prior to plotting (Kresch, 1994). Departures from normal were calculated, accumulated, and then plotted for each of the climate stations. Graphs of cumulative departure from normal equal zero at the start, increasing during wet periods (positive departures indicate that the rate for a given year exceeds the long-term average) and decrease during dry periods (Kresch, 1994). To facilitate graphical comparison across the stations, the cumulative departures from normal are then standardized or rescaled (divided by the standard deviation) to illustrate the PDO pattern.

The important fact to glean from Figures A-4 to A-7 is that the trends in the data are consistently increasing or decreasing within a given regionally identified Pacific Decadal Oscillation phase (noted as vertical lines per Mote, 1999). For Centralia (Figure A-4), the pattern is distinct and coincides with the reported regional PDO patterns (Mote et.al. 1999); Figure A-4 displays a declining pattern pre-1945, moving to an increasing pattern until the mid-1970s then declining again.

The pattern during warm/dry PDO phases at the Aberdeen station (Figures A-5) is also fairly distinct and coincident with the reported regional patterns. However, the adherence to regional patterns was less clear for the cool /wet phase; a shift occurred in the rescaled departures from normal in 1945 (at the same time as the regional phase shift), however, annual values plateaued instead of increasing.

Figure A-4. Annual Precipitation for 1931-1999 for Station #451276, Centralia, WA (Elevation = 185 feet)

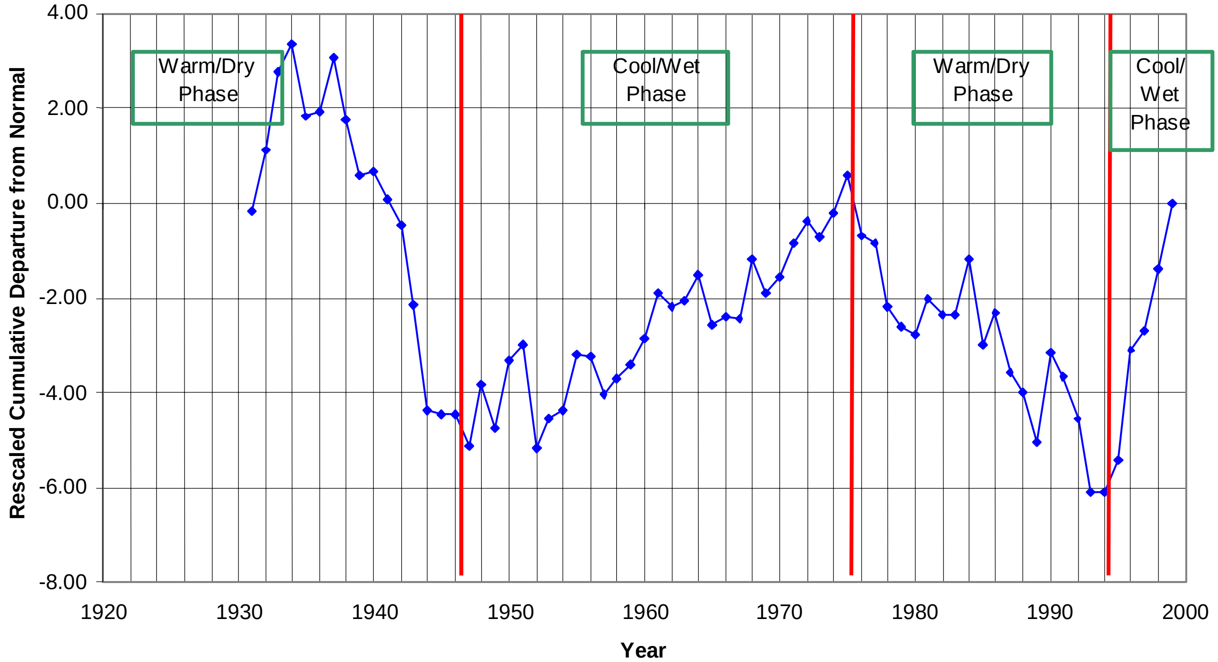
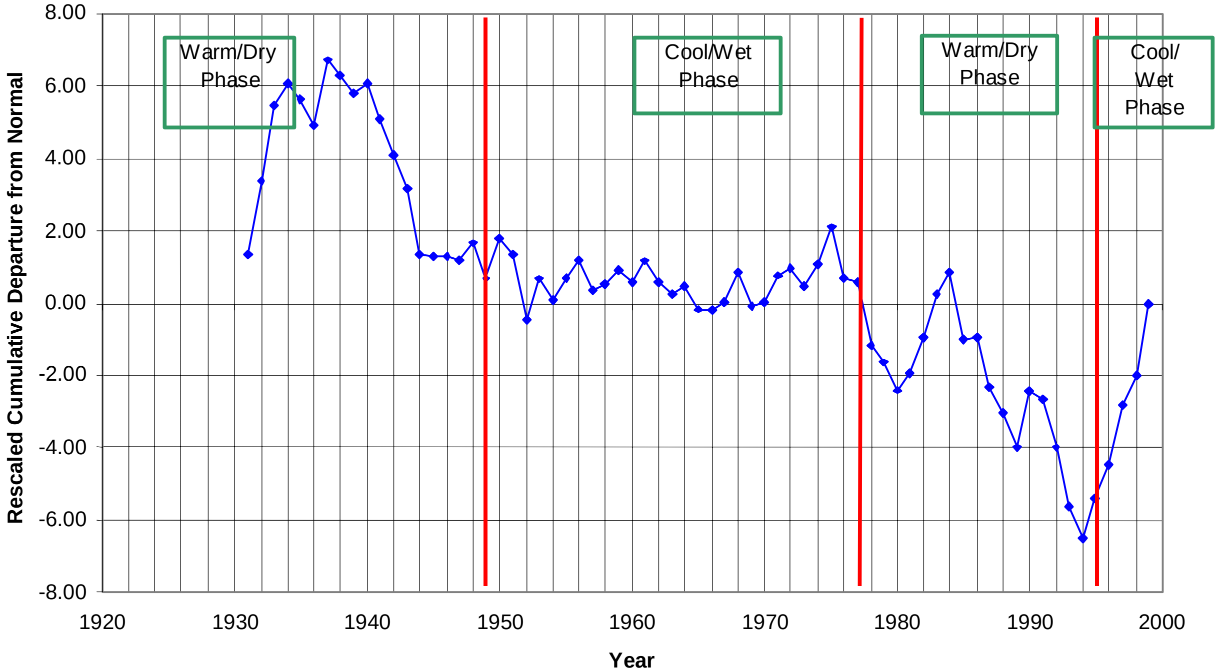


Figure A-5. Annual Precipitation for 1931-1999, Station #450008, Aberdeen, WA (Elevation = 10 feet)



A similar analysis of departures from normal and rescaled cumulative values was undertaken with the streamflow records at the longest continuously recording gage in the Chehalis Basin, the Satsop River near Satsop station (#12-035000). Annual departures from normal, as a percentage, are displayed in Figure A-6 to distinguish wet and dry years over the long period of record at the Satsop gage. The trends in the data, evident in Figure A-7, show the pattern of climate variability at the Satsop gage distinct and coincident with the reported regional PDO patterns (Mote et.al. 1999).

Figure A-6. Mean Annual Streamflow Departures from Normal for 1931-1999, Satsop River near Satsop, WA

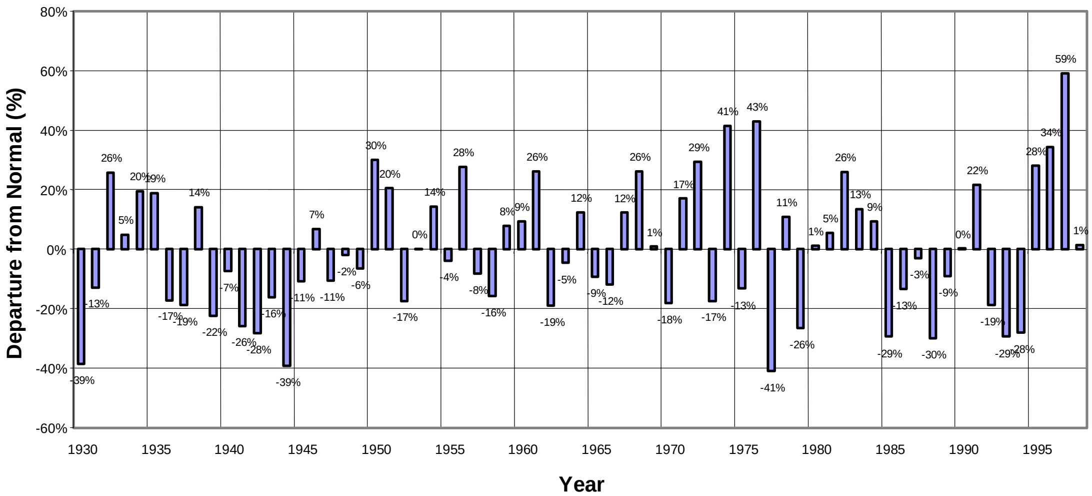
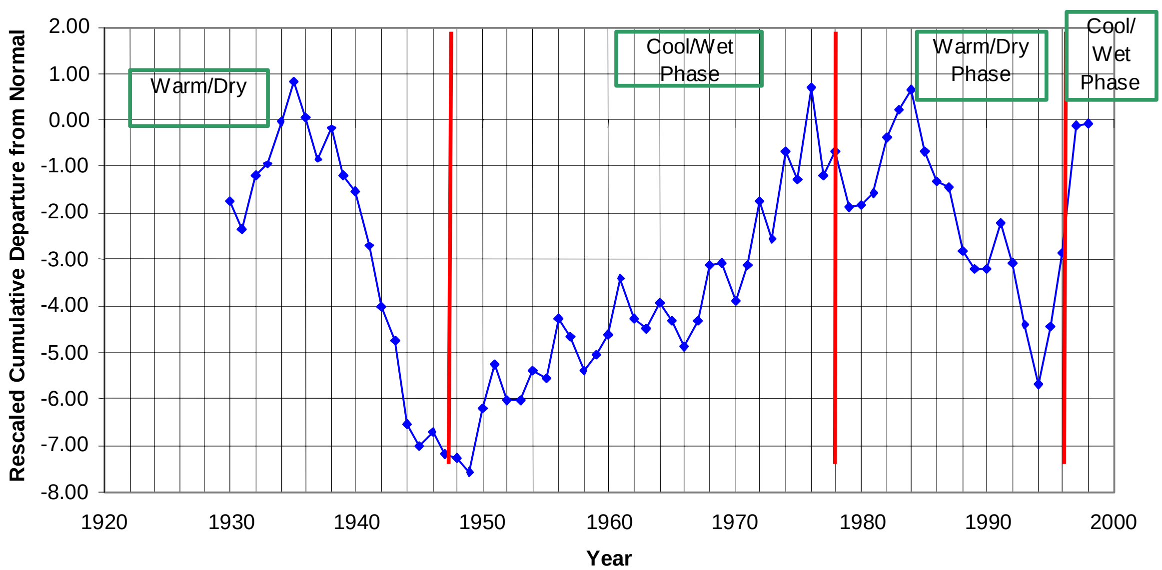


Figure A-7. Mean Annual Streamflow Cumulative Departure from Normal for 1931-1999, Satsop River near Satsop, WA



In summary, the stations analyzed in the Chehalis Basin show clear adherence to the regionally identified natural climate variability; no alternative trends in either streamflow or precipitation were identified at this level of analysis. Investigation of shorter-term gage records used in the subsequent section take this fact into consideration; the records were analyzed in the context of the mix of wet and dry years experienced at the Satsop River gage.

UNDEPLETED GAGE FLOW

Of the 30 subbasins identified in the Chehalis Basin, all but five (Decker Creek, M Fk Hoquiam, E Fk Hoquiam, Elks River, and the Chehalis Lower Reach 2 to the mouth) had some systematic streamflow records located within the boundaries. While substantial streamflow data area available, few of these streamflow stations have recorded flows unhampered by human uses. Several factors (e.g. upstream regulation/diversion, climatic conditions, land use during the period of record of the gaged flows) influence the adequacy of the gage records to represent natural or undepleted flows. Prior to using the numerous gage records to generate summary statistics representative of "undepleted" flows, two factors were investigated: 1. the extent of upstream regulation and abstraction of water, and 2. the climate variability over the period of record. A detailed streamflow depletion analysis was not conducted for any of the gages in the Chehalis Basin but could be considered for a level 2 analysis; the term undepleted is used in this report to qualify the reviewed gage records.

Base gage selection

Twenty gages located in thirteen of the 30 subbasins were identified as having sufficient streamflow data reflective of "undepleted" flows; these were termed base gages. Nine of these gages were located in lower Chehalis and eleven in upper Chehalis (Table A-8). The criteria for selection as a base gage were threefold: 1. length of streamflow record greater than 10 years; 2. little or no regulation or diversion upstream of gage, and 3. a minimum of development in the watershed upstream of the gage. The USGS remarks section in the gaging station records was reviewed for initial information on regulation/ diversions etc. occurring upstream of the gage potentially influencing the recorded streamflow data. The WDOE Water Supply Bulletin #60 (Sinclair and Pitz, 1999) was used as an additional source of information regarding the extent of potential upstream diversions for each of the base gages. Registered dams were identified (WDOE GIS Layer, Dams in Washington) and the location reviewed to assure no upstream regulation by small dams. Observations on water withdrawal (pumps, dams/ diversions) from the USFS Chehalis Habitat database (Wampler et.al., 1993) was reviewed cursorily but should be pursued in more depth in Level 2.

Table A-8. Selected Streamflow Base gages (meeting criteria of >10 years unregulated records and only small or minor diversions)

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation gage (ft)	Remarks on Regulation and Diversions *= USGS Water Supply Bulletin #15 , 1962 Data source for all other Earthinfo 1994 CDRom
Lower Chehalis				
12039000	Humptulips R nr Hump	1933-35 1942-79	130 mi^2 120 ft	No diversion above station Slight low flow regulation by fish hatchery on west fork*
12037400	Wynoochee R Abv Black Crk nr Montesano	1956 – current	155 mi^2 179 mi^2 * 40 ft	Only used the 1956-69 unregulated portion; Small diversions for domestic and irrigation use
12036650	Anderson Crk nr Montesano	1972-85	2.72 mi^2 150 ft	No remarks
12036400	Schafer Crk nr Grisdale	1987-96	12.1 mi^2 280 ft	No regulation or diversions upstream
12036000	Wynoochee R Abv Save Crk nr Aberdeen	1925-52; 1952-current	74.1 mi^2 401 ft elev	Only used the 1925-52 unregulated portion (published as at Oxbow 12035500) and the 1952-69 unregulated portion; No diversions upstream of station
12035450	Big Crk nr Grisdale	1972-96	9.57 mi^2 600 ft	No regulation or diversions upstream
12035000	Satsop R nr Satsop	1929-current	299 mi^2 sea level (0)	No regulation or diversion upstream
12034200	E Fk Satsop R nr Elma	1957-71	65.9 mi^2 205 ft	No regulation or diversion upstream
12032500	Cloquallum R at Elma	1942-72	65.8 mi^2 20 ft	Small diversions on minor tributaries Some regulation by log pond –Wildcat Crk*
Upper Chehalis				
12031000	Chehalis R at Porter	1952-72 1975-current	1,294 mi^2 23.64 ft	Only used 1952-1971 unregulated portion This station is influenced by a large Consumptive Use – (54.5 peak, 30 cfs avg) by Centralia Steam Plant
12030000	Rock Crk at Cedarville	1942-71	24.8 mi^2 70 ft	No regulation upstream Some diversion for irrigation*
12027500	Chehalis R nr Grand Mound	1928- current	895 mi^2 123.65 ft	Only used 1928-1971 unregulated portion This station is influenced by consumptive Use – (54.5 peak, 30 cfs avg) by Centralia Steam Plant; Municipal water supply 4cfs (Centralia, Chehalis) only supplemental supply. Small diversions for domestic and irrigation use
12026000	Skookumchuck R nr Centralia	1929-34 1939-69	61.7 mi^2 317.34 ft	No regulation No diversions upstream
12025700	Skookumchuck R nr Vail	1967- current	40.0 mi^2 710 ft	No regulation No diversion upstream
12025000	Newaukum R nr Chehalis	1929-31 1942-81 1982- current	155 mi^2 (revised) * 190 ft	Municipal diversion of 5 cfs (cities of Chehalis and Centralia) No regulation upstream
12024000	SF Newaukum R nr Onalaska	1944-49 1957-72	42.4 mi^2 540 ft	No regulation or diversion

Table A-8 (Continued). Selected Streamflow Base gages (meeting criteria of >10 years unregulated records and only small or minor diversions)

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation gage (ft)	Remarks on Regulation and Diversions *= USGS Water Supply Bulletin #15 , 1962 Data source for all other Earthinfo 1994 CDRom
12021000	SF Chehalis R at Boistfort	1942-50 1961-66	48 mi^2 255 ft	No remarks
12020900	SF Chehalis R nr Boistfort	1961-81	44.9 mi^2 280 ft	No remarks
12020500	Elk Crk nr Doty	1942-50 1968-70	360 ft	No remarks
12020000	Chehalis R nr Doty	1939-current	113 mi^2 302.1 ft	No regulation or diversions upstream

The accuracy of frequency analysis results, and any summary statistics, is largely a function of the period of record used to generate the statistics. Statistics based on short records can be influenced by a non-representative mix of wet and dry years. Even stations with 10 years of record may not be representative of climate variations and should be extended where possible (Robison, 1991). Using the annual departures from normal for the Satsop River long-term records (Figure A-6) as an indicator of regional climate norms, tallies were taken of the number of wet and dry years over the period of record for each base gage (Table A-9). The mix of wet/dry year tallies were similar to the long-term records for most stations and, therefore, assumed representative of natural variability. For three gages (12020500, 12021000, and 12036650), the mix of wet and dry years covered within the period of record was not similar to the Satsop gage. Data generated from these gages were coded as to the respective bias based on the predominance of wet or dry years.

Table A-9. Pertinent Information on Base Gages

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation of gage (ft)	Mean Annual Flow (cfs) [cfs/mi2]	Period of Record (Mixed, Wet or Dry based on Satsop record)[1]
Lower Chehalis					
12039000	Humptulips R nr Hump	1933-35 1942-79	130 mi^2 120 ft	1337 [10.3]	Mixed +22/-20
12037400	Wynoochee R Abv Black Crk nr Montesano	1956 – 69 pre dam portion	155 mi^2 179 mi^2 * 40 ft	1299 [8.4]	Mixed +24/-19
12036650	Anderson Crk nr Montesano	1972-85	2.72 mi^2 150 ft	15 [5.5]	WET +9/-5
12036400	Schafer Crk nr Grisdale	1987-96	12.1 mi^2 280 ft	75 [6.2]	Mixed +4/-6
12036000	Wynoochee R Abv Save Crk nr Aberdeen	1925-52	74.1 mi^2 401 ft elev	772 [10.4]	1929-52 period +8/-15
12035450	Big Crk nr Grisdale	1972-96	9.57 mi^2 600 ft	113 [11.8]	Mixed +13/-12

Table A-9 (Continued). Pertinent Information on Base Gages

Station Number	Station Name	Period of Record	Drainage Area (mi2) Elevation of gage (ft)	Mean Annual Flow (cfs) [cfs/mi2]	Period of Record (Mixed, Wet or Dry based on Satsop record)[1]
12035000	Satsop R nr Satsop	1929-current	299 mi^2 sea level (0)	2033 [6.8]	Mixed +34/-35
12034200	E Fk Satsop R nr Elma	1957-71	65.9 mi^2 205 ft	374 [5.7]	Mixed +16/-20
12032500	Cloquallum R at Elma	1942-72	65.8 mi^2 20 ft	274 [4.2]	Mixed +19/-13
Upper Chehalis					
12031000	Chehalis R at Porter	1952-72 1975-current	1294 mi^2 23.64 ft	4107 [3.2]	Mixed +25/-20
12030000	Rock Crk at Cedarville	1942-71	24.8 mi^2 70 ft	89 [3.6]	Mixed +14/-16
12027500	Chehalis R nr Grand Mound	1928-current	895 mi^2 123.65 ft	2823 [3.2]	Mixed +34/-35
12026000	Skookumchuck R nr Centralia	1929-34 1939-69	61.7 mi^2 317.34 ft	247 [4.0]	Mixed +16/-20
12025700	Skookumchuck R nr Vail	1967-current	40.0 mi^2 710 ft	201 [5.1]	Mixed +19/-13
12025000	Newaukum R nr Chehalis (deregulated)	1929-31 1942-81 1982-current	155 mi^2	498 [3.2]	Mixed +21/-22
12024500	NF Newaukum R nr Forest	1957-66	31.5 mi^2 380 ft	103 [3.3]	Mixed +4/-6
12024000	SF Newaukum R nr Onalaska	1944-49 1957-72	42.4 mi^2 540 ft	200 [4.7]	Mixed +10/-12
12021000	SF Chehalis R at Boistfort	1942-50 1961-66	48 mi^2 255 ft	199 [4.2]	DRY +4/-11
12020900	SF Chehalis R nr Boistfort	1961-81	44.9 mi^2 280 ft	175 [3.9]	Mixed +12/-9
12020500	Elk Crk nr Doty	1942-50 1968-70	360 ft	163 [3.5]	DRY +4/-8
12020000	Chehalis R nr Doty	1939-current	113 mi^2 302.1 ft	573 [5.1]	Mixed +29/-31

[1]Using the Satsop gage departure from normal graph (Figure A-6) tally of number of years that annual streamflow was above or below normal Dry = >60% of years above normal

For these 20 base gages, summary statistics were generated on a monthly basis and normalized into runoff per square mile to allow comparison of runoff production across the basin. Unit runoff characteristics representative of annual runoff, seasonal, and maximum and minimum monthly values are compiled in Table A-10 under the subbasin name in which the base gages occur.

Table A-10. Chehalis Basin Unit Runoff Characteristics

Sub-basin No.	Subbasin Name and drainage area to mouth	Base Gage within the subbasin	Mean Unit Runoff (cfs/mi^2)				
			Annual	Max Month	Winter Avg[1]	Summer Avg[2]	Min Month
1	Chehalis R 116 mi^2	12020000	5	11	10	<1	<1
2	Elk Creek 60 mi^2	12020500	3	9	7	<1	<1
3	SF Chehalis 50 mi^2	12020900	4	10	8	<1	<1
		12021000	4	10	9	<1	<1
5	SF Newaukum 42 mi^2	12024000	5	10	8	1	1
7	Newaukum 82 mi^2	12025000(with municipal diversions added back in)	3	7	6	<1	<1
9	Skookumchuck R 177 mi^2	12025700	5	10	9	1	1
		12026000	4	8	8	1	1
10	Chehalis River - Middle Reach 1 102 mi^2	12027500	3	7	7	<1	<1
13	Chehalis River – Middle Reach 2 226 mi^2 WRIA 23	12030000	4	9	8	<1	<1
		12031000	3	8	7	<1	<1
14	WRIA 22 Cloquallum Creek 70 mi^2	12032500	4	10	9	1	1
15	EF Satsop R 57 mi^2	12034200	6	13	11	2	1
18	Satsop River 137 mi^2	12035000	7	14	13	1	1
20	Wynoochee R 198 mi^2	12035450	12	24	22	3	2
		12035500	11	21	18	3	2
		12036000 (52-69 yrs)	10	22	19	4	3
		12036400	6	14	12	1	1
		12036650	6	13	10	1	<1
		12037400	8	18	15	2	1
25	Humptulips R. 244 mi^2	12039000	10	21	18	3	2

[1]Winter Avg. = December through March
[2]Summer Avg. = July through September

Primarily due to the extreme variation in precipitation across the Chehalis Basin, the amount of runoff varies dramatically (up to four-fold) from 3 cfs/mi^2 annually along the low lying valley bottom area to more than 12 cfs/mi^2 in the upper watersheds draining the Olympic Mountains. Based on the unit runoff characteristics (Table A-10), in conjunction with basin characteristics (precipitation isohyets, geology, etc.), and low flow values (Sinclair and Pitz, 1999 and Cummans, 1975), the Chehalis Basin was divided into 6 hydrologically similar areas as presented in Table A-11. Insufficient streamflow data existed on the South Bay tributaries (Johns, Elk, Charley) to determine representative unit runoff ranges in the Level 1 assessment.

Table A-11. General Areas of Hydrologic Similarity within the Chehalis Basin

Description of Hydrologically Similar Areas	Annual Unit runoff range (cfs/mi^2)	Winter Average unit runoff[1]	Summer (low flow) average unit runoff)[2]
North Bay/ Inner Harbor low-lying tributaries (Hoquiam, Lower Humptulips)	5-8	10-15	1-2
Humptulips to Wynoochee Upper Watersheds	10-12	21-24	3-4
WRIA 22 & 23 Low-lying valleys along Chehalis and tributaries	3-4	7-9	<1
Satsop River Basin	6-7	9-13	1
WRIA 23 Mid-basin major tributaries with headwaters in foothills of cascade range (Black, Skookumchuck, Newaukum)	4-5	8-9	1
WRIA 23 Upper Chehalis headwaters in Willapa Hills (Elk, SF, Stillman..)	3-5	7-10	<1

[1] Winter Season for this study is defined as December through March
[2] Summer Season for this study is defined as July through September

These regions of similarity will be useful for Level 2 analyses to produce flow estimates in ungaged basins. Level 2 analyses may also involve hydrologic techniques such as correlation analysis between miscellaneous flow measurements and concurrent gage data and normalization of flows by drainage area (per unit runoff calculations for various flow events). Additionally, a core period of record could be selected to assure that undepleted flow estimates reflect the natural variability in climatic conditions. Base station streamflow records could be extended through correlation analysis with nearby gages as appropriate to cover the selected core period of record then unit runoff calculations could be updated.

DISCUSSION OF APPROPRIATE EXCEEDANCE LEVELS

For watershed planning purposes, it is of interest to understand the amount of time that streamflow can be expected to be at different levels e.g. low flows, or median flows. Frequency analysis techniques can be used to determine exceedance percentiles representing how often a given flow value can be expected to be equaled or exceeded based on the long-term streamflow records. For instance, the 90% exceedance value is defined as that flow met or exceeded 90% of the time (e.g. in four out of five flow values). Since exceedance values are indirectly proportional to the flow, the 90% exceedance will always be less than the 50% which represents the median flow value for the data series used (half of the values will be less than the 50% exceedance value and half will be greater). In this report, the 90% exceedance flow is presented as a marker of low flows while 50% exceedance value is indicative of normal flows.

In 1991, Oregon Water Resources Dept. completed a statewide water availability study in which 80% exceedence flows were used for planning purposes to determine if a stream is over-appropriated, while the 50% exceedence flows were used for evaluation of water right applications. The State of Washington has not completed a statewide water availability study. In the absence of state standards regarding water allocation policy, 90% exceedance values are used in this document; use of the 90% values would yield overallocated results prior to use of the 80% exceedance values.

In addition, exceedance values for this study were derived for each month based on daily flow values for the period of record available or synthesized. According to Robison's 1991 study, results from a comparison of exceedance values derived from monthly mean flow values, to those derived from daily flow time series for 88 gaged records in Oregon, showed that flow exceedance values based on daily data have a tendency to be lower than those based on monthly data.

DATA GAPS

GEOLOGY

The direct connection between shallow groundwater bodies and streamflow in portions of the Black and Middle Chehalis Rivers, as well as Scatter Creek, has been well documented. Interaction of ground and surface water elsewhere in the Chehalis Basin has not received comparable study. While the nature of the surface deposits in the major river valleys allows us to assume a high degree of ground/surface water continuity, a wide spectrum likely exists with respect to discharge/recharge timing, volumes, and relative contribution to surface flows. Due to the discontinuous nature of confining lenses within the glacial/alluvial deposits found in valley bottoms, interaction between surface and shallow groundwater bodies is variable, even in the well studied Black River area.

Given the increasing reliance on groundwater and the recognized importance of groundwater in supporting stream flow, there is a paucity of data dealing with their interaction in the Chehalis and other basins. Without this information, we can not adequately address the question of potential impacts of ground water withdrawals at the subbasin level, much less on a basin level scale.

HYDROLOGY

Hydrologic analyses rely heavily on time series of streamflow data, and the Chehalis Basin is fortunate to have numerous streamflow stations distributed throughout the basin. However, 5 of the 30 subbasins do not have any record of streamflow in the basin and several others have only a few years of record. Hydrologic analyses can be undertaken in level 2 to estimate flows in these ungaged subbasins in the absence of collecting new data. Future management decisions however, would be facilitated if streamflow gages were installed or re-instated coincident with the instream flow control points of primary fishery concern.

The only specific data gap identified for surface water hydrology was that insufficient streamflow data existed on the South Bay tributaries (Johns, Elk, Charley) to determine representative unit runoff ranges in the Level 1 assessment. If fishery concerns exist on the South Bay tributaries, more streamflow data would be helpful.

RECOMMENDATIONS

GEOLOGY

Level 2 investigations in the groundwater portion of the study need to clearly define the interaction of groundwater with surface water. Develop a hydrologic water balance for each subbasin to screen areas for issues related to ground water and stream flow interactions. Components of a water balance include precipitation, interception, evaporation, evapotranspiration, surface water runoff, ground water storage, and recharge (including septic system return flow), and losses or gains to the basin from interbasin transfers of water. These components can be estimated from available data or calculated using hydrologic techniques. This essentially dictates that some degree of three-dimensional modeling be undertaken in the basin. Modeling a subset of subbasins to infer conditions elsewhere in the basin is likely the most cost efficient method of obtaining needed information. It would make sense to focus the modeling on those subbasins, which have significant groundwater withdrawals, and aquifer/geologic systems which have been studied to some degree. Modeling of the most heavily studied subbasins such as the Black River and Scatter Creek subbasins would be a logical place to start given the plethora of available information on groundwater and geologic conditions. Other basins which may have slightly less information concerning groundwater conditions, such as the middle Chehalis and Newuakum drainages, should also be modeled. Additionally, modeling should be undertaken in those subbasins which are, after additional fisheries work, identified as low flow limiting from a habitat perspective.

HYDROLOGY

The natural flow values presented in this document were intended as preliminary or screening level to guide prioritization for Level 2; use of the exceedance values as a true representation of natural flow must be done with caution. The records generated for each of the five basins reflected some degree of anthropogenic effect. In some of the basins, (e.g. #25 the Humptulips) the estimated natural flows may be closer to the true value while in other basins, the gaged streamflow was depleted by the cumulative impact of many small diversions upstream. Deregulating a streamflow record in mixed use, high agricultural use areas (e.g. #7 Newaukum) or mainstem sub-basins (#19) would be very complex and beyond the Level 1 effort. Documenting the amount of upstream diversions may be necessary in the Level 2 assessment. In addition, in high unit runoff areas (e.g. Humptulips), the effects of neglecting a few minor water withdrawals may not substantially impact the magnitude of the flow duration curve except during the low flow season; in basins with low unit runoff, more emphasis should be placed on identifying diversions upstream of stream gages. Adequate estimates of natural flow may never be obtained short of conducting continuous hydrologic modeling.

Estimates of natural streamflow were developed for 5 of the 30 subbasins, level 2 efforts should continue developing natural streamflows for the remaining 25 subbasins. Prioritization should be based on subbasins with agricultural and rural residential development or basins with known low flow problems. Seventeen of the 30 subbasins do not have base gages within the sub-basin boundaries and will require further hydrologic analyses for the estimation of natural flows in level 2. Hydrologic techniques such as correlation analysis between miscellaneous flow measurements and concurrent gage data and normalization of flows by drainage area (per unit runoff calculations for various flow events) can be used as necessary. USGS gage ratings for the base gages should be reviewed to reveal cases where flows, particularly low flows, are not collected with reliable accuracy due to shifting streambed control at the gaging station. Additionally, a core period of record can be selected to assure that natural flow estimates reflect the natural variability in climatic conditions (e.g. includes both warm/dry and cool/wet cycles). Base station streamflow records can be extended through correlation analysis with nearby gages as appropriate to cover the selected core period of record then unit runoff calculations could be updated.

Initial information on land use in the watershed and its possible relationship to streamflow were reviewed for watersheds draining to the identified base gages. More detailed investigation of land use changes may be necessary at a later date (during Level 2 or 3), such as a review of aerial photos to determine: 1) the changes in land use and watershed conditions over the length of the gage records; and 2) the difference between land use and historic watershed conditions.

At this level of analysis, any suspected trends in streamflow data cannot be attributed to any specific cause (e.g. regulation by upstream dams, increased water use, climate change etc.) associations can be made. Level 2 analyses will need to address the effect of the combination of water use and land use changes over time, along with streamflow regulation to detect underlying trends.

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APPENDIX B: *WATER RIGHTS AND WATER USE*

WATER RIGHTS ANALYSIS

The purpose of this analysis was to determine the amount of allocated water within each of the 30 subbasins. The primary effort was focused on summarizing the water rights on file with the Department of Ecology. The water rights represent the major proportion of the allocated water, however, exempt ground water withdrawals (or exempt wells) are also legal entitlements to the use of water. Accounting for these exempt wells is a more difficult process since no tabulation of these wells is available. Hence, an analysis of two approaches to determine the number of water users withdrawing water from exempt wells was also undertaken. (It is easier to determine the number of water users rather than the number of wells since population numbers are readily available but the number of wells is not and, in addition, there may be more than one household per well).

METHOD

The Washington State Department of Ecology (WDOE) maintains a database, the Water Rights Accounting and Tracking System (WRATS), for tracking and storing water rights information. The WRATS database and GEOWRATS, a format of WRATS designed to spatially display the data, were obtained from WDOE in September 1999. GEOWRATS was used to identify, to the extent possible, the subbasin in which the point of diversion (POD) for each water right was located. WDOE has assigned the location of the POD of each water right in the database by using the nearest quarter-quarter (Q/4-Q/4) section of the actual POD legal description; the legal description of the point of diversion is not in the database but is on the original application, permit, and/or certificate.

The certainty of assigning a subbasin number to each water right depended on whether the Q/4-Q/4 section lay entirely within a subbasin or whether the subbasin boundary bisected the Q/4-Q/4 section. The former provided the most certainty of identifying the subbasin in which the water right POD was located. In the latter case, the assumption was made that if more than 75% of a Q/4-Q/4 section was within a particular subbasin, the POD located at the centroid of that Q/4-Q/4 section was assigned to that subbasin. These two steps covered 92% of the water rights and claims in the database. The remainder of the rights and claims were assigned subbasins using the following assumptions:

- If the majority of a Q/4-Q/4 section (based on visual inspection) was in a particular subbasin, a water right with that location was assigned to that subbasin.
- If the Q/4-Q/4 was bisected by a subbasin boundary, then the water right with that Q/4-Q/4 section location was assigned to the next downstream subbasin.
- If the Q/4-Q/4 section was entirely outside of the WRIA or if the right was tributary to the Pacific Ocean, the right was not included in this analysis.

Once water rights were assigned to a subbasin, review and organization was undertaken. The WRATS database included numerous duplicate entries that identified multiple points of diversion and/or points of use for the same water right document number. In addition, there were many *change* documents. Changes to water rights could include a change in use, additional points of diversion/withdrawal, change in point of diversion, and/or a change in the place of use. Under state law, a water user is required to file a change application for any of these alterations to a water right. (For more information, go to the WDOE website: http://www.wa.gov/ecology/pubs/981802wr/index.html). The duplicates were not counted in the overall summary of water rights, however, the number of *changes* to rights were noted in the summary table, but not added to the total numbers, either in allocated amounts or number of rights.

The number of water right certificates, permits, and applications for both surface and ground water were summarized by subbasin in Table B-4. The number of rights and claims were also tabulated by primary purpose and the total allocated amount was computed for each subbasin (Table B-3). Claims were summarized similarly (Table B-5), however, allocated amounts were not summarized since those data were not always included in the WRATS database.

Many anomalies have been noted using WRATS and GEOWRATS databases. In other western Washington projects, some water rights found on paper were not found in this database or the amount for each use associated with a water right was not clearly identified in WRATS. A more detailed analysis of the WRIA 22 and 23 data would be required to determine the extent to which that is the case for Chehalis Basin. Further, certain fields in the WRATS and GEOWRATS tables were blank, including allocated amounts and locations. Some of the missing data were obtained by contacting WDOE and requesting the information. Because of the missing data and the inexact nature of identifying the location of water right diversions/withdrawals based on the Q/4-Q/4 section, the information provided in this section is preliminary in nature and intended to provide a general understanding of the water allocation within each subbasin.

RESULTS

Based on the WRATS database (September 1999), the Chehalis Basin had a total of 2,597 water rights and 7,452 claims, including rights tributary to Grays Harbor. The database contained eight water rights and 129 claims that were identified either outside of the two WRIAs or that drained to the Pacific Ocean; these were not included in this analysis. The total allocated amount for diversions/withdrawals was almost 3,718 cfs with an annual volume limit of nearly 238,000 acre-feet. The total volume of storage rights was about 107,000 acre-feet. The water rights cover roughly 45,500 acres of irrigated land.

WRIA 22 - Lower Basin

There were a total of 769 water rights in WRIA 22 including 9 storage rights for a total allocated diversion/withdrawal amount of 2,901 cfs and volume limits at nearly 120,000 acre-feet. The largest number of rights was attributed to irrigation (406) and secondly, domestic use (200). There were about 10,204 acres associated with water rights assigned irrigation as a primary beneficial use; another 1,355 irrigated acres were associated with water rights for which other beneficial uses were primary, such as domestic or stock watering (Table B-1). Surface water rights accounted for 91% (2,497 cfs) of the instantaneous rate, and ground water accounted for 9% (260 cfs). The vast majority of the 769 water rights were certificates; there were 63 applications and 16 permits in WRIA 22.

In WRIA 22, 30 of the water rights represented 90% of the total allocated diversion/withdrawal rate (Figure B-1); 27 surface water rights and 3 ground water rights. The largest allocation was a water right certificate for hydropower generation on the Wynoochee River (Subbasin 20) at 1,400 cfs; a non-consumptive right except within the reach between the point of diversion and the point of return flow. This right represents nearly half of all the allocated water in WRIA 22. Also, in Subbasin 20 there were two water right certificates for 110 cfs and 45 cfs for municipal and commercial/industrial uses; these rights were for the City of Aberdeen. In the Satsop River Basin (Subbasin 18), there was a 570 cfs surface water certificate for multiple domestic purposes held by Lake Arrowhead Community Club. This water right was substantial considering the use to which it has been allocated; 570 cfs could easily supply the demand for a large city. This right should be investigated in Level 2 to determine whether or not this was a data entry error. These four rights were the largest in WRIA 22. The next largest water right allocation was 35 cfs on the Hoquiam River in Subbasin 22, designated for commercial and industrial uses.

The largest ground water right was a power right for 35,909 gpm (approximately 80 cfs); this right was associated with the now defunct thermonuclear power plant, at the mouth of the Satsop River, built by Washington Public Power Supply System. It is possible that this right has never been used. Of the remaining two ground water rights, one was designated multiple domestic use and the other was municipal use for 4.9 cfs and 4.5 cfs, respectively.

The largest irrigation right in WRIA 22 was for 5.5 cfs from North Bay, hence, there were no significant single irrigation rights in this WRIA.

As part of the Level 2 Assessment, the status of these 30 water rights should be investigated to determine which ones are actually being used and which ones are not, or never have been used.

Table B-1: WRIA 22 Summary of Water Rights By Primary Beneficial Use

Primary Purpose	Number of Rights	Total Instantaneous Withdrawal Rate (cfs)	Annual Volume Limit (acre feet)	Irrigated Acres
Commercial	20	86.66	1,348	3
General Domestic	1	2.24	1,625	0
Multiple Domestic	85	612.44	4,218	5
Single Domestic	114	1.92	77	3
Environmental Quality	1	0.05	0	4
Frost Protection	5	6.72	961	0
Fish Propagation	34	157.56	411	0
Heat Exchange	3	1.84	118	0
Irrigation	406	175.84	13,102	10,204
Municipal	28	206.2	112,837	0
Power	6	1,489.43	54,360	9
Recreation	3	0.36	55	12
Right of Way	2	0.56	102	0
Stock	55	12.80	1,765	1,256
Wildlife	6	1.84	157	63
TOTAL	769	2,756.46	191,135	11,559

WRIA 23 -Upper Basin

In all, WRIA 23 contained 1,828 water rights for a total allocated amount of 961 cfs for direct flow diversions and ground water withdrawals; the volume limit was 116,728 acre-feet plus an additional storage volume of 35,657 acre feet (14 storage rights). Similar to WRIA 22, the largest number of rights were associated with irrigation use (1,102) and secondly, domestic use (347). Irrigation rights were tied to 33,947 acres (Table B-2). Excluding storage rights, the rights were split evenly between surface and ground water rights in WRIA 23. Surface water rights accounted for 55% (533 cfs) of the instantaneous rate and ground water accounted for 45% (428 cfs). The vast majority of the 1,828 water rights were certificates; there were 45 applications and 34 permits in WRIA 23.

As displayed in Figure B-1, 40% of the rights (724 in number) covered 90% of the allocated water. Twenty-two rights (~1%) covered 40% of the allocation. There were a significant number of small water rights throughout WRIA 23 that spread the allocation to many as compared to the few found in WRIA 22.

The largest two water rights in WRIA 23 were power rights for 140 cfs and 80 cfs held by Pacific Power and Light; the latter includes commercial use as well. The source of supply for these two rights was the Skookumchuck River (Subbasin 9). The top three ground water rights were intended for fish propagation for a total of 18,000 gpm or 40 cfs.

Table B-2: WRIA 23 Summary of Water Rights By Primary Beneficial Use

Primary Purpose	Number of Rights	Total Instantaneous Withdrawal Rate (cfs)	Annual Volume Limit (acre feet)	Irrigated Acres
Commercial	27	9.18	1,518	0
Multiple Domestic	210	42.69	6,783	0
Single Domestic	137	3.19	207	21
Frost Protection	2	8.12	360	145
Fire Protection	10	2.38	625	0
Fish Propagation	44	128.94	37,426	0
Heat Exchange	3	0.59	109	0
Highway	1	0.25	0	0
Irrigation	1,102	411.60	48,202	29,277
Municipal	36	60.92	14,003	24
Power	10	232.32	35,001	73
Recreation	28	5.93	583	118
Right of Way	4	1.55	572	0
Stock	194	51.02	6,871	4,242
Wildlife	20	2.57	125	47
TOTAL	1,828	961.25	152,385	33,947

The number of irrigation water rights (1,102) was 60% of the total number of rights, representing nearly 43% of the total allocated water (412 cfs) in WRIA 23. Many of these rights included single or multiple domestic use as a secondary beneficial use. Sorting out an amount associated with each beneficial use was not possible at this level of analysis. The largest surface and ground water irrigation rights were 3.33 cfs and 4.45 cfs for 33 acres and 30 acres, respectively. Although irrigation rights represented the largest allocation by beneficial use, the amounts of the individual rights were relatively small compared to the largest rights in WRIA 23 (i.e. power and fish propagation).

While stock watering appeared to have a rather high allocation (51 cfs), a secondary use associated with this beneficial use was the irrigation of 4,242 acres. As stated above, at this Level 1 Assessment, the rates associated with primary, secondary, tertiary, etc., beneficial uses could not be separated out. The next highest number of rights is for domestic use, with 347 rights, for a total instantaneous withdrawal rate of 45.88 cfs.

Power and fish propagation, generally non-consumptive uses, represented 361 cfs or 38% of the total allocated rate. Included in this total was a surface water right for 80 cfs held in the name of Pacific Power & Light and intended for the Centralia Steam Plant, a thermoelectric power system high in its consumptive use of water. Therefore, all power rights cannot be assumed non-consumptive uses. Power, fish propagation, and irrigation accounted for 81% of the total allocation in WRIA 23. Power generation represents the highest water use per right (23.9 cfs/right), and frost protection the second highest (4.06 cfs/right). Fish propagation ranks third with 2.93 cfs/right, and municipal ranks fourth with 1.69 cfs/right. All other categories indicate less than 1 cfs per right. The ratio of cfs per right for irrigation uses was 0.37.

As part of a Level 2 Assessment, it would be worthwhile to investigate the 22 rights that cover 40% of the allocated water to determine whether or not these are currently being exercised under Washington State water law. Understanding the extent to which water rights are actually being used in WRIA 23 would be a more involved and costly endeavor than in WRIA 22, due to the significant number of small rights spread throughout the upper basin. In addition, Mahlum (WDOE, 1976) identified a number of rights within the Skookumchuck River basin that have not been developed; status of these should be determined in Level 2.

Figure B-1
Cumulative Allocated Water Assigned to Number of Rights
Chehalis River Basin (WRIAs 22 and 23)

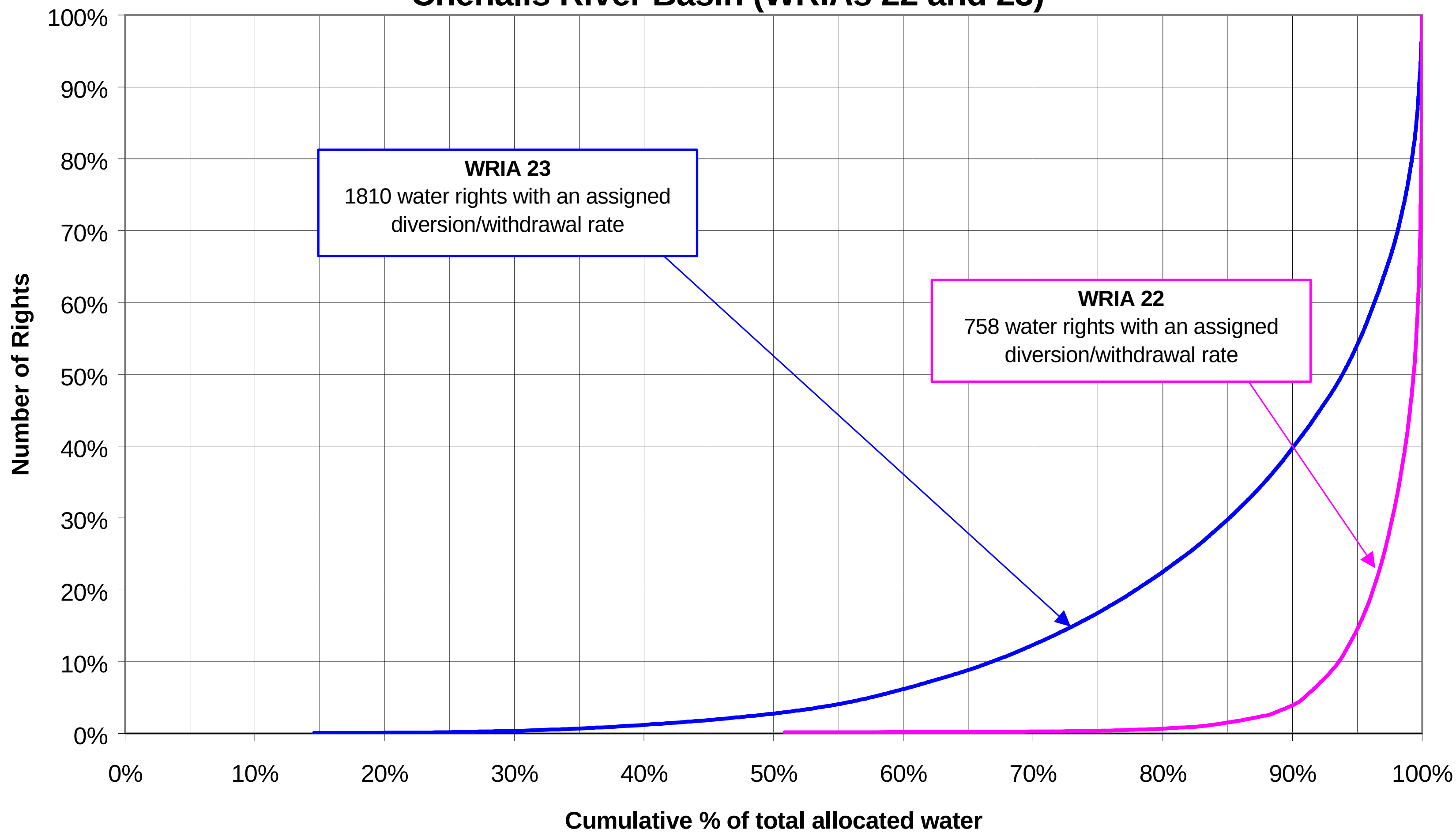


Table B-3. Summary of Water Rights' Allocated Amounts and Purposes. (Highlighted rows indicate subbasins which were selected for more detailed analysis in Section 3.)

	Allocated Amounts of Surface & Ground Water Right				Number of Water Rights by Primary Purpose									
Subbasin	cfs	acre feet	acres	Storage (acre feet)	Domestic	Irrigation	Recreation	Commercial	Power	Fish or Wildlife Propagation	Municipal	Stock Watering	Other	Total Uses
1	12.47	684	370	-	8	24		1	2	2	4	7	-	48
2	8.69	124	67	-	-	3	-	-	1	1	-	2	-	7
3	10.99	1,061	1,124	-	-	23	-	-	-	-	-	4	-	27
4	66.51	6,976	4,865	5	46	157	7	1	1	9	1	19	4	245
5	9.97	2,243	253	-	1	11	1	-	-	2	1	3	-	19
6	14.00	139	77	-	4	3	-	-	-	2	1	2	-	12
7	62.46	7,636	4,642	-	26	129	2	3	1	8	5	29	-	203
8	2.50	237	323	-	2	6	-	-	-	-	1	1	2	12
9	312.87	12,063	1,549	35,399	21	69	-	5	2	4	12	7	3	123
10	67.48	10,204	4,332	17	44	162	3	7	1	7	4	22	-	250
11	217.56	33,218	8,092	224	109	227	12	7	1	18	1	38	6	419
12	2.07	329	184	-	4	5	-	-	1	-	-	1	-	11
13	173.68	41,768	8,067	60	83	285	2	3	-	9	6	59	5	452
Subtotal (WRIA 23)	***961.25***	***116,680***	***33,946***	***35,705***	***348***	***1,104***	***27***	***27***	***10***	***62***	***36***	***194***	***20***	***1,828***
14	17.29	2,876	699	-	22	45	-	4	-	-	3	5	1	80
15	76.04	1,088	61	-	9	3	-	1	-	13	-	-	2	28
16	3.20	249	174	-	3	6	-	-	-	1	-	1	1	12
17	0.94	153	104	-	4	5	-	-	-	-	-	3	-	12
18	604.28	1,556	871	-	8	19	-	-	1	5	-	12	-	45
19	71.55	11,399	5,453	6	27	114	1	1	-	2	4	12	1	162
20	1,574.28	36,129	1,204	70,050	12	29	1	3	1	2	4	7	1	60
21	22.94	145	204	48	18	13	-	1	-	2	2	1	-	37
22	60.17	179	52	12	24	9	-	1	1	1	3	2	1	42
23	-	-	-	-	-	-	-	-	-	-	-	-	-	-
24	7.38	88	52	-	9	8	-	1	1	2	-	3	-	24
25	86.55	633	309	469	7	12	-	-	1	7	-	1	2	30
26	-	-	-	-	-	-	-	-	-	-	-	-	-	-
27	1.59	231	-	-	2	-	-	2	-	-	-	-	-	4
28	-	-	-	-	-	-	-	-	-	-	-	-	-	-
29	2.10	-	-	-	1	-	-	-	-	-	1	-	-	2
30	123.31	60,603	1,771	605	28	56	-	3	1	5	5	8	-	106
GH	104.84	4,617	607	-	26	87	1	3	-	-	6	-	2	125
Subtotal (WRIA 22)	***2,756.46***	***119,945***	***11,559***	***71,190***	***200***	***406***	***3***	***20***	***6***	***40***	***28***	***55***	***11***	***769***
TOTAL	***3,717.71***	***236,625***	***45,505***	***106,895***	***548***	***1,510***	***30***	***47***	***16***	***102***	***64***	***249***	***31***	***2,597***

Table B-4. Summary of Ground and Surface Water Rights and Storage Rights. (Highlighted rows indicate Subbasins which were selected for more detailed analysis in Section 3.

	Surface Water					Ground Water					Storage	
Subbasin	# applications	#permits	# certificates	#changes	Total # rights	# applications	#permits	# certificates	#changes	Total # rights	#storage right	Total # Rights
1	2	2	43	-	47	-	-	1	-	1	-	48
2	-	1	6	-	7	-	-	-	-	-	-	7
3	-	-	27	-	27	-	-	-	-	-	-	27
4	1	2	170	2	173	5	2	62	1	69	3	245
5	-	-	16	2	16	-	-	3	-	3	-	19
6	1	-	11	-	12	-	-	-	-	-	-	12
7	2	-	123	-	125	6	4	68	2	78	-	203
8	-	-	6	-	6	-	-	6	-	6	-	12
9	-	-	68	-	68	5	2	44	1	51	4	123
10	1	1	116	1	118	1	1	129	1	131	1	250
11	-	-	164	-	164	9	8	234	7	251	4	419
12	-	-	7	-	7	-	1	3	-	4	-	11
13	-	1	139	-	140	12	8	290	12	310	2	452
Subtotal (WRIA 23)	***7***	***7***	***896***	***5***	***910***	***38***	***26***	***840***	***24***	***904***	***14***	***1,828***
14	2	1	48	-	51	3	1	25	-	29	-	80
15	4	-	16	-	20	3	-	5	-	8	-	28
16	-	-	8	-	8	-	-	4	-	4	-	12
17	-	-	12	-	12	-	-	-	-	-	-	12
18	1	2	21	1	24	-	1	20	1	21	-	45
19	2	-	80	-	82	7	1	71	3	79	1	162
20	2	1	34	1	37	2	-	19	-	21	2	60
21	-	-	36	-	36	-	-	-	-	-	1	37
22	-	-	38	-	38	-	-	3	-	3	1	42
23	-	-	-	-	-	-	-	-	-	-	-	-
24	-	1	22	-	23	-	-	1	-	1	-	24
25	1	1	15	-	17	1	-	10	-	11	2	30
26	-	-	-	-	-	-	-	-	-	-	-	-
27	-	-	2	-	2	1	-	1	-	2	-	4
28	-	-	-	-	-	-	-	-	-	-	-	-
29	-	-	2	-	2	-	-	-	-	-	-	2
30	2	-	67	-	69	2	1	32	-	35	2	106
GH	10	1	32	1	43	20	5	57	2	82	-	125
Subtotal (WRIA 22)	***24***	***7***	***433***	***3***	***464***	***39***	***9***	***248***	***6***	***296***	***9***	***769***
TOTAL	***31***	***14***	***1,329***	***8***	***1,374***	***77***	***35***	***1,088***	***30***	***1,200***	***23***	***2,597***

Table B-5. Water Claims Summary. (Highlighted rows indicate subbasins which were selected for more detailed analysis in Section 3.)

Subbasin	Surface Water # Claims	Ground Water # Claims	Combined Surface & Ground Water Claims	Total # Claims	Purposes: General Domestic	Irrigation	#Acres	Stock	*Unknown*	Total
1	**35**	**67**	**1**	**103**	**90**	**8**	**158**	**-**	**5**	**103**
2	10	28	-	38	37	1	50	-	-	38
3	3	17	-	20	17	-	10	1	2	20
4	97	726	1	824	766	19	681	27	12	824
5	97	20	-	117	106	3	114	6	2	117
6	3	3	-	6	5	-	13	1	-	6
7	**53**	**618**	**-**	**671**	**638**	**7**	**1,200**	**23**	**3**	**671**
8	22	90	-	112	103	1	158	6	2	112
9	2	7	-	9	7	-	-	-	2	9
10	76	903	-	979	910	37	965	25	7	979
11	67	944	2	1,013	957	11	1,290	31	14	1,013
12	-	1	-	1	1	-	-	-	-	1
13	81	958	2	1,041	976	19	3,660	27	19	1,041
Subtotal (WRIA 23)	***546***	***4,382***	***6***	***4,934***	***4,613***	***106***	***8,299***	***147***	***68***	***4,934***
14	**52**	**230**	**-**	**282**	**263**	**7**	**363**	**7**	**5**	**282**
15	21	70	-	91	86	3	47	1	1	91
16	11	53	-	64	64	-	18	-	-	64
17	13	14	-	27	26	1	27	-	-	27
18	19	87	-	106	100	1	2,226	3	2	106
19	**65**	**351**	**-**	**416**	**368**	**16**	**542**	**17**	**15**	**416**
20	51	119	-	170	159	2	116	6	3	170
21	70	112	-	182	154	14	808	8	6	182
22	67	131	-	198	188	5	921	1	4	198
23	-	-	-	-	-	-	-	-	-	-
24	32	74	-	106	98	3	25	3	2	106
25	**31**	**211**	**-**	**242**	**224**	**8**	**2,012**	**6**	**4**	**242**
26	-	4	-	4	4	-	-	-	-	4
27	9	58	-	67	64	-	20	-	3	67
28	7	6	-	13	11	1	1	-	1	13
29	-	3	-	3	2	1	12	-	-	3
30	86	460	1	547	486	40	1,386	8	13	547
GH	21	-	1	22	21	-	-	-	1	22
Subtotal (WRIA 22)	***555***	***1,983***	***2***	***2,518***	***2,055***	***102***	***8,524***	***60***	***59***	***2,518***
TOTAL	***1,101***	***6,365***	***8***	***7,452***	***6,668***	***208***	***16,823***	***207***	***127***	***7,452***

WATER USE

Estimates of actual water use have not previously been determined for WRIAs 22 and 23. Outside of large diversion/withdrawals for municipal or industrial use, records of water use are generally not available. In the absence of these records, estimating actual water use was a difficult task. The estimates developed for this analysis were based on population data from the 1990 census. These estimates should be viewed as preliminary and should be refined using 2000 census data in the Level 2 Assessment in conjunction with a comprehensive review of all public water system plans.

ESTIMATION OF CURRENT AND FUTURE POPULATION

The estimate of current and future water use is, in part, based on population statistics. Population data were most often summarized by political boundaries rather than watershed boundaries, making it difficult to translate the data into water use for a particular basin or subbasin. The Chehalis Basin encompasses the majority of Grays Harbor County and a portion of both Lewis and Thurston Counties. Population statistics, such as number of people per household, and population projections into the 21st century for these three counties, were the primary sources (Census Bureau: (http://venus.census.gov/)) used to develop water use estimates.

Table B-6: County Population Data and Projections

Year	Grays Harbor County		Lewis County		Thurston County	
	Population	% increase	Population	% increase	Population	% increase
1990	64,175	-	59,358	-	161,238	-
1995	67,699	5	65,498	10	189,203	17
2000	71,848	6	70,286	7	214,767	14
2005	73,905	3	76,004	8	243,550	13
2010	76,821	4	80,843	6	267,988	10
2015	81,010	5	86,249	7	295,443	10
2020	86,309	7	92,395	7	324,911	10

The population in Grays Harbor County was projected to grow at a rate of 0.6% to 1.4% per year; Lewis County was expected to grow from between 1.2% to 2% per year and; projected growth for Thurston County, which includes Olympia, was anticipated at a rate of 2% to 3.4% per year, the fastest growing of the three counties.

Three sources were reviewed for population data within each WRIA: Chehalis Basin Action Plan (1992), U.S.G.S. Water Use Study for 1990 and 1995, and the actual 1990 census data in a GIS format for Lewis County. The latter was used in estimating populations for two of the five subbasins in Chapter IV. Without GIS census data from Thurston County, the GIS data format could not be used to estimate WRIA 23 population. A GIS layer for Grays Harbor County census data was not available for WRIA 22. The Action Plan numbers were also based on the 1990 census data.

Population data summarized from the two primary sources varied considerably (Table B-7). Since the Action Plan (1992) reported 1990 population data only, the 1995 numbers were estimated based on County growth projections. The USGS estimated the 1990 population at about 55% of the Action Plan number for WRIA 22. In WRIA 23, the USGS estimated the 1990 population at about 20,000 fewer than the Action Plan. The USGS estimates were lower overall than the Action Plan estimates.

Table B-7: Population Data for each WRIA

Source	WRIA 22		WRIA 23	
	1990	1995	1990	1995
Chehalis River Basin Action Plan (1992)	57,600	60,480[1]	77,000	84,700[2]
USGS	37,080	36,110	58,1200	83,330

[1]Projected population based on Grays Harbor County statistics.
[2]Projected population based on Lewis County statistics

The USGS numbers appeared to be low since the public water systems in WRIA 22 reported serving a population of 49,343 in 2000. Applying the increase in growth for Grays Harbor County to the 1995 USGS population figures, the 2000 population would be 37,915, nearly 12,000 people fewer than the number served by the public water systems in that WRIA. Therefore, the Action Plan (1992) numbers were used as a better representation of the actual population.

Current and future populations were estimated using the average rate of growth for the County populations, i.e. Grays Harbor County statistics were used to estimate future population for WRIA 22, and Lewis and Thurston County statistics were used to estimate future population for WRIA 23. About one-third of WRIA 23 is situated in Thurston County, therefore, a weighted growth rate for the two counties was developed using this ratio. Using these estimated WRIA populations, water use for the residential sector was estimated to the year 2020 (Table B-8).

Table B-8: Future Population Projections by WRIA

WRIA	2000	2005	2010	2020
22	64,109	66,032	68,673	76,914
23	94,000	103,400	110,640	122,810

[1]Projected population based on Grays Harbor County statistics.
[2]Projected population based on Lewis County statistics

CURRENT RESIDENTIAL WATER USE

Method

Without actual records, an estimate of residential water use can be determined by using design standards for the development of public water systems (WDOH,1999). The Water System Design Manual (WDOH, 1999) bases its determination of water demand on average annual rainfall by the following equation:

$$\mathbf{ADD = (8{,}000/AAR) + 200}$$

where ADD = average day demand per equivalent residential unit (ERU);
AAR = average annual rainfall.

An ERU was defined as a residential unit equivalent to a single-family residence. The average number of people per household must also be determined to convert the ADD to an average daily demand per person (gallons per capita per day = gcd).

The monthly distribution of water for residential water use is constant for in-house use, but increases primarily in the months of July, August, and September when precipitation is the lowest and crop water requirements for lawns and gardens are highest. Outside lawn and garden watering can increase summertime demand by more than 50% (WDOH, 1998). In the Water System Design Manual (1999), the recommended maximum day demand for designing water systems is:

$$\mathbf{MDD = 2 \times ADD}$$

where MDD = maximum day demand.

The majority of the population in the Chehalis Basin is concentrated in two areas (Aberdeen/Hoquiam and near Centralia/Chehalis) and along the low-lying river valleys of the basin. The location of Elma was used to represent the mid-basin area. While the average annual precipitation is significantly higher in the upper part of the watershed, relatively few people live in these areas. Therefore, the precipitation values used for determining residential water use were based on the three areas defined above. As shown in Table B-9, the average day demand for one single-family residence ranged from 296 in Aberdeen to 374 in Centralia.

Table B-9: Average Annual Precipitation near Population Centers

	Average Annual Precipitation (inches)	Average Day Demand gallons per day/ERU[1] (ADD)	Per Capita Daily Demand (gcd)
Aberdeen	83	296	118
Elma	67	319	128
Centralia	46	374	144

[1]ERU = equivalent residential unit ~ 1 single-family residence

From the 1990 census data, there were approximately 2.5 people/household in Grays Harbor County and 2.6 people per household in Lewis and Thurston Counties. Using these data, the average daily per capita water demand was computed and ranged from 118 gcd (gallons per capita per day) to 144 gcd. The maximum day demand (double the average day demand) ranged from 236 gcd to 288 gcd. The latter values represent water use during periods of extensive outside lawn and garden watering in the dry season.

A significant portion of irrigation water is lost to evapotranspiration while the remaining water either becomes subsurface flow or overland flow; the amount returned can be as much as 60% of the withdrawal. In-house residential water use consumes about 20% to 30% of the water delivered, the remainder (70% to 80%) returns to surface or ground water depending on treatment of discharge. Wastewater treatment at a centrally located plant will discharge water back to the river at a designated point. Septic systems will delay the return flow as the wastewater is filtered through the leach field following subsurface pathways, a portion of which may return to a surface water body and a portion of which may return to ground water.

Keeping these concepts in mind, residential water withdrawals have associated return flows that must be accounted for in a water balance. The reach of the river that experiences the total impact of the withdrawal is between the point of diversion and the point of return. Therefore, downstream of the point of wastewater discharge, the impact is less than the total diversion.

Results

The ADD and MDD were applied to the current estimated populations in both WRIAs to understand the total current water use for the residential sector (Table B-10).

Table B-10: Estimated Current Residential Water Demand

WRIA	Average Per Capita Water Demand (gcd)	Year 2000 Average Day Water Demand (cfs)	Year 2000 Maximum Day Water Demand (cfs)
22	123	12	24
23	144	21	42
TOTAL		33	66

In WRIA 22, the total allocated water for domestic or municipal use was 820.56 cfs. The municipal portion of this amount (206.2 cfs) may include commercial and light industrial uses as well. In any event, the allocation amount was significantly larger than the total population demand of 12 cfs for the average day demand, and 24 cfs for the maximum day demand. The very large multiple domestic right (570 cfs), allocated to Lake Arrowhead Club, was an outlier for the typical allocation associated with this primary purpose.

In WRIA 23, 45.88 cfs has been allocated for single- and multiple- domestic use while the municipal water rights totaled 60.92 cfs; the total of these rights was 106.8 cfs. Again, this allocation was more than double the year 2000 residential water demand.

While municipal rights are often not used to their full entitlement reserving for future growth, investigation into the multiple domestic rights would be a worthwhile endeavor to understand what portion of the rights are actually being used. The single domestic rights were sufficiently small to place those at a lower priority for investigation. Multiple domestic rights are those associated with more than one dwelling, i.e. motels, trailer courts, campgrounds, parks, schools, port districts, public utility districts, diking and drainage districts, water districts, reclamation districts, and counties, none of which are under municipal control.

Public Water Systems

Another avenue for arriving at residential water use was to investigate public water system records. A list of public water systems was obtained in 1999 from the Washington State Department of Health for the entire Chehalis Basin. This database included the number of residential and non-residential connections, the population served, and the locations (to the nearest quarter-quarter section) of the public water systems' sources of supply. Since service area boundaries were not available for the public water systems at this time, the point of withdrawal was used as the identifier for assigning the water system to the appropriate subbasin. The locations of the systems can be refined, if necessary, in a Level 2 assessment, by using service area boundaries rather than the source water location.

Information for all the water systems in WRIAs 22 and 23 is summarized by subbasin in Table B-11. There were 586 public water systems on the WDOH list (1999), 481 in WRIA 23, and 106 in WRIA 22. By point of diversion, 72 systems were located outside of the WRIA boundary; 55 from WRIA 23 and 17 from WRIA 22. Further review of service boundaries would have to be conducted to understand whether or not these water systems are actually outside of the basin and not just their point of diversion. If these water systems are within the boundary of either WRIA, their water use would be considered an importation and the associated return flow would be augmenting the Chehalis River system.

Of the total public water systems in WRIA 23, more than two-thirds were small systems; 335 (70%) were Group B systems and the remaining 146 were Group A systems. Group A systems represent the larger facilities that serve 15 or more connections or 25 or more people/day for 60 or more days/year. Group B systems serve 1) less than 15 connections and less than 25 people for 60 or more days/year or 2) any number of people for less than 60 days per year or 3) less than 15 connections in use less than 60 days per year. In WRIA 22, there were nearly an equal number of small and large water systems: 72 in Group A and 63 in Group B water systems.
A summary of the WDOH data indicate the total resident population in 1999 served by a public water system was 39,390 in WRIA 23 and 49,343 in WRIA 22; total resident connections were 15,312 and 16,862, respectively. The resident population divided by the resident connections results in the number of people per household for each WRIA; 2.6 and 2.9 people per household in WRIA 23 and 22, respectively. The former agrees with the Lewis County average of 2.6 people/dwelling unit, as found in the U.S. Census Bureau database. The Grays Harbor County average is higher than the 2.5 people/dwelling unit estimated by the U.S. Census Bureau. The public water system data reflects a higher household density in the more urban centers, while the county data represents the rural areas as well.

Table B-11. Public Water System Summary for WRIA 22 and 23. *(Highlighted rows indicate subbasins which were selected for more detailed analysis in Section 3.)*

WRIA 22 Public Water System Summary

Subbasin #	# PWS	Group A	Group B	Resident Population	Resident Connections	Total Connections	Largest Supplier
14	20	12	8	2,083	923	972	City of McCleary
15	6	1	5	25	12	18	Bingham Creek Hatchery
16	4	2	2	11	5	8	Chappell Cole Water Supply
17	-	-	-	-	-	-	NA
18	7	3	4	18	10	52	Schafer State Park
19	15	7	8	3,314	1,322	1,335	City of Elma
20	7	4	3	4,426	1,495	1,911	City of Montesano
21	3	2	1	18,035	4,990	4,991	City of Aberdeen
22	4	1	3	9,042	3,522	3,522	City of Hoquiam
23	-	-	-	-	-	-	NA
24	1	-	1	2	1	2	R& L Grocery
25	10	4	6	80	34	55	Riverview Recreation Area
26	-	-	-	-	-	-	NA
27	4	3	1	49	20	24	Wildwood Mobile Home Park
28	-	-	-	-	-	-	NA
29	-	-	-	-	-	-	NA
30	10	6	4	4,578	1,308	1,331	Grays Harbor Co Water Dist 2
GH	15	8	7	7,680	3,220	5,824	City of Westport
Unknown	12	6	6				
Out of Basin	17	13	4				
TOTAL	**106**	**72**	**63**	**49,343**	**16,862**	**20,045**	

WRIA 23 Public Water System Summary

Subbasin #	# PWS	Group A	Group B	Resident Population	Resident Connections	Total Connections	Largest Supplier
1	2	1	1	600	360	377	Town of Pe Ell
2	-	-	-	-	-	-	NA
3	1	1	-	4	2	3	Camp Grace
4	35	9	26	3,716	1,312	1,326	Boisfort Valley Water Corp.
5	2	-	2	15	8	9	2533 Water System
6	2	2	-	21,100	8,165	8,165	City of Centralia
7	43	14	29	1,144	467	558	Lewis Co Water Dist #2
8	5	2	3	328	104	106	K & L Water System
9	18	8	10	942	376	388	Bucoda Water Dept
10	49	18	31	557	240	331	View Ranch Estates Water Assoc.
11	106	36	70	5,106	1,980	2,199	Scott Lake
12	3	1	2	400	160	210	Cedar Creek Corrections Center
13	137	34	103	5,358	2,085	2,253	City of Tenino
UNKNOWN	23	1	22	120	53	70	Swope MH Park, Summerwood M Manor
Out of Basin	55	19	36				
TOTAL	481	146	335	39,390	15,312	15,995	

Residential water use can be estimated for the public water system supplied customers using the same techniques applied for the entire population (Table B-12). Again, the average and maximum per capita demand of Aberdeen and Elma were averaged and used for WRIA 22 and the per capita demand for Centralia was used for WRIA 23. Interestingly enough, the total demand was about the same in both WRIAs as the decrease in per capita demand in WRIA 22, due to higher precipitation levels, offset its higher population.

Table B-12: Estimated Current Public Water System Supplied Residential Water Demand

WRIA	Average Per Capita Water Demand (gcd)	Year 2000 Average Day Water Demand (cfs)	Year 2000 Maximum Day Water Demand (cfs)
22	123	9	18
23	144	9	18
TOTAL		18	36

Service area boundaries for public water systems were identified as a data gap in this analysis. In addition, some of the actual withdrawals or diversions conveyed to public water systems may be on record with WDOH.

Self-Supplied Water Users

The number of self-supplied water users can be estimated as the difference between the total WRIA population and the population served by a public water system. For WRIA 22 there were an estimated 14,766 self-supplied water users, while WRIA 23 had roughly 54,610. Self-supplied water users either withdraw/divert water under a water right or use water from a well with exempt status under RCW 90.44.050.

According to the water rights tabulation, 616.60 cfs has been allocated in WRIA 22 to domestic use for either single or multiple housing; 1.92 cfs has been allocated to 114 single-family households (~285 people). In WRIA 23, 45.88 cfs has been allocated to domestic use; about 7% or 3.19 cfs was appropriated for 137 single-family homes (~356 people).

The primary beneficial use listed in the water rights database for many of the public water systems was multiple domestic. Therefore, identification of the water rights for each water system would have to be undertaken to understand the relationship between multiple domestic rights and the self-supplied population, which would also lead to understanding the number of the self-supplied water users withdrawing water from an exempt well. Two methods for estimating exempt well use are described and evaluated in the Exempt Well section of this Appendix.

Self-supplied water use can be estimated using the same techniques applied for the entire residential population (see above). Again, the average and maximum per capita demand of Aberdeen and Elma were averaged and used for WRIA 22 and the per capita demand for

Centralia was used for WRIA 23. The self-supplied average day demand in WRIA 23 was about four times that of the demand in WRIA 22 (Table B-13).

Table B-13: Estimated Current Self-Supplied Water Demand

WRIA	Average Per Capita Water Demand (gcd)	Year 2000 Average Day Water Demand (cfs)	Year 2000 Maximum Day Water Demand (cfs)
22	123	3	6
23	144	12	24
TOTAL		15	30

Future Residential Water Use

Future residential water use was estimated using the population projections that were based on average growth rates (see above) and the same per capita demand as that calculated for current water use. The demand was converted to cfs for easy comparison with streamflows. The increased demand in WRIA 22 was roughly 3 cfs (Table B-14) over the next 20 years, while WRIA 23 anticipated future demand was calculated to increase by over 6 cfs.

Table B-14: Estimated Future Residential Water Demand

WRIA	Average Per Capita Water Demand (gcd)	Average Day Water Demand (cfs)			
		2000	2005	2010	2020
22	123	12	12.5	13	15
23	144	21	23	25	27
TOTAL		33	33.5	38	42

COMMERCIAL AND INDUSTRIAL WATER USE

Commercial and industrial water use can be supplied to an entity through a public water system or self-supplied through an individual well. An estimate of the number of commercial and industrial connections (or non-residential) served through public water systems can be computed by subtracting the residential connections from the total connections. For WRIA 22, the non-residential connections totaled 3,183; for WRIA 23, the number of commercial and industrial connections was 683.

The water rights allocated for commercial/industrial use total 86.66 cfs in WRIA 22 and 9.18 cfs in WRIA 23, for a total of 95.84 cfs. The six largest of these rights account for 86% of the total commercial/industrial allocation. Grays Harbor Pulp & Paper has three water rights for 35 cfs, 15 cfs, and 5 cfs; the Weyerhauser Company has the right to the third largest for 12.2 cfs. The

Port of Grays Harbor has a right to 3.5 cfs, and an unknown industry (Quiggs Brothers McDonald) has the right to 4.4 cfs.

Beyond this information, it is difficult to estimate current or future commercial/industrial water use without knowing the exact enterprises. Investigation of the six largest water rights to determine the associated actual use should be undertaken in a Level 2 Assessment, to understand the proportion between commercial allocations and actual use.

Irrigation

In the past, the Census of Agriculture summarizes agricultural data by county every five years including some statistics on irrigated land. The USGS reported water use information by WRIA and by county once every five years, as well. However, after 1995 these data will no longer be summarized by WRIA. Little or no information is available that details the spatial distribution of irrigated agriculture in either WRIA.

The Census of Agriculture reported that there were 5,765 irrigated acres of land in Lewis County in 1997 from which 4,842 acres were harvested for cash crops (USDA, 1999). Staff from the Natural Resource Conservation Service in Chehalis indicated that roughly half of Lewis County's irrigated lands are in the Chehalis Basin, an estimated 2,880 acres. The USGS reports irrigated land in WRIA 23 at 12,444 acres. Regardless of the data used, actual use appears to be much less than the allocation since the irrigation water rights covered 33,947 acres of land for an annual volume of irrigation water of 55,908 acre-feet (1.65 acre-feet/acre).

Grays Harbor County's data were relied on for understanding irrigated area in WRIA 22. The County reported 3,067 acres of irrigated land, 2,480 acres of irrigated croplands in the *1997 Census of Agriculture – Washington, State and County Data (USDA, 1999).* The USGS reported 2,140 acres irrigated. The total water righted acreage was 11,559 with an associated annual volume of 14,827 acre-feet (1.42 acre feet/acre). As in WRIA 23, the estimates of actual irrigated area were substantially lower than the water righted acreage.

Based on conversations with NRCS in both Grays Harbor and Lewis Counties and the data reported in the 1997 Agricultural Statistics, irrigated agriculture appeared to be on the decline. Irrigated land, which includes irrigated cropland and irrigated pasture (not a cash crop), declined by nearly 30% between 1992 and 1997 in Grays Harbor County, while irrigated cropland declined by over 40% during that same time period. Irrigated land in Lewis County decreased by about 25% and irrigated croplands declined by slightly more than 22% during that same period.

While the acres irrigated may be less than the water rights, it still represents a significant use of water. Irrigated agriculture is the highest consumptive use in the Chehalis Basin with perhaps one exception; the thermoelectric steam plant in Centralia. Because of the significance of this impact on the watershed, exploration of the relative volumes of monthly consumptive use was undertaken.

From discussions with NRCS and Conservation District staff in both Grays Harbor County and Lewis County, pasture grass has become the predominant crop currently irrigated. Pasture grass is being used to supply feed to the beef and dairy industry in both counties. Field corn is also being grown and irrigated for the same use, but to a lesser extent than pasture grass. Cannery corn and peas were grown over large areas previously, but these two crops have declined significantly in recent years. In Lewis County, the local cannery will no longer be processing corn and peas after this year; farmers are expected to convert to some other cash crop. The Grays Harbor Conservation District reported about 2,500 acres of peas and corn being grown. About 50% to 60% of these acres were planted in cannery corn, an irrigated crop. Some silage corn was also irrigated although the size of area planted was unknown. Peas were typically not irrigated since they were planted early in the spring and harvested before the weather became too dry.

According to the 1997 Census of Agriculture, there were minor amounts of corn, wheat, and potatoes grown in Lewis and Grays Harbor Counties. About 60% to 70% of the irrigated croplands were planted in alfalfa hay, with some lesser acreages in vegetables and orchards.

Crop consumptive use, the amount of water a crop directly needs, can be calculated using several different empirical methods. Irrigation requirements for Washington (James et. al, 1989) advocate the use of a modified Blaney-Criddle method, a temperature-based method. Doorenbos and Pruitt's (James et. al., 1989) adaptation of the Blaney-Criddle method is based on data from a wide-range of climates and crop coefficients for a wide range of crops, both of which are useful in Washington. A detailed description of this method is beyond the scope of this document, however, for purposes of understanding irrigation water use, certain data that were developed from the Doorenbos and Pruitt Blaney-Criddle method were selected to demonstrate the monthly variability of crop water requirements.

Pasture and field corn were used to assess crop irrigation requirements since one is relatively high in consumptive use and the other relatively low, representing the major crops grown in the area. Some vegetables have lower consumptive use, however, since the extent of their production was unknown, they were not used in this analysis. Table B-16 summarizes the mean monthly temperature and precipitation, effective precipitation, crop consumptive use, and crop irrigation requirements for pasture/turf and field corn, and the crop irrigation requirements, assuming an efficiency of 50%. Figures B-3 and B-4 indicate the seasonal variation of precipitation, temperature, and crop consumptive use of both crops for Centralia and Aberdeen. Climate data for Centralia was used for WRIA 23, and Elma and Aberdeen climate data were used for subbasin analyses in WRIA 22.

Efficiency can be defined as that portion of the delivered water that is actually used by the crop. In other words, an efficiency of 50% means that twice the water must be withdrawn as that which is actually used by the crop. This takes into account on-farm losses, ditch conveyance losses, and deep percolation to ground water. Table B-15 displays some typical on-farm efficiencies. NRCS staff recommended using an efficiency of 40% to 50% since farms in the Chehalis Basin do not have the technology and sophistication of large farms in eastern Washington.

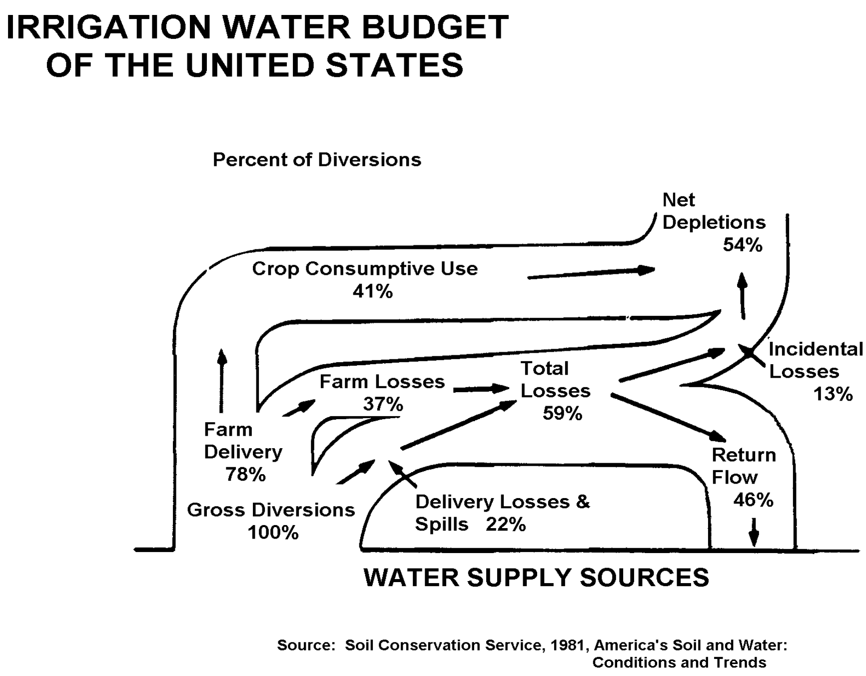
Table B-15: Typical on-farm efficiencies for various types of irrigation systems.

System	Efficiency
Surface:	
Average system, no treatment	50%
Partial treatment, i.e. land leveling or irrigation pipelines etc.	60%
Land leveling, delivery pipeline, and drainage system meeting design standards	70%
Tailwater recovery system with proper land leveling, delivery pipeline, and drainage system	85%
Sprinkler	60 – 75%
Trickle	85 – 90%

Source: From Irrigation Requirements for Washington – Estimates and Methodology, EB1513, Cooperative Extension, Washington State University, Pullman, Washington, 1989.

Figure B-2 illustrates the different pathways of water use after it has been withdrawn from a system. The percentages are based on irrigated agriculture nationwide. However, the diagram provides a good demonstration of the different physical mechanisms that take place from an agricultural diversion.

Figure B-2. U.S. Irrigation Water Budget



As an example of irrigation demand, assuming the acres irrigated in WRIA 23 were in pasture grass, their number equaled that reported by the Census of Agriculture (5,765 acres), and the on-farm efficiency was 50%, the annual volume demand would be 16,960 acre feet. For WRIA 22, a similar number was calculated and equaled 4,150 acre-feet/year. Over a four-month irrigation season the former translated to roughly 70 cfs and the latter to about 17 cfs, not insubstantial amounts of water.

Given the order of magnitude difference in the allocated and potentially irrigated acreage in both WRIAs, investigation into the actual use of irrigation water may be a worthwhile effort. As irrigated lands decline and the fact that there appears to be substantially less irrigation than the acreage allocated under water rights suggests, it would be useful to know which water rights were actually being used and which ones were not. Because irrigation represents such a high consumptive use of water, this effort may be worth the time and cost to sort out in a Level 2 Assessment, however, without the cooperation of the farmers this endeavor may prove fruitless.

Table B-16. Climate data, Crop Consumptive Use, and Irrigation Requirements

CLIMATE DATA, CROP CONSUMPTIVE USE, AND IRRIGATION REQUIREMENTS

Centralia		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Mean Temp	°F	52.7	44.9	40.9	39.3	42.4	45.5	50.3	56	60.7	64.9	64.8	60.5	
Total Precip	in	4.23	6.8	7.51	6.6	5.26	4.76	2.92	2.06	1.88	0.8	1.16	2.07	46.05
Effective Precip	in	1.58	0.35	0	0.11	0.61	1.32	1.9	1.47	1.36	0.64	0.85	1.45	11.64
Pasture/Turf														
Crop Irrigation Requirement	in	0	0	0	0	0	0	0.86	2.51	3.31	5.17	3.65	2.15	17.65
Consumptive Use	in	1.53	0.33	0	0	0.35	1.27	2.76	3.98	4.66	5.8	4.49	3.6	28.77
Irrigation Efficiency = 50%		0.00	0.00	0.00	0.00	0.00	0.00	1.72	5.02	6.62	10.34	7.30	4.30	35.30
Field Corn														
Crop Irrigation Requirement	in	0.00	0	0	0	0	0	0	0	1.07	4.44	4.36	2.49	12.36
Consumptive Use	in	1.13	0	0	0	0	0	0	0.13	2.46	5.07	5.2	3.94	17.93
Irrigation Efficiency = 50%		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.14	8.88	8.72	4.98	24.72

Aberdeen		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Mean Temp	°F	52.7	45.4	41.5	40	42.5	44.5	48.4	53	57.2	60.2	60.8	58.9	
Total Precip	in	7.57	11.37	13.75	12.38	9.96	9.17	5.68	3.57	2.6	1.45	1.78	3.73	83.01
Effective Precip	in	1.43	0.36	0.04	0.11	0.56	1.35	2.16	2.31	1.8	1.04	1.22	2.15	14.53
Pasture/Turf														
Crop Irrigation Requirement	in	0	0	0	0	0	0	0	0.75	1.54	2.67	1.72	0.19	6.87
Consumptive Use	in	1.39	0.34	0.04	0.1	0.53	1.3	2.08	3.06	3.33	3.71	2.95	2.35	21.18
Irrigation Efficiency = 50%	in	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.50	3.08	5.34	3.44	0.38	13.74
Field Corn														
Crop Irrigation Requirement	in	0	0	0	0	0	0	0	0	0	1.52	2.02	0.56	4.1
Consumptive Use	in	1.2	0	0	0	0	0	0	0	1.11	2.54	3.26	2.72	10.83
Irrigation Efficiency = 50%	in	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.04	4.04	1.12	8.20

Elma		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Total
Mean Temp	°F	52.5	44.7	40.6	39	42.5	44.6	49	54.8	59.6	63.2	63.8	59.9	
Total Precip	in	6.18	9.79	10.62	10.18	8.15	7.37	4.63	2.67	2.04	1.12	1.48	2.99	67.22
Effective Precip	in	1.42	0.33	0.01	0.07	0.55	1.36	2.18	1.82	1.43	0.8	1.03	1.89	11.13
Pasture/Turf														
Crop Irrigation Requirement	in	0	0	0	0	0	0	0	1.41	2.12	3.18	2.14	0.52	9.37
Consumptive Use	in	1.37	0.31	0.01	0.00	0.32	1.31	2.13	3.23	3.54	3.99	3.17	2.41	21.79
Irrigation Efficiency = 50%	in	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.82	4.24	6.36	4.28	1.04	18.74
Field Corn														
Crop Irrigation Requirement	in	0	0	0	0	0	0	0	0	0	1.92	2.46	0.9	5.28
Consumptive Use	in	1.18	0	0	0	0	0	0	0	1.18	2.73	3.51	2.79	11.39
Irrigation Efficiency = 50%	in	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	3.84	4.92	1.80	10.56

Figure B-3. Comparison of Precipitation and Crop Consumptive Use Aberdeen, Washington (Latitude 46.97°)
Source: WSU Cooperative Extension. Education Bulletin #1513.

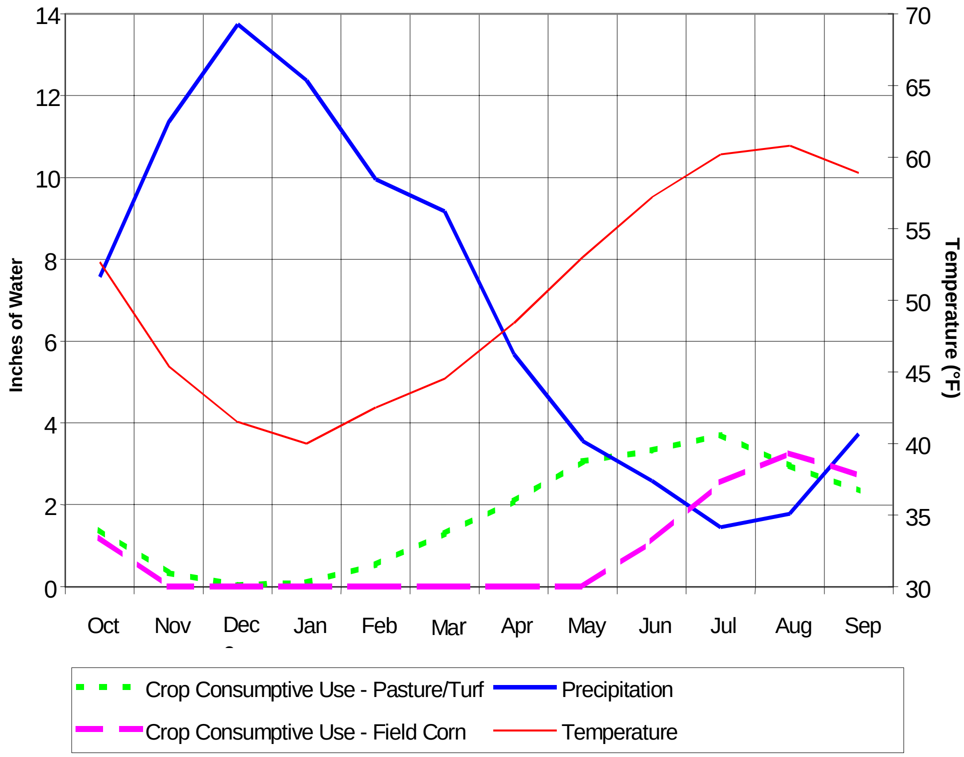
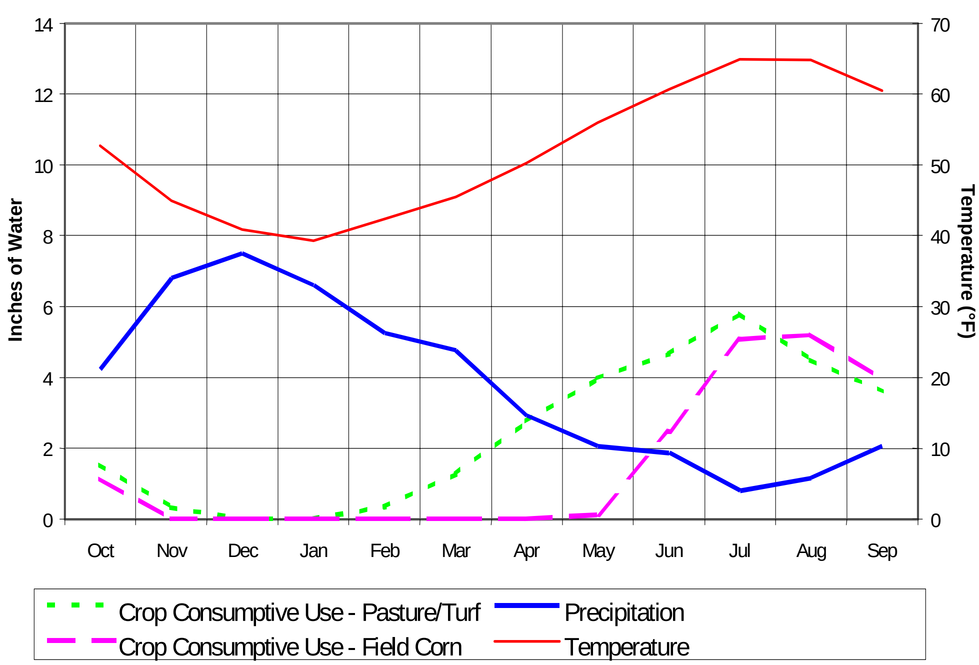


Figure B-4. Comparison of Precipitation and Crop Consumptive Use. Centralia, Washington (Latitude 46.72°)
Source: WSU Cooperative Extension. Education Bulletin #1513.



Stock Watering and Washdown

The water used by livestock is relatively small compared to other uses, although, given large numbers of animals, the cumulative use may have an impact. An inventory of farm animals was not available except at the county level. The Census of Agriculture (1997) was used to understand the relative magnitude of water use by livestock and farm operations. The county data were summarized (Tables B-17 and B-18) and the relative magnitude of the water use within each WRIA can be understood from reviewing these data. Horses were not included in these figures since they are not considered a farm commodity and estimates of the numbers in each WRIA were not available from another source.

Table B-17: Stock Water Use

	Water Use[1] (gpd/animal unit)	Grays Harbor County		Lewis County	
		# animals	cfs	# animals	cfs
Cattle	12	9,882	0.18	25,904	0.48
Dairy Cows	20	3,889	0.12	8,360	0.26
Hogs/Pigs	4	186	<0.01	518	<0.01
Sheep/Lambs	2	387	<0.01	1,106	<0.01
Chickens	5-10/100	1,146	<0.01	11,358,040	1.32

[1]Source: WDOH, 1999.

Table B-18: Livestock Facilities' Water Use

	Water Use[1] (gpd)	Grays Harbor County		Lewis County	
		# farms	cfs	# farms	cfs
Dairy Sanitation	500	24	0.02	75	0.06
Sanitary Hog Wollow	20	12	<0.01	57	<0.01

[1]Source: WDOH, 1999.

Based on the county data and the computations in Table B-17 and B-18, in WRIA 22, probably less than 0.5 cfs is used for livestock operations, while in WRIA 23 the use may be as much as 1 cfs. Water rights associated with stock watering totaled 12.80 cfs in WRIA 22 and 51.02 cfs in WRIA 23. In addition to stock watering, these rights were also associated with 1,256 and 4,242 irrigation acres, respectively. In any event, the water rights were significantly higher than the calculated estimates of stock water demand herein. Relative to other water uses, this sector does not warrant further investigation.

EXEMPT WELL ASSESSMENT APPROACHES

The Chehalis Basin Partnership has expressed interest in understanding the number of exempt ground water withdrawals (i.e. exempt wells) that may be present throughout both WRIAs 22 and 23. According to the law (RCW 90.44.050), certain small-scale water uses are provided an exemption from the requirement to obtain a permit/water right as follows:

"…any withdrawal of public ground waters for stock-watering purposes, or for the watering of a lawn or of a noncommercial garden not exceeding one-half acre in area, or for single or group domestic uses in an amount not exceeding five thousand gallons a day, or for an industrial purpose in an amount not exceeding five thousand gallons a day, is and shall be exempt from the provisions of this section…"

Exempt wells are most often constructed for single or multiple domestic purposes. While exempt ground water withdrawals have been assigned a rate of withdrawal, they have not been assigned an annual volume limit. Water rights issued for domestic purposes since the 1960's have been assigned a rate of diversion/withdrawal and an annual volume limit. The lack of an annual volume limit associated with exempt wells has resulted in significant residential development statewide for which reliance on the full rate of 5,000 gallons per day has occurred. For example, certain development interests have constructed exempt wells and then proceeded to build six houses, commonly known as "six packs." These six packs likely will use the full rate of 5,000 gallons per day, yet a single-family home is less likely to use that full rate. The implementation of six packs, as well as the cumulative effect of numerous exempt wells pose the potential for greater use of ground water and, therefore, greater impact on the system.

While it is difficult to arrive at an accurate number of wells, two approaches were used, one based on population data and one based on land parcel data, to provide an estimate of water use by exempt wells. The first method was used as part of the five subbasin analyses in Section 3, and the second method was applied to two sections as examples for the Chehalis Basin Partnership to review. The latter being more detailed and, therefore, more costly was beyond the scope of the Level 1 Assessment. The purpose of this section is to compare the methods for future analyses; the results from these two methods cannot be compared since the methods were not used on the same land area. The two approaches are described below.

POPULATION-BASED ESTIMATE

This method utilizes population data, public water system information, and the WRATS water rights database to determine the number of exempt wells. The current subbasin population of self-supplied water users was estimated by subtracting the population served by a public water system from the estimated subbasin population. The next step was to identify, if possible, the multiple domestic water rights associated with small public water systems; the remaining rights would cover a portion of the self-supplied water users. That portion not covered by water rights was assumed to be using water from exempt ground water withdrawals.

The water demand by exempt wells was calculated from the population estimate described above and a per capita per day design water demand calculated from the equation developed by the Department of Health (1999). Detailed steps are included in Appendix B-1: Detailed steps for assessing exempt well status and associated water use.

In three of the five subbasins in which this approach was used, the number of water rights and the number of public water systems were too numerous or too difficult to match the two at this level of analysis. Examples describing results of the method as it was applied are provided below for comparison. The information was extracted from Section 3: Selected Subbasin Assessment. The application of the method varied slightly depending on the information available.

Subbasin #1 Example

In the Chehalis River Headwaters, the year 2000 population was estimated at 1,540. The Town of Pe Ell was the only public water system that served residential connections; population served was 600. The difference between the subbasin population and the Town of Pe Ell resulted in a total of 940 self-supplied water users. According to WDOE's WRATS database, there were 20 rights designated for domestic use (three of which were multiple domestic water rights as a beneficial use although not necessarily listed as the primary use). On the average, WDOE assigns a diversion rate of 0.01 cfs and a volume limit of 1 acre foot to a single domestic right. The multiple domestic rights had a rate of 0.29 cfs. To estimate the number of households potentially served by these three multiple rights, the rate of 0.01 cfs per household was used. Roughly 29 homes were supplied under these multiple rights. For the remaining 17 single domestic rights, one water right was assumed to provide a supply to one household. Adding these to the 29 homes under the multiple domestic right resulted in 46 households, or 120 people (Lewis County estimate = 2.6 people/household), withdrawing water under a legal entitlement. The remaining 820 people were either covered under a claim or exempt well. Using the average of 79 gallons per capita per day (gcd) (same as computed for the Town of Pe Ell), an estimate of 0.1 cfs of domestic water use can be made for the combined claim and exempt well population. For comparison, using the WDOH (1999) method the per capita per day demand was estimated at 111 gallons; using this number 820 people would use an estimated 0.14 cfs for domestic supply. Applying an efficiency of 75%, the withdrawal from exempt wells required to satisfy the demand ranged from 0.13 to 0.19 cfs. An adequate efficiency ranges from 70% to 80% (Summers, 1997); 75% was used for the purposes of this study. The actual value was unknown, except for the Town of Pe Ell.

Subbasin #14 Example

In the Cloquallum River (Subbasin # 14), Chehalis River Mainstem Lower Reach 1 (Subbasin #19) and the Neuwaukum River Subbasin #7, this method could only be partially completed. The result was estimated water use for the self-supplied water users under multiple domestic water rights, claims, and exempt wells. Multiple domestic rights would need to be further researched to determine which ones were associated with public water systems. The population served by multiple domestic rights not associated with a public water system must be determined and subtracted from the total population of self supplied water users to reach an estimate of exempt wells.

Subbasin #14 is discussed here as an example of the method's shortcomings. In Subbasin #14, the estimated year 2000 population was 3,330. The public water systems in the subbasin supplied a population of 2,083; the difference of 1,247 was assumed to be self-supplied water users. There were six single domestic rights providing water for about 15 people. The difference of 1,232 self-supplied water users (total self-supplied users less those covered under single domestic rights) were estimated to use about 0.24 cfs (127 gcd calculated using WDOH(1999)). Assuming an efficiency of 75%, the estimated rate of withdrawal was approximately 0.32 cfs. A portion of this amount may be from exempt ground water withdrawals, however, at this level of analysis it was difficult to discern that portion from the self-supplied users under multiple domestic water rights and those using water under the ground water withdrawal exemption.

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There were 20 public water systems and 16 multiple domestic rights, not all of which could be matched against each other. Ten of the 16 rights were tentatively matched with a public water system. One of the remaining six rights was an application and may not be used yet. The remaining 5 domestic multiple rights could not be associated with a public water system. A Level 2 analysis, if warranted, would involve researching the water rights associated with the different public water systems if the population method were to be employed.

An estimate of actual water use for the total population (applying 127 gcd) was approximately 0.66 cfs. Assuming water losses accounted for 25% of the withdrawal, a total demand of 0.87 cfs was estimated. The combined municipal and domestic water rights total 3.52 cfs, which means the estimated actual water use was about 25% of the total allocated water for this sector.

Subbasin #25 Example

In the Humptulips River, it was possible to associate most of the small public water systems with water rights and then assume a population under the remaining domestic rights. The residential population served by the public water systems was 80, with 34 residential connections. Fifty-eight of the 80 people lived within mobile home parks, and the remaining 22 people were associated with commercial enterprises.

There was one single domestic water right for 0.02 cfs and 6 multiple domestic water rights for 20.62 cfs. The largest residential right of 20 cfs was allocated to the City of Ocean Shores and constituted an out-of-basin diversion. One multiple domestic right was held by the Olympic National Forest for 0.1 cfs and was most likely associated with the Campbell Tree Grove Campground, federally owned and listed in the WDOH public water system database with one non-residential service connection.

Of the remaining four multiple domestic rights, with a total withdrawal rate of 0.52 cfs, three were tied reasonably well to the following public water systems: Timberview Mobile Home Park (population 25, residential connections 12); Warren Dahl (population 33, residential connections 11); and Riverview Recreation Area with 15 non-residential connections. At this level of analysis, the latter is an assumption since the only information available was the location of the system withdrawal in Township 20 North Range 10 West Section 7, which coincided with an irrigation/general domestic water right in the same section. The fourth multiple domestic right, Copalis Water Fund Inc., could not be specifically identified with a public water system since there were none that identified a point of withdrawal in the same section.

According to the Grays Harbor County Assessor's database, there were 308 single-family parcels, 1 unit of 2 to 4 households, and 3 mobile home parks. At least two of the mobile home parks appeared to be covered by water rights. The third mobile home park was not identified as a public water system, however, the water right in the name of the Copalis Water Fund Inc. may cover this use. Assuming this was the third mobile home park, the parcels that appeared to have no water rights total 310 (307 of the single-family households and one 2- to 4-unit dwelling (assumed 3 units). These 310 households appeared to be covered by claims or exempt wells. Applying the Grays Harbor average people per household of 2.5, there were 775 people using water under exempt wells or claims. Assuming 119 gcd (WDOH, 1999) for self-supplied water users and an efficiency of 75%, the total water use from exempt wells was estimated at roughly 0.19 cfs.

PARCEL-BASED METHOD

The parcel-based method involved a detailed mapping of water rights on assessors' parcel maps, using water right documents from Ecology, public water system information (WDOH), and the county assessors' databases. This method offers an additional benefit of incorporating a water rights analysis that can lead to discovering water rights tied to parcels now served by public water systems, parcels to which more than one water right is associated but not used/needed, parcels to which water right(s) and claim(s) overlay one another, etc. This more detailed approach offers not only an understanding of exempt ground water withdrawals but also an opportunity to improve the water rights database so that the allocation of rights better represents the actual water use.

This method involves plotting the points of diversion and the places of use for each certificate, permit, application, and claim on a parcel map from the county assessor's office. The public water system boundaries must also be clearly defined. The data can be input into a GIS file and easily displayed. The final map can display the parcels served by a public water system, those that have water rights attached to them, and those that have no water right. Exempt wells are most frequently located on residential parcels; i.e. the parcels that do not fall within a service area or under the place of use for a water right. Although the exact number of wells will not necessarily be available, the number of households not served by a public water system or a water right can be determined. An average number of people per household for the county can be used to translate this into population. A per capita usage estimate can then be used to approximate water use.

This method was tested on two sample sections, one in Lewis County (Township 13N Range 2W Section 14) and one in Grays Harbor County (Township 17N Range 6W Section 10). The intent was to select a section in each of the two major counties in the Chehalis Basin; sections were selected based on the diversity of potential water uses. One is a section in the Neuwaukum River subbasin near the Town of Chehalis; the second is a section south of the Chehalis River near the Town of Elma. The outcome can be reviewed in Figures IV-1 and Figures IV-2 and has been summarized as follows.

Section 14:

Known Data (assessor's data, water rights, and public water system data).

- 11 water rights (see cross-hatched areas on figure)
- 15 claims
- 1 public water system (City of Chehalis) covers ~75% of the section (proposed urban growth area, water service boundary) including 97 parcels

Data Interpretation (overlay of rights with parcels)

- 1 agricultural parcel without a water right; unknown whether it is irrigated
- No residential/industrial parcels without water rights outside of public water system boundary
- 10 claims on parcels now within public water system boundary
- 6 water rights on parcels now within public water system boundary
- No exempt wells identified
- Total domestic water use can be estimated by the following equation, assuming there is one house per parcel of residential land:

97 parcels * 354 gallons/day per residential unit (WDOH, 1999) = 0.05 cfs.

Based on using the water service boundary for the proposed urban growth area, none of the 97 parcels were supplied water from an exempt well.

Section 10:

Known Data (assessor's data, water rights, and public water system data).

- No water rights
- 11 claims
- No public water system

Data Interpretation (overlay of rights with parcels)

- 1 agricultural parcel without a water right; unknown whether it is irrigated
- 37 residential parcels with structures
- 11 claims cover 14 residential parcels, 2 utilities parcels, 3 undeveloped residential parcels
- 23 parcels must be using individual domestic wells (exempt status)
- Total domestic water use can be estimated by the following equation, assuming there is one house per parcel of residential land:

37 residences * 319 gallons per day (DOH, 1999) = 0.018 cfs

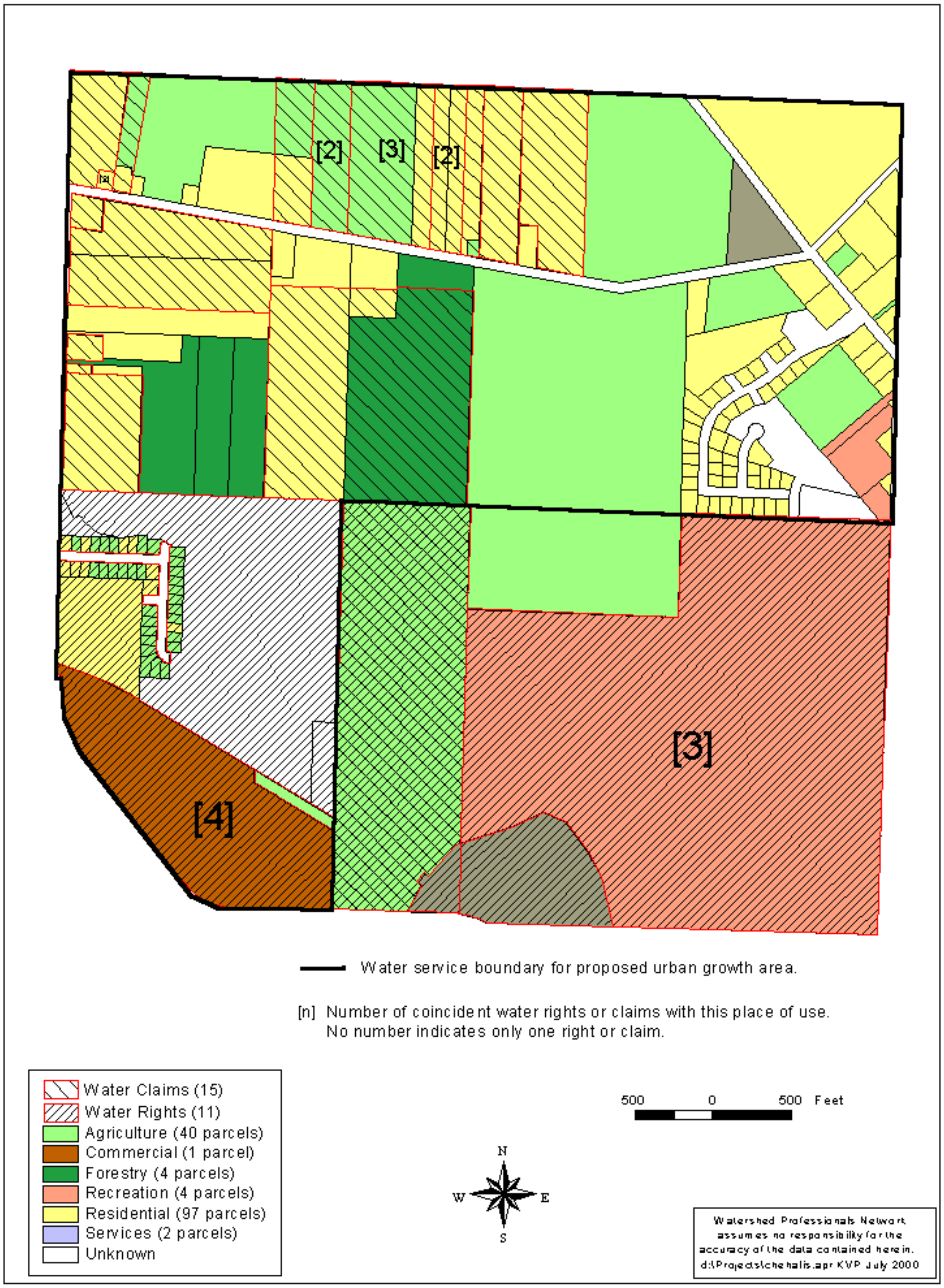

Figure IV-1. Parcel based approach for water rights and water use - Lewis County (T13N R02W S14) sample area.

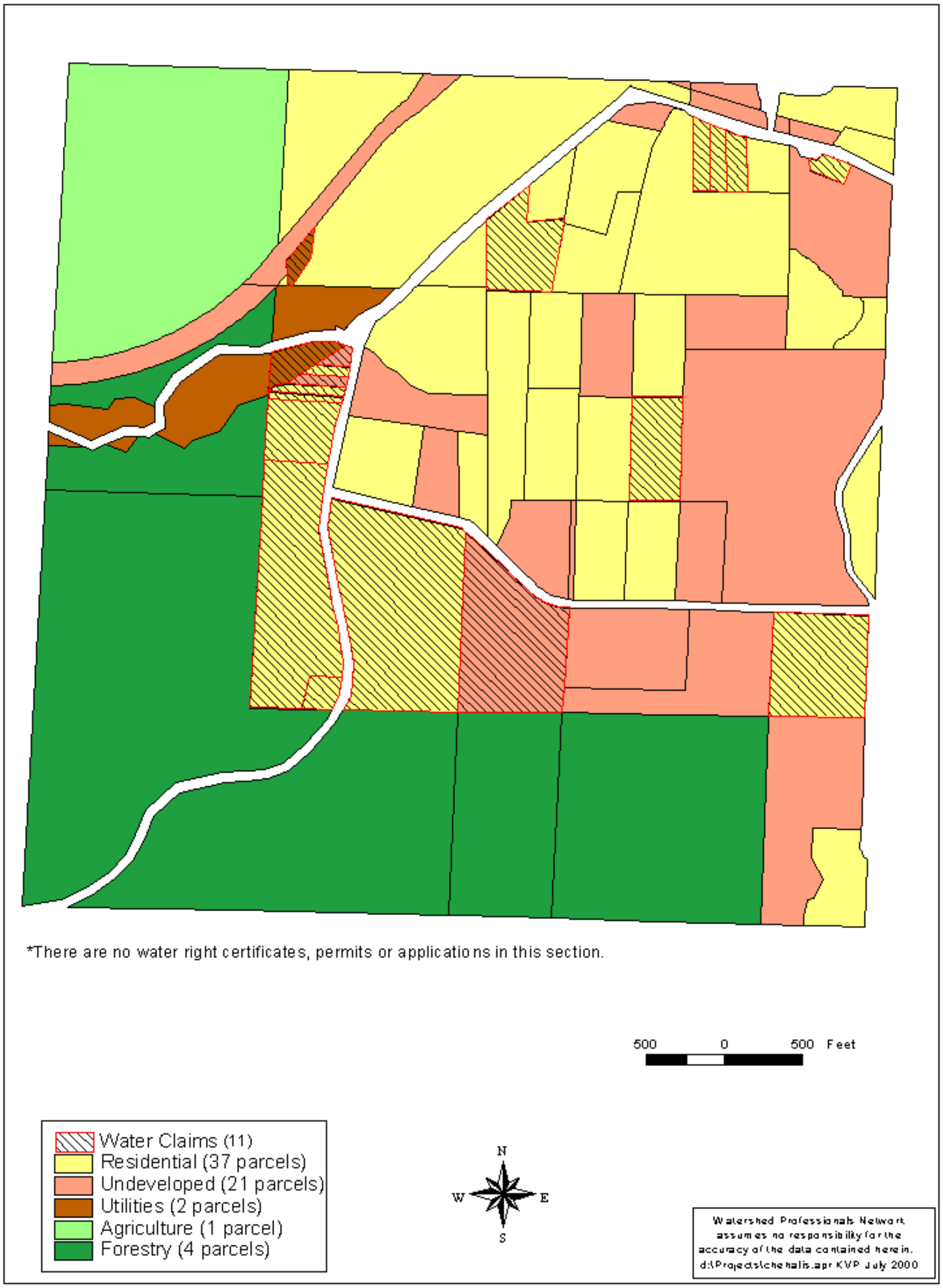

Figure IV-2: Parcel based approach for water rights and water use - Grays Harbor County (T17N R 06W S10) sample area.

CONCLUSIONS OF EXEMPT WELL ASSESSMENT APPROACHES

Population-Based Method

This method provided a rough estimate of the number of exempt wells in two of the five subbasins discussed above. In the case of Subbasins #7, #14, and #19, the number could not be derived without further inquiry into the original documents and applying the parcel-based method at least for the multiple domestic rights and public water systems. Also, the difficulty in Subbasin #14 was the lack of adequate population data. The number of self-supplied water users was the best that could be attained which included those covered by single and multiple domestic water rights. Therefore, using the number of self supplied water users would tend to overestimate the water use from exempt wells. This was the best that could be achieved in the Level 1 Assessment.

Parcel-Based Method

In Section 14, all of the residential parcels were within the public water system boundary urban growth area, leading to the understanding that there were currently no exempt wells in operation in this section. The 10 claims and 6 water rights on parcels within the service area could be retired based on the fact that these parcels now have an alternative source of supply.

Since there were no water rights in Section 10, all 37 of the residential parcels were assumed to be using exempt wells. The water use for these parcels was estimated to be 0.018 cfs (~13 acre-feet/year).

Section 14 was sufficiently close to a more urban environment, where rights that were identified may not be in actual use due to public water system expansion. In comparison, in Section 10, most of the water users were self-supplied, either under claims or exempt wells.

In addition to the identification of residential parcels, there were several agricultural parcels with claims to the use of water and several with water rights. To understand the actual use for irrigated agriculture, this parcel-based information would be useful as a starting point to determine whether these parcels were actually being irrigated. Also, the parcels that had overlapping rights, or claims, or both would need to be investigated to understand if multiple rights were necessary for the current uses of water.

The parcel-based method encompasses greater detail and would be more costly to perform, however, the water rights analysis portion of this exercise would enable Ecology to have a more accurate picture of actual versus allocated water use. The parcel-based method better defines the exempt well population by identifying the specific parcels not served by a public water system and not covered by a water right. The population-based method is useful in basins with few public water systems and few domestic rights, while the parcel-based method better defines exempt wells in more complicated basins.

RECOMMENDATIONS

- In WRIA 22, investigate the 30 largest water rights representing 90% of the allocated water to determine actual use.
- In WRIA 23, investigate the 22 rights to determine actual use. In addition, determine the status of the rights in the Skookumchuck River basin (those that potentially have not been developed) (Mahlum, 1976).
- Investigate the multiple domestic rights to understand actual use; especially the 570 cfs multiple domestic right for Lake Arrowhead Community Club.
- Obtain service area boundaries for public water systems and plot to determine subbasin location for place of use. Obtain actual use records, if available.
- Identify the water rights for each public water system to determine the multiple domestic rights that may be self-supplied.
- Investigate the six largest commercial/industrial water rights to determine the relationship between allocated and actual use for this particular sector.
- Determine the actual irrigated area in each WRIA and in each subbasin by engaging the Chehalis Basin Partnership to assist in developing communication with the farm community.
- Investigate the status of the 35,909 gpm (~80 cfs) power right for the now defunct thermonuclear plant (WPPS).
- Investigate the status of the 80 cfs right for thermoelectric power for the Centralia Steam Plant (WRIA 23) to understand the actual and consumptive use of the water withdrawn.

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APPENDIX C - WATER QUALITY

INTRODUCTION

The water quality analysis of the Level 1 Watershed Assessment is designed to summarize known surface water quality problems in the subbasins. The emphasis of this analysis is on those pollutants that have the most direct relationship to water quantity and fish habitat. Temperature and dissolved oxygen concentrations are two of the factors which can most directly affect fish populations. Seasonal trends along the mainstem over the past three decades are analyzed for these two parameters, as well as for total phosphorus (TP), total suspended solids (TSS), and fecal coliform levels. This assessment also provides an evaluation of water quality data obtained in the past decade from six mainstem and nine tributary ambient monitoring stations. Where 50% exceedance monthly flows are available (four mainstem stations and two tributaries), TP, inorganic nitrogen (IN), and TSS loading and yields are evaluated. Subbasin comparisons of pollutant yields can serve as a tool to focus resources on those subbasins with the highest yields. This assessment also includes a summarization of available data by subbasins.

Grays Harbor was not included in this Level 1 Assessment. Grays Harbor, at the mouth of the Chehalis watershed, has been the focus of a number of studies. The conditions within the estuary vary depending on the location, the degree of tidal and wind mixing, and degree of density stratification (Jennings, 1996). The harbor is separated into an inner harbor area and an outer harbor area, each with different water quality classifications under the water quality standards. The inner harbor is designated as a Class B water and is listed under section 303(d) of the Clean Water Act as not meeting water quality standards for fecal coliform bacteria. The outer harbor is a Class A water body. While the outer harbor is not listed as impaired on the 303(d) list for fecal coliform, there is mounting evidence that this indicator parameter may be a concern in some areas of the outer harbor (Jennings, 1996). A recently published TMDL indicated that the primary source of the fecal coliform loading was from the Chehalis River, with the Humptulips, Hoquiam, Wishkah, and Satsop rivers accounting for nearly 80% of the total loading (Pelletier, 2000). The TMDL recommended a 65% reduction in the non-point source load allocations; and the TMDL recommended wasteload allocations for the two major point sources (Weyerhaeuser Cosmpolis and Weyco) (Pelletier, 2000).

This Appendix is organized in the following order:

- Methods of Data Analysis - a description of parameters selected and methods of analysis.
- Mainstem Chehalis - an analysis of water quality at four mainstem stations and evaluation of seasonal, temporal, and river mile trends.
- Major Tributaries - a summary of available data on nine major tributaries with emphasis on the Newaukum River and the Humptulips River.
- Subbasin Analysis - a description and analysis of available data by subbasin.
- Water Quality Impairment Under the Clean Water Act - lists impaired stream segments.

- Data Limitations - a discussion of additional data needs and limitations of the analyses.
- Conclusions and Recommendations for the Level 2 Assessment - a summary of basin-wide and subbasin conclusions and recommendations for the next actions.

METHODS

Evaluation of the water quality data required selection of monitoring stations and water quality parameters, analytical techniques for data interpretation and presentation, and assumptions about the data. These are described in this section.

Ambient water quality monitoring data from WDOE were selected for the majority of the data evaluation. Station locations are shown on the basin map (Figure C-1). These data were selected because they provide the longest period of monthly or bimonthly data at a location. At a number of stations, the record is longer than 20 years. Other stations had records that were not continuous from the 1970's until the present. For example, ambient monitoring station data have not been collected from the Wynoochee and Wishkah rivers since the 1970's. Monitoring at the Montesano station on the mainstem Chehalis River was interrupted in 1992. This station is particularly critical as it represents the cumulative impacts of activities upriver of most of the tidal influence.

Where more than one ambient monitoring station was available for a subbasin, the station that was closest to the mouth of the tributary was selected. Protocols for sample collection at the WDOE ambient monitoring stations have been standardized for a number of years, increasing the comparability. Methods of chemical analyses have also been relatively standardized, although several techniques have improved since the 1970's. Thus, the WDOE ambient water quality monitoring stations were selected for the long period of record, consistent sampling locations and sampling and analytical protocols. The station locations, period of record, and parameters monitored are provided in Table C-1.

A number of parameters were selected to serve as indicators of the water quality in the basin. These include temperature, dissolved oxygen, total phosphorus, inorganic nitrogen, total suspended solids, and fecal coliform. Parameters were selected for analysis either because they were directly related to fish habitat and flow problems (dissolved oxygen (DO) and temperature), or because they are appropriate indicators of water pollution (total phosphorus (TP) and total suspended solids (TSS)), or because they are important in the basin since they are tied to a commercial industry (fecal coliform bacteria (FC)).

Table C-1. Ambient Water Quality Monitoring Station Data Assessed

River Mile	Location (Subbasin #)	Years	Flow	Temp	DO	pH	TP	NH_3	NO_{2+3}	TSS	FC	Comment
Mainstem												
101.7	Dryad (1)	77-99	x	x	x	x	x	x	x	x	x	
77.7	Claquato (4)	96-97	-	x	x	x	x	x	x	x	x	
67.5	Centralia (10)	77-93	x	x	x	x	x	x	x	x	x	
59.9	Prather Rd. (10)	94-97	x	x	x	x	x	x	x	x	x	
33.3	Porter (13)	70-99	x	x	x	x	x	x	p/s	s/p	p/s	s = sporadic 82-87 p = consistent from 82
13.15	Montesano (30)	71, 77-92	s	x	x	x	x	x	p	p	p	s = flow data sporadic p = consistent from 77
Tributaries												
3.0	S. Fork Chehalis (3)	96-97	x	x	x	x	x	x	x	x	x	
0.1	Newaukum (5-7)	92-93	x	x	x	x	x	x	x	x	x	
2.3	Skookumchuck (9)	92-93, 96-97	x	x	x	x	x	x	x	x	x	
7.1	Black (11)	90-97	-	x	x	x	x	x	-	x	x	
2.7	Satsop (15-18)	71, 74-93	s	x	x	x	x	x	p	p	p	s = sporadic p = consistent from 77
13.6	Wynoochee (20)	72-74, 76-77	p	x	x	x	s	x	-	-	p	s = sporadic
12.3	Wishkah (21)	72-74, 76-77	p	x	x	x	x	x	-	-	p	p = consistent from 76
9.3	Hoquiam (22-24)	73-74, 93-94	p	x	x	x	p	x	p	p	p	p = consistent from 83
23.6	Humptulips (25)	71-74,77-99	x	x	x	x	x	x	x	p	p	p = consistent after 80

x = Relatively consistent data; - = No data; p = partial data; s = sporadic data

The following paragraphs describe some of the guidelines used for this assessment.

- DO, temperature, and FC bacteria are compared against state water quality standards. Phosphorus becomes a pollutant of concern at higher concentrations. MacKenthun (1973) suggests that TP should not exceed a concentration of 0.05 mg/l in a stream at the point at which it enters a reservoir or lake (or for example, the Centralia Reach). For other flowing streams MacKenthun recommends that concentrations of TP not exceed 0.1 mg/L. The USEPA adopted these concentrations as guideline levels (USEPA, 1986). The USGS reported a background level of TP of 0.1 mg/l in 20 National Water Quality Assessment (NAWQA) units across the country (Mueller and Helsel, 1996).

- IN includes two chemical forms of nitrogen; ammonia-N and nitrate + nitrite (nitrate+nitrite-N). Ammonia (a by-product of animal waste) can be toxic to fish at concentrations that are temperature and pH dependent. Nitrate is also considered a pollutant of concern at high concentrations although it is a nutrient required for plant growth at lower concentrations. The USGS reported background concentrations for nitrate-N of 0.7 mg/l and for ammonia-N 0.1 mg/l (Mueller and Helsel, 1996). These concentrations were part of a NAWQA study of 20 major surface water hydrologic units across the country (Mueller and Helsel, 1996). The ratio of total nitrogen to total phosphorus (TN:TP) is an important indictor of stream health. A TN:TP ratio of less than 7 indicates a water body is no longer phosphorus limited, but nitrogen limited (Welch, 1980). Such river systems generally support a greater population of algae and aquatic macrophytes.

- No water quality standard exists for TSS, although it is somewhat related to turbidity, for which there are water quality criteria.

The three-year wet and dry season parameter averages were calculated for the Dryad, Porter, and Montesano (1970's dry season only) stations. Seasonal averages were used for upstream/downstream comparisons and comparisons over the timeframe of three decades. These ambient monitoring stations were selected for their location on the mainstem Chehalis River and the availability of three years of monthly data. Because data was only available for the last three years in the 70’s, only data from the last 3 years of each decade were used for the trend analysis, to equalize the size of the data sets between decades. During the 1990’s, 5 stations were routinely monitored on the mainstem. This data is assessed separately to allow for a more comprehensive look at possible trends with distance downstream. Wet and dry season averages of monthly samples obtained during the last three years of the 1970's, 1980's, and 1990's were calculated to make these comparisons. These years were selected as they span the period of record and represent the years in which the most data were available for statistical analyses. For this study, wet season data comprised samples gathered from November 1 through March 31 of a water year. Dry season samples were defined as those that were gathered between August 1 and October 31 of a water year. These data were used for the graphical presentations. Statistical comparisons of the averages were made between the decades and between the upstream and downstream stations to ascertain any differences. The student's t-test was initially used for this evaluation; however, data gaps in the period of record and large variation between the monthly grab samples caused the data to violate the assumptions of homogeneity and normal distribution of the data. Thus, statistical comparisons were made using the non-parametric Mann-Whitney test which does not assume a normal data distribution (Conover, 1980). Statistically significant differences were evaluated at the p = 0.95 level.

Many of the analytical water quality data used in this report were denoted as “qualified”. Qualification means there is less confidence that the value reported accurately represents the actual conditions. Qualified data is particularly prevalent with the fecal coliform results. Qualifiers for this parameter included indicators of “spreader colonies” and “presence of background organisms”. These qualifiers generally indicate that the reported result underestimates the actual colony forming units in the river segment. Fecal coliform data that were qualified were included in calculations of 3-year geometric means because they did not lead to an over estimate and to allow for statistical analyses. More recent fecal coliform data tended to have fewer qualifiers than older data, improving the accuracy of the data.

Results of chemical analysis were often at the limits of detection, especially for ammonia-N, but also for total phosphorus, and less so for nitrate+nitrite-N. Results qualified as at or below the detection limit provide an over estimate of the concentration in the river. To reduce the inflationary effects of data that were qualified as at or below the detection limit, averages, loads, and yields were calculated using one-half of the detection limit value. While this technique is useful for making comparisons between subbasins of the Chehalis and with other Puget Sound basins, future improvement in analytical methods would reduce the impact of this method of estimation.

To gain a better understanding of the watershed in recent years and to make use of the data available, all ambient monitoring data gathered during the 1990's at the mainstem and two tributaries were used to calculate TP loads and yields, inorganic nitrogen yields, and TSS loads and yields. Wet and dry season averages (as defined previously) were calculated from results of monthly grab samples gathered during the 1990's. Loading was calculated by multiplying the parameter concentration (mg/l) by the median monthly (50% exceedance) flow (cfs) from the USGS gage stations and adjusting for unit differences. Loading is provided in units of pounds/day (lb/day). Where flow data were not obtained at the time of sampling, USGS gage flows from a nearby station were used for the date, if other tributaries were not located between the ambient monitoring station and the gage station (e.g., Montesano). Instantaneous flows were used to calculate TP and TSS loadings at individual stations for graphical presentation.

Average annual yields were calculated for TP, IN, and TSS. Average annual yields were calculated using monthly grab sample data and averaged over the entire year to obtain a more accurate reflection of annual conditions. To obtain yields for these stations, the parameter loadings (based on median flows) were divided by the size of the drainage basin and adjusted to units of tons/year/square mile. Where the monitoring station was substantially above the mouth of the river (e.g., Humptulips River), an estimate of the basin size to the station was made from the map.

In each of the subbasins where data were available, the ratio of TN:TP was calculated from concentrations averaged across all months. TN:TP ratios were compared to the ratio of 7 recommended by Welch (1980) as the delimiter between phosphorus-limited and nitrogen-limited streams.

NPDES permitted discharges within the basin were provided from the Water Permit Life Cycle System (WPLCS) database. Based on permitted limits and assumptions made by Embry and Inkpen (1998), the total phosphorus loading from NPDES permits to the mainstem at Porter and Montesano were calculated. The median total phosphorus concentration determined for municipal wastewater treatment plants in Puget Sound of 4.2 mg/l (Embry and Inkpen, 1998) was applied to the average design flow from WPLCS to calculate loading contributions of municipal plants. Loadings were summed for discharges above the Porter station and above the Montesano station to determine their contribution to seasonal loading. These NPDES loadings are worst cast scenarios based on design flow and assumed TP concentrations and may over estimate TP loading from the NPDES dischargers.

WATER QUALITY CRITERIA

Washington State water quality criteria (WAC 173-201A) for temperature, dissolved oxygen, and fecal coliform levels vary within the Chehalis Basin. The majority of the basin is defined as Class A (excellent) waters. Exceptions to this classification include three rivers and one mainstem reach for which Class AA (extraordinary) criteria apply, and two river sections for which Class B (good) criteria apply. Surface waters rated as Class AA include the Chehalis headwaters (Subbasin 1 and 2), the upper portion of the Humptulips (Subbasin 25), the Middle, East, and West Fork Satsop (Subbasin 17 and 18), the upper Skookumchuck (Subbasin 9), and the West Fork Wishkah and southern tributaries (Subbasin 21). Surface waters rated as Class B are the lower reach Hoquiam (Subbasin 22) and the first six miles of the Wishkah (Subbasin 21). Standard criteria for the different classes are provided in Table C-2.

A notable exception to the Class A criteria on the mainstem Chehalis is the “Centralia Reach” (river mile 65.8-75.2). A natural sill in the river causes the water to “pool” upstream. This naturally slow moving reach has merited setting separate criteria for dissolved oxygen and temperature. The criteria for this reach includes a special condition stipulating that dissolved oxygen shall exceed 5.0 mg/l from June 1-September 15 and temperature shall be between 18 and 20.4°C (exact temperature standard depends on segment).

Table C-2
Washington State Water Quality Criteria.

Class	Temperature	DO	Fecal Coliform
AA	shall not exceed 16°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 9.5 mg/L	shall not exceed a geometric mean of 50 colonies/100mL and shall not have > 10% of all samples exceeding 100 colonies/100mL
A	shall not exceed 18°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 8.0 mg/L	shall not exceed a geometric mean of 100 colonies/100mL and shall not have > 10% of all samples exceeding 200 colonies/100mL
B	shall not exceed 21°C from human conditions or if >16°C exists naturally, no temp increase >0.3°C	shall exceed 6.5 mg/L	shall not exceed a geometric mean of 200 colonies/100mL and shall not have > 10% of all samples exceeding 400 colonies/100mL

MAINSTEM CHEHALIS

The three mainstem locations (Dryad, Porter, and Montesano) where data were available were used to make parameter comparisons 1) between wet and dry seasons, 2) along the mainstem, and 3) across the three decades. Subsequent discussions are presented by parameter. In addition, available TP, IN, and TSS data from the most recent decade were used to calculate loading and yield at four stations on the mainstem and two tributaries. These are also presented in the context of the parameter discussions. Finally, results of the Total Maximum Daily Load (TMDL) studies are used to summarize recent and future actions necessary to improve water quality.

Figure C-2 depicts average wet and dry season temperature with each river mile. As shown, average dry season temperatures approach the water quality criterion. Within each season, temperature is relatively constant with river mile. Temperature at the mainstem stations has changed relatively little over the last three decades; no statistically significant differences between decades were found in this analysis at p = 0.95.

While average temperatures showed no water quality criteria exceedances, temperature exceedances of samples in several of the tributaries in WRIA 23 have been reported above the 18^oC criterion. Table C-3 provides the maximum temperatures observed in the 1990's at the ambient monitoring stations along the mainstem. All of the maximum temperatures exceed the criterion. Dry season temperatures near and exceeding the criterion coincide with periods of the lowest flow. Elevated temperatures are not surprising based on Wampler's assessment that loss of riparian canopy was widespread over the entire Chehalis mainstem (Wampler, et al., 1993). Pickett (1994a) noted that temperatures generally increased in the upper Chehalis Basin (above Porter) as water flowed downstream. The highest temperatures were measured in the slow flowing Centralia Reach (Pickett, 1994a). The Centralia Reach is more similar to a reservoir or lake than to a river. Temperature stratification is established during the summer months, causing higher surface temperatures and prohibiting mixing between stratified layers. Dry season temperature exceedances precipitated an Upper Chehalis temperature TMDL (Butkus and Jennings, 1999).

Figure C-3 shows dissolved oxygen concentration for wet and dry seasons with each river mile for three decades. As expected, average dry season dissolved oxygen concentrations are lower than those measured during the wet season. Even, during the dry season, the average dissolved oxygen concentrations were within the water quality criterion for Class A streams of 8.0 mg/l. However, individual measurements of dissolved oxygen indicate that at some locations, the criterion is not met. Minimum concentrations from several ambient monitoring stations along the mainstem indicate that only at Dryad and Montesano did the dissolved oxygen concentration remain above the criterion. In the slow-flowing Centralia Reach area, temperature stratification and accompanying oxygen depletion occurs with depth (Pickett, 1994a). While the average dissolved oxygen concentrations appear to decline with river mile, no statistically significant differences were found. Nor were statistically significant differences found across the three decades. Because the dissolved oxygen water quality criterion is often exceeded at individual stations during the dry season, a TMDL was conducted in the upper basin WRIA 23. The TMDL recommended reductions in point and non-point sources of oxygen depleting contaminants such as biochemical oxygen demand (BOD), ammonia-N, and total phosphorus (TP) (Pickett, 1994a).

Table C-3 presents the average and the maximum total phosphorus concentrations at stations along the mainstem for the past decade. Notably, TP concentrations were highest between river mile 77.7 and 67.5 (Table C-3), as the river flows into and through the Centralia Reach. At these two stations, TP average concentrations exceeded the EPA recommended level of 0.05 mg/l (MacKenthum, 1973).

Average total phosphorus (TP) loading (based on instantaneous flow) was used to compare trends across wet and dry seasons, with river mile and across three decades (Figure C-4). The mean TP loading is greater during the wet season than during the dry season. Because of greater wet season flows and because phosphorus is sorbed onto particulates, elevated wet season TP loadings might be expected. However, this is not always the case. If a river is primarily impacted by point source pollutant loadings, the wet season load will not increase as much as those streams affected by nonpoint sources. TP loading, is almost constant with river mile. Comparisons across decades at an individual station during the wet season yielded no statistically significant differences for TP loading.

TP loading was also evaluated along the mainstem stations using 1990's data and median monthly flows from the USGS gage stations. In addition to the three stations included in the previous analysis, data for these years were available at the Prather Road station (river mile 59.9). These data are depicted graphically for the mainstem in Figure C-5. In the 1990's, both wet and dry season TP loads, generally increase in the downstream direction from Dryad to Montesano.

Table C-3. Ambient Water Quality Parameters - 1990s Data
(Average and Maximum or Minimum)

River Mile	Location (Subbasin #)	Temp (°C)		DO (mg/l)		TP (mg/l)		NH_3 (mg/l)		NO_{2+3} (mg/l)		TSS (mg/l)		FC^2 (cfu/100 ml)	
		ave	max	ave	min	ave	max	ave	max	ave	max	ave	max	ave	max
Mainstem															
101.7	Dryad (1)	10.3	24.5	11.1	8.0	0.03	0.36	0.01	0.08	0.30	0.96	26	782	33	2,800
77.7	Claquato[1] (4)	10.2	20.1	10.2	7.5	0.09	0.41	0.02	0.04	0.46	0.87	20	102	61	730
67.5	Centralia (10)	12.1	21.3	9.7	5.4	0.08	0.38	0.06	0.58	0.48	1.1	16	109	47	1,000
59.9	Prather Rd. (10)	11.2	22.1	10.0	7.2	0.06	0.14	0.03	0.12	0.59	0.86	15	118	37	1,500
33.3	Porter (13)	11.4	22.1	10.1	7.1	0.05	0.19	0.02	0.08	0.68	2.13	13	95	29	1,300
13.15	Montesano (30)	12.2	20.5	10.0	8.4	0.04	0.17	0.03	0.04	0.46	0.74	14	131	43	790

[1] Sampled only in 1970's
[2] Fecal coliform average is geometric mean

The 1990's TP loading data were used to calculate TP yields for the mainstem stations. Yield provides a load per square mile of drainage. These are presented as wet and dry season averages and annual averages in Table C-4. Comparisons of yields across subbasins can be a useful tool to determine where the greatest contribution of phosphorus per square mile is originating. Along the mainstem, TP yield was highest at the Montesano station. The average annual TP yields are compared to those reported by USGS authors, Embry and Inkpen (1998) for rivers and streams in the Puget Sound and Olympic Peninsula regions. They evaluated data from the 1980's through 1993 and calculated TP yields for the major Puget Sound basins. These are presented in Table C-5 for comparison. The TP yields at the Chehalis mainstem stations are within the range of the river systems evaluated by Embry and Inkpen. The authors reported that generally the rivers on the Olympic Peninsula had lower TP yields than those found in the Puget Sound region (Embry and Inkpen, 1998).

Average and maximum ammonia-N and nitrate+nitrite-N concentrations were assessed at stations along the mainstem (Table C-3). The Centralia Reach (rm 67.5) had the highest average and maximum ammonia-N concentrations. The maximum ammonia-N concentrations at this station exceeded the USGS reported background concentrations of ammonia-N (0.1 mg/l) (Mueller and Helsel, 1996). The Porter station had the highest average and maximum nitrate+nitrite-N concentrations (Table C-3). While the maximum nitrate+nitrite-N concentration measured at the Centralia station was the second highest, it was less than half of that measured at Porter. None of the average nitrate+nitrite-N concentrations exceeded the USGS reported background concentrations for nitrate-N of 0.7 mg/l (Mueller and Helsel, 1996).

Inorganic nitrogen yields (IN yields) for the Chehalis River mainstem were calculated and are presented in Table C-4. Along the mainstem, IN yield increased in a downstream direction. In evaluating nutrient loading of Washington rivers, Embry and Inkpen (1998) also calculated inorganic nitrogen (IN) yield for Puget Sound and some Olympic Peninsula rivers. Their findings are presented in Table C-5.

Table C-4.
Total Phosphorus Loading and Yield and IN Yield along Chehalis Mainstem - 1990's Data

River Mile	Location	TP Loading (lb/day)		TP Yield (tons/yr-mi^2)		TP Yield (tons/yr-mi^2)	IN Yield (tons/yr-mi^2)
Season		Wet	Dry	Wet	Dry	Ave. Annual*	Ave. Annual*
Mainstem							
101.7	Dryad	197	8.7	0.31	0.01	0.14	1.4
59.9	Prather Rd.	1,099	105	0.23	0.02	0.12	1.5
33.3	Porter	1,851	126	0.26	0.02	0.13	1.9
13.15	Montesano	3,779	231	0.39	0.02	0.18	2.2

Average annual yield calculations based on all data available for 1990's

Table C-5. Pollutant Yields for Chehalis Basin Mainstem and Tributary Stations. Source: Embry and Inkpen, 1998

River Mile	Location	TP Yield (tons/yr-mi^2)			TSS Yield (tons/yr-mi^2)			IN Yield (tons/yr-mi^2)[1]
Season		Wet	Dry	Average	Wet	Dry	Average	Average
101.7	Dryad	0.31	0.01	0.14	343	2.3	143	1.43
59.9	Prather Rd.	0.23	0.02	0.12	90	1.1	42	1.59
33.3	Porter	0.26	0.02	0.13	107	1.3	49	1.92
13.15	Montesano	0.39	0.02	0.18	93	30	48	2.22
0.1	Newaukum	0.15	<0.01	0.08	155	11.3	7.8	2.03
23.6	Humptulips	0.41	0.03	0.2	396	6.1	186	1.15

[1]IN=inorganic nitrogen. This information is provided to allow comparisons to other basins in the Puget Sound

Average and maximum TSS concentrations at the mainstem stations are reported in Table C-3. Both average and maximum TSS concentrations were highest at the Dryad station, the uppermost ambient monitoring station in the watershed. The station at Porter had the lowest average and maximum TSS concentrations. Average wet and dry season TSS loadings were evaluated (based on instantaneous flows) at the stations along the mainstem over the last three decades (Figure C-6). As anticipated, the average TSS load is greater during the wet season than during the dry season. During the more frequent and intense wet season precipitation events, greater volumes of stormwater are generated which carry greater concentrations of solids. No trends are apparent with downstream flow during either season. Comparisons across decades during the wet season at a single station yielded no statistically significant differences for TSS loading.

Available 1990's TSS data were also used to calculate seasonal and annual TSS yield at mainstem and tributary stations using median flows (Table C-6). The watershed above Dryad contributes a substantially higher TSS yield (especially during the wet season) as evidenced by the higher yield than any other portion of the watershed. Average annual TSS yield at the other three mainstem stations were similar to one another.

Table C-6. Total Suspended Solids Yield along Chehalis Mainstem - 1990's Data

River Mile	Location	TSS Yield (tons/yr-mi^2)		TSS Yield (tons/yr-mi^2)
Season		Wet	Dry	Ave. Ann.*
Mainstem				
101.7	Dryad	343	2.3	143
59.9	Prather Rd.	90	1.1	42
33.3	Porter	107	1.3	49
13.15	Montesano	93	30	48

* Average annual yield calculations based on all data available for 1990's

Fecal coliform concentrations over the past decade are presented in Table C-3. The geometric mean concentrations were all less than the 100 colony forming units (cfu)/100 ml criterion. However, the maxima concentrations at all of the stations exceeded the 200 cfu/100 ml portion of the standard, with the stations at Dryad and Prather Road having the highest exceedances. Fecal coliform loading was calculated based on instantaneous flows. Average fecal coliform loadings over the last three decades are represented by river mile in Figure C-7. Seasonal differences can be attributed to higher wet season flows. Fecal coliform loading did not show statistical differences with river mile. Nor were water quality improvements or degradations statistically significant over time.

MAJOR TRIBUTARIES

Recent water quality data are available for ambient monitoring stations at or near the mouths of a number of tributaries. In WRIA 23 these include: the South Fork Chehalis River, Newaukum, Skookumchuck, and the Black rivers. In the lower watershed (WRIA 22), data are available for the Hoquiam (@ RM 9.3) and for the Humptulips (@ RM 23.6). For the Wynoochee and Wishkah rivers, data date back to the 1970's. Average and maximum or minimum concentrations for water quality parameters are presented in Table C-7.

The average temperature for the South Fork Chehalis River was the lowest of any of the tributaries, while the average temperature for the Black River was the highest. Maximum temperatures in the Black and Humptulips Rivers exceeded the water quality criterion. Maximum temperatures in the Wishkah and Wynoochee rivers also exceeded the water quality criterion in the 1970's. Dry season temperature exceedances in several of the tributaries in WRIA 23 have been reported (Pickett, 1994a). Temperature exceedances lead to the Upper Chehalis temperature TMDL (Butkus and Jennings, 1999). The study concluded that existing shade in several of the subbasins was insufficient. The TMDL recommended additional shade requirements to meet the temperature criterion, and stipulated that no additional reductions of base flow to the river be allowed (Butkus and Jennings, 1999).

Average and minimum dissolved oxygen concentrations are provided in Table C-7 for the major tributaries to the Chehalis River watershed. The Black River had the lowest average oxygen concentration and the lowest recorded minimum concentration. Dissolved oxygen deficiencies have been reported for many of the tributaries in the upper Chehalis (WRIA 23) (Table C-10). These have been attributed to high BOD and nutrient loading (Pickett, 1994a). The Upper Chehalis Dry Season TMDL noted that some portions of the mainstem Chehalis River (notably in the Centralia Reach area) had no loading capacity remaining for parameters leading to the depletion of dissolved oxygen.

Average total phosphorus concentrations were highest in the South Fork Chehalis and Black Rivers, while the Black River had the highest measured maximum TP concentration (Table C-7). TP loading and yields were calculated for the two subbasins, the Newaukum and Humptulips Rivers, based on monthly median (50% exceedance) flows. Wet TP loading in the Humptulips was more than two times higher than that in the Newaukum River (Table C-8). However, seasonal differences in TP loading were greater in the Newaukum River. TP yields were also

Table C-7. WDOE Ambient Monitoring Water Quality Program - 1990s Data Summary (except as noted)
(Average and Maximum or Minimum)

River Mile	Location (Subbasin #)	Temp (°C)		DO (mg/l)		TP (mg/l)		NH_3 (mg/l)		NO_{2+3} (mg/l)		TSS (mg/l)		FC[2] (cfu/100 ml)	
		ave	max	ave	min	ave	max	ave	max	ave	max	ave	max	ave	max
Tributaries															
3.0	S. Fork Chehalis (3)	9.5	17.5	10.5	8.0	0.05	0.08	0.02	0.05	0.56	0.77	14	80	117	540
0.1	Newaukum (5-7)	10.8	17.2	10.6	8.7	0.03	0.05	0.02	0.03	0.61	1.60	27	90	78	760
2.3	Skookumchuck (9)	10.6	16.9	10.3	9.1	0.04	0.14	0.02	0.07	0.54	1.48	8	43	41	960
7.1	Black (11)	11.2	19.7	8.5	3.3	0.05	0.17	0.03	0.16	-	-	3	12	39	1,200
2.7	Satsop (15-18)	10.0	17.9	11.2	9.6	0.02	0.11	0.01	0.05	0.23	0.60	17	170	15	110
13.6	Wynoochee[1] (20)	10.9	21	11.3	9.0	0.03	0.09	0.07	0.24	-	-	-	-	13	70
12.3	Wishkah[1] (21)	10.4	18.5	11.0	9.4	0.02	0.11	0.04	0.09	-	-	-	-	10	110
9.3	Hoquiam (22-24)	9.7	15	11.1	9.7	0.01	0.02	0.01	0.07	0.13	0.43	2	4	10	51
23.6	Humptulips (25)	9.9	21	11.2	9.0	0.02	0.29	<0.01	0.04	0.11	0.34	17	344	8	290

[1] Sampled only in 1970's
[2] Fecal coliform is calculated as a geometric mean value.

calculated for these two tributaries (Table C-8). The Humptulips had the higher average annual TP yield. This yield was the same as that reported for the Green River (Embry and Inkpen, 1998). The annual yield of the Newaukum River was similar to that reported for the Nisqually River (Embry and Inkpen, 1998).

Inorganic nitrogen concentrations are presented in Table C-7. Average and maximum ammonia-N concentrations were highest in the Black River. The Hoquiam and Satsop rivers had the lowest average ammonia-N concentrations. Nitrate+nitrite-N was not measured as consistently in the tributaries. For those subbasins where data were available, the Newaukum River had the highest average and maximum concentrations of nitrate+nitrite-N. The average nitrate+nitrite-N concentration in the South Fork Chehalis, Newaukum, and Skookumchuck approached this background concentration of 20 major surface water units across the country (Mueller and Helsel, 1996). The maximum concentrations in these three tributaries all exceeded the NAWQA background concentration of 0.7 mg/l.

Inorganic nitrogen (IN) yields were also calculated for the two tributaries where appropriate data were available. IN yield was higher in the Newaukum than in the Humptulips. The Newaukum IN yield was also slightly higher than any of the Puget Sound rivers identified by Embry and Inkpen (1998) (Table C-5).

Table C-8. Total Phosphorus Loading and Yield and IN Yield
Chehalis Tributaries - 1990's Data

River Mile	Location	TP Loading (lb/day)		TP Yield (tons/yr-mi^2)		TP Yield (tons/yr-mi^2)	IN Yield (tons/yr-mi^2)
Season		Wet	Dry	Wet	Dry	Ave. Ann. **	Ave. Ann**
0.1	Newaukum	125	5.7	0.15	<0.01	0.08	2.03
23.6	Humptulips	292	20	0.41	0.03	0.20	1.15

** Average annual yield calculations based on all data available for 1990's

Average TSS concentrations were highest in the Newaukum, Satsop, and Humptulips rivers and lowest in the Hoquiam River (Table C-8). The Humptulips River subbasin was observed to have the highest maximum TSS, which was substantially higher than any other tributary. Wet and dry season TSS yields were calculated for the Newaukum and Humptulips Rivers (Table C-9). Average annual and wet season TSS yields were substantially higher in the Humptulips than the Newaukum. The Humptulips had the highest TSS yield of any station calculated for this study. As with TP and IN yields, these differences in TSS yield could be used to prioritize activities to reduce loading within the proportionally higher subbasins.

The geometric mean of fecal coliform concentrations indicated the South Fork Chehalis had a geometric mean that exceeded the water quality criterion of 100 cfu/100ml (Table C-7). Maximum fecal coliform levels exceeded the 200 cfu/100 ml portion of the standard in all, but the Satsop and Hoquiam rivers (of those rivers with recent data). (The Wishkah and Wynoochee rivers did not appear to have a problem with fecal coliform in the 1970's, but no recent data were available.) The Black River had the highest maximum level with 1,200 cfu/100 ml.

Implementation of the wet season TMDLs on the Black River (Coots, 1994) and Upper Chehalis (WRIA 23) (Pickett, 1994) should eliminate fecal coliform exceedances in the upper river tributaries.

Table C-9. Total Suspended Solids Yield - 1990's Data

River Mile	Location	TSS Yield (tons/yr-mi^2)		TSS Yield (tons/yr-mi^2)
Season		Wet	Dry	Ave. Ann.*
0.1	Newaukum	155	11.3	7.8
23.6	Humptulips	396	6.1	186

* Average annual yield calculations based on all data available for 1990's

SUBBASINS ANALYSIS

SUBBASIN 1. CHEHALIS RIVER HEADWATERS

An ambient water quality monitoring station has been maintained at Dryad (rm 101.7) from 1977 until the present time. The more than 20 year period of record and the breadth of water quality parameters monitored assisted in providing a good understanding of water quality in this subbasin. This station is located at the base of subbasin and is, therefore, reflective of the cumulative water quality in the subbasin (Figure C-8). Monthly data are available for temperature, dissolved oxygen, pH, and flow; data are somewhat less continuous for TP, TSS, and inorganic nitrogen species. In the subsequent discussions, data are presented as individual measurements in figures, and as wet season, dry season, and annual averages over 3, and 10 year periods. Evaluation methods and the data limitations are discussed in greater detail in the first section of this appendix. Data from the long-term station are compared with more in-depth studies, such as the TMDL study (Pickett, 1994a).

Temperature at the Dryad station exceeds the water quality criterion of 18^{o}C with some regularity (Figure C-8). No significant differences were identified between the 3-year dry season average in the 1970's and that in the 1990's. The lack of difference indicates that no improvements to (or deterioration of) temperature conditions have occurred over the past 20 years. This stretch of the river was included in the temperature TMDL (Butkus and Jennings, 1999). The study concluded that existing shade in this basin (53%) was sufficient, but recommended that no additional removal of forest canopy nor additional reductions of base flow to the river be allowed (Butkus and Jennings, 1999).

Dissolved oxygen concentrations (DO) have been consistently above the Class A water quality standard of 8.0 mg/L at the ambient station (Figure C-8). However, exceedances were observed in the summers of 1991 and 1992 (Pickett, 1994a). To maintain consistently high dissolved oxygen concentrations in this stretch of the river, the TMDL requires reductions to the carbonaceous BOD and the ammonia-N loading from both point and non-point sources (Pickett, 1994a).

Data on total phosphorus indicate that while the river is generally has TP concentrations less than 0.1 mg/L (MacKenthun 1973) for unimpaired waters. Annual spikes of TP during the wet season in this stretch of the mainstem are not uncommon. Phosphorus tends to be the limiting nutrient in this stretch of the river during the summer months of higher primary productivity. The ratio of total nitrogen to total phosphorus (TN:TP) was more than 13.4 in the critical summer months (Pickett, 1994a).

A plot of TP loading (based on instantaneous flows) for the period of record (Figure C-9) indicates an apparent trend for higher TP loading in the past decade than previously. However, comparisons of the 3-year average dry season TP loads in the 1970's and 1990's showed no statistically significant difference. Thus, average data show neither improvements nor deterioration of conditions. The TP yield at Dryad was similar to other stations along the mainstem Chehalis River (Table C-4) and is between the TP yields of the Newaukum and Humptulips Rivers (Table C-8). The TP yield at Dryad was in the range of yields reported by Embry and Inkpen (1968) for Puget Sound rivers (Table C-5).

IN yield at this station was the lowest IN yield calculated for the mainstem and was between that of the two tributaries for which IN yield was calculated (Table C-8). IN yield was also similar to the yields reported by Embry and Inkpen (1968) for Puget Sound rivers (Table C-5).

Total suspended solids concentrations have ranged from a maximum concentration of 782 mg/l to a minimum of 1 mg/l, with average and median annual concentrations of 28 mg/l and 3 mg/L, respectively. This broad variation indicates high wet season loads associated with winter run-off. Figure C-10 depicts the suspended solids loading based on instantaneous flow over the period of record including a 12-month moving average. The 12-month moving average appears to indicate that the suspended solids concentrations are generally increasing over time, although no statistically significant differences were found. TSS yield at this station was almost three times higher than measured elsewhere along the mainstem with the wet season representing a 150-fold increase over the dry season.

Fecal coliform concentrations are depicted in Figure C-11. Generally concentrations of these indicator bacteria are below the Class A water quality criterion of 100 cfu/100 ml. The geometric mean for the last decade at this station across all seasons is 32 cfu/100 ml. However, the 1994 TMDL study reported higher fecal coliform measurements between river mile 106 and 108.6. Pickett (1994a) reported concentrations between 8 and 690 CFU/100ml, with a geometric mean of 95.7 cfu/100 ml. The study attributed the elevated instances of fecal coliform concentration to the wastewater treatment plant at Pe Ell.

Landuse Impacts on Water Quality

Forest lands comprise 95% of the landuse in this subbasin, with only 3% under agricultural use and less than 1% commercial and industrial landuse categories. While the landuse would suggest little impact from human activities, the TSS yield would indicate water quality has been degraded. The elevated wet season TSS yield, coupled with the elevated dry season fecal coliform levels and temperatures reported in the TMDL (Pickett, 1994a), are a concern. The 1994 TMDL recommends reductions in ammonia-N and carbonaceous BOD from both point and non-point sources. The 1999 TMDL for temperature concluded that no additional removal of forest canopy nor additional reductions of base flow to the river be allowed (Butkus and Jennings, 1999).

Subbasin Conclusions

Identification of sources and reductions in TSS contributions to this subbasin should be a priority based on the relative standing among the segments along the mainstem Chehalis River. Implementation of the recommendations from both TMDLs should receive a high priority, including preparation of the Detailed Implementation Plan for reducing temperature (Butkus and Jennings, 1999) and identification and management of non-point sources contributing to the elevated TSS yield.

SUBBASIN 2. ELK CREEK

No ambient monitoring station is located within this basin. However, the Elk Creek Basin was studied between 1991 and 1992 in the Upper Chehalis TMDL (Pickett, 1994a). Elk Creek enters the Chehalis River at river mile 100.2, below the Dryad monitoring station (river mile 101.7). During the low flow period, the creek contributed almost one half of the flow to the mainstem below the creek's confluence (Pickett, 1994a). Field data indicate that the water quality parameters of temperature, pH, and dissolved oxygen (DO) were within the water quality criteria. During the summer months of this study, the temperature reached a high of 17.2^{o} C, but DO during this time did not drop below 9.0 mg/L (Pickett, 1994a).

Laboratory parameters indicated mostly good water quality, with the exception of fecal coliform bacteria. Pickett (1994a) reported that the station near the mouth of Elk Creek exceeded the water quality criterion of 100 cfu/100 ml in 5 of the 6 summer samples. The measurement of 2,000 cfu/100ml sample on August 27, 1991 was associated with elevations of other pollutants (BOD, TP, chloride, and total organic carbon [TOC]).

During the summer low flow period of the TMDL, total phosphorus measured as low as 0.017 mg/L in August of 1992, but as high as 0.120 in August of 1991, exceeding the recommended concentration of 0.1 mg/L for streams not flowing into reservoirs (MacKenthun, 1973).

Inorganic nitrogen (nitrate+nitrite-N plus ammonia-N) ranged between 0.068 mg/L as N and 0.099 mg/L as N, substantially below the sum of the National Water Quality Assessment (NAWQA) program's national background for nitrate-N (0.7 mg/L) plus ammonia-N (0.1mg/L) (Embry and Inkpen, 1998). Suspended solids were also low, and ranged between 1 and 6 mg/L.

Landuse Impacts on Water Quality

Landuse in this subbasin is dominated by forestland (98.4%) on which logging takes place. The agricultural uses represent only 0.6% of the landbase, which is less than the Upper Chehalis River (above Dryad) and the South Fork Chehalis River. Thus, the higher dry season TP concentrations of the Elk Creek subbasin is surprising. Pickett (1994a) suggested that the sources of fecal coliform, TP, and BOD lie between this station and the station 2.3 miles upstream.

Data Gaps

This subbasin has no routine monitoring station, although intense monitoring was conducted for the TMDL. Establishment of a routine ambient monitoring station at the mouth of Elk Creek may not be as critical as conducting intensive monitoring after implementation of actions that would reduce the oxygen depleting pollutant and TP loading.

Subbasin Conclusions

The water quality in the Elk Creek subbasin is generally good, although reductions in the sources of TP and fecal coliform are needed. Pickett (1994a) recommended that livestock access area in the vicinity of Murnen and Nine Creek and potential inadequate on-site systems near Murnen should be the starting points in identifying and remediating the sources of fecal coliform, elevated TP, and BOD concentrations.

SUBBASIN 3. SOUTH FORK OF THE CHEHALIS RIVER

The South Fork Chehalis River enters the mainstem at river mile 88. With 50 square miles of drainage, this subbasin represents only about 2% of watershed that discharges to the mainstem. An ambient water quality monitoring station 3.0 miles above the mouth of the South Fork Chehalis (monitored during water year 96-97) provides data relevant to this study.

Temperature and DO were within the water quality criteria for a Class A stream (Figure C-12) for the year measured. However, the TMDL study indicated temperature exceedances of the river in July 1991 of 1.4 and 1.6^{o}C at both stations monitored for the study (Boistfort Bridge and the Tanker Intake). Estimates of existing shade on the South Fork Chehalis River made in the 1999 TMDL study (Butkus and Jennings, 1999) were 52 %. The TMDL recommended a shade load allocation of 74 % to reduce the temperature, thus an increase of 22 % is needed in this subbasin. The TMDL also recommended an 80% reduction in the width-to-depth-ratio of the South Fork Chehalis (Butkus and Jennings, 1999). It was also noted that in-stream flow levels must remain the same and additional surface water withdrawals must not be allowed (Butkus and Jennings, 1999).

The Upper Chehalis Dry Season TMDL recommended load allocations of the oxygen depleting substances, ammonia, and carbonaceous BOD. The TMDL recommended load allocations from non-point sources at the background loadings.

Nutrient concentrations are generally low in the South Fork Chehalis River (Figure 13). Low TP concentrations were also measured during the TMDL study, ranging between 0.010 and 0.016 mg/l. TP loading (based on instantaneous flow) at the station is plotted in Figure C-14.

Inorganic nitrogen measured at the ambient monitoring station is reported in Table C-7 and depicted in Figure C-13. Ammonia-N concentrations peaked at 0.05 mg/l, less than the NAWQA background concentrations, Nitrate+nitrite-N averaged 0.56 mg/l and peaked at 0.77 mg/l, the peak slightly exceeding the recommended background nitrate concentration of 0.7 mg/L (Embry and Inkpen, 1998). During the TMDL study TN ranged between 0.23 and 1.12 mg/L as N (Pickett, 1994a). Two measurements made near Boistfort were both over 1 mg/L;

nitrate+nitrite-N represented 83% of the total nitrogen. The TN:TP ratio calculated from this data was as high as 70, an indicator that phosphorus is the limiting nutrient.

TSS concentrations at the ambient monitoring station (river mile 3.0) ranged between 1 and 80 mg/L; with the highest measurement recorded in November. The November sampling date was also the date of highest flow and a turbidity reading of 40 NTU (water quality criterion is 5 NTU). TSS loading for the 96-97 water year is graphically presented in Figure C-14.

The geometric mean FC concentration for the 96-97 water year (117 cfu/100 ml) exceeded the water quality criterion. Additionally, five of the 12 individual measurements during the 96-97 water year exceeded the 200 cfu/100ml portion of the standard (Figure C-15). Elevated levels of fecal coliform bacteria were recognized as a water quality problem in this stretch of the watershed by Pickett (1994a).

Landuse Impacts on Water Quality

While this subbasin is predominately forestland (89%), agricultural landuses (9.5%) in this subbasin are higher than in the Elk Creek of Upper Chehalis. Agricultural practices could be the source of the elevated fecal coliform, and high TP, IN, and TSS yields. Pollutant inputs were identified to this subbasin by the USFWS survey at over 15 separate locations (Wampler, et al., 1993). Cattle access was identified on over 21% of the stream/river miles in the South Fork subbasin (Wampler, et al., 1993). Numerous dairies were identified in the subbasin including one near Curtis and the monitoring station, and ten farms in the Boistfort Prairie area (Pickett, 1994a).

Data Gaps

Although the period of record at the ambient monitoring station is limited in this subbasin, implementation of the TMDL recommendations should precede additional monitoring.

Subbasin Conclusions

Water quality in the South Fork Chehalis River is degraded for temperature and fecal coliform. A detailed plan to implement an increased shading regime needs to be developed and implemented to reduce critical summer temperatures. While nutrient concentrations are not above national standards, this subbasin has the highest average TP concentrations (tied with the Black River) of any tributary in the watershed. The average nitrate+nitrite-N concentration in the South Fork Chehalis subbasin is the second highest of the tributaries measured. Improvements to the existing nutrient loading in this subbasin should focus on survey of livestock operations and improvement in farm management practices as suggested by Pickett (1994a).

SUBBASIN 4. UPPER CHEHALIS RIVER

An ambient monitoring station just above this subbasin at river mile 77.7 (Claquato) was maintained for the 96-97 water year. Data indicate two exceedances of the temperature criterion (Figure C-16). Because temperature exceedances were measured during critical low flow periods, the TMDL recommended an additional 30 % shade be provided to the river between the convergence of Elk Creek and the Newaukum River to maintain temperatures and to assist in maintaining dissolved oxygen concentrations in the river. However, additional shading along the mainstem, even in the upper reaches, may be ineffective at reducing summer temperatures due to the width of the river.

Data indicate exceedances of the dissolved oxygen criterion on the same two monitoring dates as the temperature exceedances (Figure C-16). To improve oxygen conditions in the subbasin, the TMDLs recommended not only shading but also limitations of ammonia-N and carbonaceous BOD from non-point sources to background loadings.

TP concentrations averaged 0.09 mg/l for the 96-97 water year with two monitoring dates showing TP higher than the MacKenthun (1973) recommendation of 0. 0.5 mg/l for waters flowing into a lake or reservoir similar to this stretch of river, which is slightly upstream of the Centralia Reach.

Ammonia-N and nitrate+nitrite-N concentrations averaged 0.02 mg/l and 0.46 mg/l, respectively during the 96-97 water year. Both parameters were similar to concentrations found at other mainstem stations.

The TSS concentrations ranged from a low of 4 mg/l to 102 mg/l and averaged 20 mg/l. The average TSS concentration at this station was similar to that measured at the Dryad and Newaukum River stations. Fecal coliform data for the 96-97 water year equaled or exceeded the 100 cfu/100 ml standard on three of the 12 monitoring dates, although the geometric mean was 61 cfu/100 ml. This geometric mean was greater than observed at other mainstem stations and most of the tributaries (Tables C-3 and C-7).

The following is a description of streams within this subbasin.

Bunker Creek

Pickett (1994a) provided the only substantial data on Bunker Creek and Stearns Creek that flow into the mainstem of the Chehalis at river miles 84.6 and 78.0, respectively. Bunker Creek represents less than about 2% of the flow into the Chehalis River below their confluence. Temperature was within the water quality criteria, but dissolved oxygen was consistently depressed below the 8.0 mg/l criterion during the summer months of the study. DO was measured as low as 3.3 mg/l at the sampling site. The depressed level may be a function of the low flow of the creek which ranged from 1.3 cfs in 1991, to 0.2 cfs in 1992 - likely very shallow water depth. TSS, turbidity, TOC, and BOD were also fairly high compared to other tributaries (Pickett, 1994a). TN and TP concentrations averaged 0.46 and 0.07 mg/l, respectively. The TN:TP ratio, 6.6, indicates that Bunker Creek may be nitrogen limited. Fecal coliform counts were above the 100 cfu/100 ml on both days sampled. The USFWS study (Wampler, et al., 1993) indicated that livestock access and other pollutant inputs were the causes of degradation.

Stearns Creek

The flow in Stearns Creek during the 1991 and 1992 TMDL study were in the range of 2 to 4 cfs, representing less than 5% of the flow into the Chehalis River below the creek's confluence (Pickett, 1994a). Temperatures were measured above the water quality criterion of 18^{o}C and DO was consistently depressed below 8.0 mg/L. The lowest measured DO was 6.5 mg/l. Like

Bunker Creek, Stearns Creek was likely shallow during the summer months of the study. Picket (1994) reported that TSS (mean = 15 mg/l) and turbidity (mean = 16.5 NTU) in this creek were higher than in any other tributary to the river in the study. He also reported elevated levels of total dissolved solids (TDS), TOC, TP, and ammonia-N (maximum = 0.093 mg/l). TP averaged 0.37, while TN averaged 0.66. The TN:TP ratio was 1.78 which indicates a strongly nitrogen limited water body. Fecal coliform concentrations were elevated to 580 cfu/100 ml on one of the two dates sampled.

Landuse Impacts on Water Quality

Subbasin 4 is less dominated by forestlands (81%), than other upper watershed subbasins. Agricultural landuses are higher (17%), and located along the floodplain of the river. The subbasin is still relatively undeveloped with residential and urban landuses representing less than 1% of the land.

Impairments to dissolved oxygen and fecal coliform were attributed to the impact of agricultural practices that have been documented by the USFWS (Wampler, et al., 1993). This survey estimated a high percentage of stream miles were degraded by livestock practices. Agricultural practices may also be the source of the elevated TP and fecal coliform levels.

Data Gaps

A long period of water quality monitoring data is absent from this subbasin. Two recommendations for future monitoring are advisable. First, a USGS gage station should be recommended in the vicinity of the ambient monitoring station. Flows are necessary to calculate pollutant loadings and yields. Second, water quality monitoring data should continue to be collected at Claquato. Sample collection could be performed on a rotating basis, but not less frequently than every third year.

Subbasin Conclusions

Water quality is degraded in this subbasin, with exceedances of the temperature, dissolved oxygen, and fecal coliform criteria. TP concentrations are also evaluated. The fact that Bunker and Sterns Creeks are nitrogen limited also indicates that specific sources of phosphorus loading should be identified and reduced. Recommendations for the future include the flow and water quality monitoring described above and reduction or elimination of the agricultural sources of pollutants particularly from the Bunker and Stearns Creek areas.

SUBBASINS 5, 6, AND 7. SOUTH FORK, NORTH FORK, AND NEWAUKUM RIVER

These South and North Fork Newaukum Rivers and the Newaukum River (Subbasins 5, 6, and 7) converge and the combined flows are represented at the ambient monitoring station at the mouth of the Newaukum River (river mile 0.1). This ambient monitoring station at the mouth of the subbasins provides recent water quality data that reflect the cumulative impacts to the river. Data for flow, temperature, DO, pH, TP, inorganic nitrogen species, TSS, and fecal coliform are more or less continuous for the 1992 -93 water year. Two other ambient monitoring stations further upstream have more historical data. The first of these is located at river mile 4.5 and was monitored from 1972 through 1977. The second ambient monitoring station, located at river mile 11.1, was monitored for the 1974-75 water year only. Separate information on the two tributaries (North and South Forks) is lacking. Data from this station are compared to monitoring conducted by Pickett (1994a).

The combined drainage area of these three subbasins is 156 square miles, representing approximately 7% of the Chehalis River watershed drainage above the mouth. Flow at the mouth of the Newaukum River varied from a summer average low flow of 61 cfs, to average wet month flows of 985 cfs. The average low flow measured at the monitoring station during water year 92-93 is in the same range as those found by Pickett in 1991 and 1992 (1994a).

Figure C-17 indicates that temperatures at the ambient station approached, but did not exceed the water quality criterion. However, data collection during the TMDL study indicated that temperature exceeded the water quality standard of 18^{o}C on 3 of the 6 dates measurements were taken at the mouth station in the 91-92 water year, but were within the standard during the 92-93 water year (Pickett, 1994a). While the temperature TMDL did not establish a new temperature criterion for the Newaukum River, it did recommend an additional 35% shade be provided to consistently meet the criterion (Butkus and Jennings, 1999). The Newaukum River was also determined to need to reduce the width-to-depth ratio by 72% to meet the load allocation required in the TMDL (Butkus and Jennings, 1999). How this reduction is to be accomplished was not specified.

The 92-93 water year ambient monitoring data and the TMDL data indicated that dissolved oxygen met the criterion of 8.0 mg/l at the mouth of the Newaukum River. However, depleted dissolved oxygen concentrations on the mainstem Chehalis resulted in recommendations for reduction in tributary sources of carbonaceous BOD from non-point sources to prevent summer oxygen depletions (Pickett, 1994a).

Total phosphorus concentrations at the ambient station ranged from the detection limit of 0.01 mg/l to 0.05 mg/l and averaged 0.03 mg/l, well below the 0.1 mg/l level recommended by MacKenthun (1973). The average and maximum TP concentration were at the lower end of the range of tributaries for which data were available (Table C-7). Inorganic nitrogen concentrations averaged 0.02 mg/L for ammonia-N and 0.61 mg/l for nitrate+nitrite-N. Seasonal fluctuations of the nitrate+nitrite-N are depicted in Figure C-18. Pickett (1994a) reported somewhat lower nutrient concentrations; TP averaged 0.017 mg/l and TN averaged 0.17 mg/l, indicating the river is phosphorus limited (Pickett, 1994a). The higher averages for the full water year are a result of higher wet season concentrations (Figure C-18). The average inorganic nitrogen concentrations measured in both studies were less than the NAWQA background concentrations of 0.8 mg/l (Embry and Inkpen, 1998).

The TP loading from the Newaukum River to the mainstem of the Chehalis at Porter represents only 5% of the total dry season loading, but 7% of the wet season TP loading (Table C-8). The average annual TP yield of the Newaukum River is lower than the mainstem stations of the Chehalis, but represents 62% of the yield at Porter. The TP yield compares favorably to the rivers in Puget Sound evaluated by Embry and Inkpen (1998), slightly less than the TP yield for the Deschutes (Table C-5).

The IN yield for the Newaukum River was the second highest yield, second only to the yield at Montesano. IN yield is also higher than the rivers in the Puget Sound study (Embry and Inkpen, 1998) (Tables C-5 and C-8). Ammonia loading (one component of IN) was recognized as a problem in the 1994 TMDL study (Pickett, 1994a). The TMDL recommended an 87% reduction in the non-point source load allocation for ammonia-N to the Newaukum River (Pickett, 1994a).

TSS ranged from 3 mg/l to 90 mg/l in the 92-93 water year at the ambient monitoring station at river mile 3.0. The average TSS concentration (Table C-7) is higher than any other tributary. Wet and dry season and average annual TSS yields are presented in Table C-9. The TSS yield from the Newaukum River represented 16% of the average annual yield at the Porter station. TSS yield in the Newaukum watershed is substantially lower than that in the Humptulips subbasin (Table C-9).

The Newaukum River is listed on the 303(d) list as impaired for fecal coliform. Fecal coliform levels were higher than 100 cfu/100 ml in 3 of 12 months, although the geometric mean was less than the criterion, and less than 10 % of the samples exceeded 200 cfu/100 ml standard. Elevated levels were associated with the wet season and were not, therefore, observed during the TMDL study which was conducted in the dry season (Pickett, 1994a).

Landuse Impacts on Water Quality

Landuse in Newaukum River watershed is dominated by forest (79.4%). This subbasin has a relatively high percentage of agricultural activity (17%) compared to other subbasins. Only the Black River subbasin has a higher percentage of agricultural activities. The agricultural activities are likely to be the source of the high inorganic nitrogen yield and should be identified and managed. Reductions in ammonia-N and carbonaceous BOD load were recommended to improve water quality in the Newaukum as well as along the mainstem Chehalis River. Based on the high percentage of agriculture, load reductions should focus on improving run-off from agricultural practices.

Subbasin Conclusions

Water quality in the Newaukum River subbasin is degraded for temperature and fecal coliform. In addition IN yields were higher than at Porter or Dryad. Actions taken to improve these parameters should follow the TMDL recommendations by increasing shading and reducing sources of inorganic nitrogen, predominantly ammonia loading.

SUBBASIN 8. SALZER CREEK

Despite the small size of the Salzer Creek subbasin (19 mi^2) and its relatively low flow (2 to 4 cfs during the 91 and 92 dry seasons), it has been the focus of a number of water quality investigations. There is ambient monitoring station in this subbasin, this discussion is based on limited site specific studies.

In October 1979, low dissolved oxygen was observed in the mainstem of the Chehalis River at Mellen Street in Centralia. The source of the problem was identified as the failure of a food processing wastewater pipe that resulted in a release to Salzer Creek. The wastewater was being applied to and adjacent to the creek by National Fruit Canning Company (which has since been purchased by National Frozen Foods). Low dissolved oxygen was documented in Salzer Creek for some time after the release (Johnson and Prescott, 1982 and Joy, 1984). In 1986, Ecology conducted a survey of the creek to identify point and non-point sources in the drainage and associated impacts on water quality (Crawford, 1987b). Both low dissolved oxygen and high fecal coliform levels were measured. The causes of the poor water quality were cited as poor farm management practices and infiltrations of leachate from the Centralia landfill. Stormwater runoff from the Southwest Washington Fairgrounds was also identified as a potential pollutant source to Salzer Creek (Crawford, 1987b). Actions were undertaken to correct the identified problems.

Degraded water quality persisted and was again identified in the 1994 TMDL study (Pickett, 1994a). Temperatures exceeded the 18^{o}C criterion on several occasions. The 1999 temperature TMDL adjusted the temperature criterion for Salzer Creek to 19.9 ^{o}C based on predictions of natural stream conditions (Butkus and Jennings, 1999). The temperature TMDL also recommends an additional 13 % shade be provided to the creek to maintain the adjusted criterion temperature.

Dissolved oxygen was well below the 8.0 mg/l criterion during the 91 and 92 dry seasons. In late August 1991, the creek was "virtually anoxic" (Pickett, 1994a). To maintain high dissolved oxygen concentrations in the subbasin and along the mainstem, the TMDL recommended non-point source loading for ammonia-N and carbonaceous BOD remain at background levels.

Consistently elevated conductivities (above 1,000 umhos/cm), TDS, and chlorides were greater than any other tributary and were indicative of high concentrations of dissolved pollutants (Pickett, 1994a). Nutrient levels were also elevated. TP averaged 0.09 mg/l and TN averaged 0.61 mg/l, with spikes as high as 1.2 mg/l. Sources to the creek from a sump at the Fairgrounds were as high as 12.2 mg/l TN and 0.64 mg/l TP. Fecal coliform exceeded 1,000 cfu/100 ml on three different dates (Pickett, 1994a). Pickett (1994a) recommended additional investigation of sites previously identified (Crawford 1989b) and urged corrective actions be taken to improve water quality.

Landuse Impacts on Water Quality

Salzer Creek subbasin is a relatively developed portion of the basin with almost 3% of the land as urban or commercial and industrial. Agricultural uses comprise 12.9% of the subbasin, with the remainder dominated by forestlands (83.9%). Sources of water quality degradation in the subbasin have been identified and include the fairgrounds sump, wastewater discharged by National Frozen Foods, stormwater, and potentially leachate from the Centralia Landfill.

Data Gaps

Data on the impaired quality of this subbasin is prevalent, although no routine ambient monitoring station is located in the subbasin. Future monitoring efforts should be implemented following the necessary actions required to eliminate the sources of pollutant loading.

Subbasin Conclusions

Water quality problems in the subbasin have been identified but unresolved for a number of years. Since the sources have been identified, actions to correct the water quality problems emanating from these sources should be a priority. Post-corrective action monitoring can be used to verify the results of the actions.

SUBBASIN 9. SKOOKUMCHUCK RIVER

The Skookumchuck River enters the Chehalis River at river mile 66.9. An ambient monitoring station 2.3 miles upstream of the mouth of the Skookumchuck is sampled intermittently. Data were available for water years 92-93 and 96-97. Instantaneous flows at this station ranged from a dry season low of 77 cfs to a wet season high of 910 cfs.

Ambient monitoring station temperatures did not exceed the criterion. Average temperature for the station was 10.6^{o}C, and maximum temperature was 16.9^{o}C (Table C-7). Pickett (1994a), however, found temperatures elevated above the 18^{o}C criterion on several occasions. To assist in reducing summer water temperatures, the TMDL recommends an additional 20% shade be provided to this subbasin (Butkus and Jennings, 1999).

Dissolved oxygen was not recorded at concentrations less than the criterion at the ambient monitoring station or during the TMDL study. While Pickett (1994a) indicated that oxygen depleting pollutants (BOD, TOC, and nutrients) were detected at relatively low levels, the TMDL recommended that load allocations for the oxygen depleting pollutants (ammonia-N and carbonaceous BOD) not exceed background conditions. This recommendation implies that no additional landuse activities that would increase the contribution of these constituents should be allowed.

An average TP concentration of 0.04 mg/l and an inorganic nitrogen concentration of 0.56 mg/L was measured in the ambient data. The average TP concentration at this station was exceeded only by the average concentrations on the Black and South Fork Chehalis Rivers (Table C-7). Average ammonia-N concentration at ambient station on the Skookumchuck was low. While the average nitrate+ nitrite-N concentration was among the higher tributaries and exceeded only by the Newaukum and South Fork Chehalis Rivers, it was below the NAWQA national background concentration of 0.7 mg/l (Mueller and Helsel, 1996). Pickett (1994a) noted relatively low nutrient concentrations as well.

TSS concentrations ranged from an average of 8 mg/l to a maximum of 43 mg/l. The average and maximum TSS concentrations were among the lowest of the major tributaries (Table C-7). Fecal coliform concentrations were generally within the water quality standards, with a geometric mean of 41 cfu/100 ml and a peak of 960 cfu/100 ml. Pickett (1994a) also noted low fecal coliform counts.

Hanaford Creek

Hanaford Creek is a major tributary to the Skookumchuck River. Its basin is the site of a major open-pit coal mine and power plant. Baseline conditions were assessed in Hanaford Creek watershed in 1970 and 1971 during initial operations at the mine site and in preparation for the potential impacts of the coal mine/power plant projects (McCall, 1971). Elevated turbidity and iron levels that were observed were attributed to the construction. Dissolved oxygen concentrations were less than 8.0 mg/L (the water quality criterion) at 6 of the 7 stations monitored on Hanaford Creek and at one station at the mouth of South Hanaford Creek. Temperatures at three stations exceeded the 18^{o}C criterion on at least one occasion.

Pickett (1994a) monitored temperature, dissolved oxygen, and nutrients in Hanaford Creek above the Skookumchuck River. Temperature exceeded the criterion on some dates. Dissolved oxygen levels remained above the 8.0 mg/l level even on the days of elevated temperatures (Pickett, 1994a). Nutrient concentrations were relatively low; TP and TN averaged 0.053 mg/l and 0.54 mg/l, respectively (Pickett, 1994a).

Landuse Impacts on Water Quality

As with other subbasins in the watershed, landuse is dominated by forestlands (86.5%). Agricultural activities represent 7.5% of land uses, with commercial and industrial categories representing 2.4% of the land and urban representing only 1.4% of the landuse. The lower percentage of agricultural landuse in this subbasin may be one factor in the relatively high water quality.

Data Gaps

TP, IN, and TSS loadings and yields should be calculated based on the median monthly flows (50% exceedance flows) to allow comparisons among the tributaries for prioritization of actions.

Subbasin Conclusions

The Skookumchuck River has had exceedances of the temperature criterion. Water quality in this subbasin has also been somewhat affected by contributions of TP and IN, as reflected in the slightly elevated average concentrations of these parameters. The two TMDLs have included recommendations for the Skookumchuck which are tailored predominantly to improve water quality along the mainstem Chehalis River, as well as within the Skookumchuck River itself. Implementation of the recommendations in the TMDL studies should be the main priority in this subbasin.

SUBBASIN 10. MAINSTEM NEAR CHEHALIS/CENTRALIA

The stretch of the Chehalis River between river mile 75.2 (the mouth of the Newaukum river) and river mile 66.9 (the mouth the Skookumchuck River) has been identified as the Centralia Reach. The ambient monitoring station with the longest period of record in this subbasin is river mile 67.5 near Centralia in the very slow flowing Centralia Reach, which exhibits lake-like conditions. The station was monitored from 1977 through 1993 and provides the basis for the subsequent discussion.

This section of the mainstem tends not to meet the water quality standards. Figure C-19 presents temperature over the period of record. Temperature not only exceeds the criterion of 18^{o}C but also frequently exceeded 20^{o}C. The 1999 temperature TMDL evaluated natural temperature regimes; and as a result, the water quality criteria for temperature for this stretch of river were re-established at background conditions (Butkus and Jennings, 1999). The re-established criteria are presented in Table C-10. The TMDL recommended shade requirements needed to meet the temperature criteria. These vary between 27 and 42% additional shade along this stretch of river (Butkus and Jennings, 1999).

Table C-10. Segment-Specific Water Quality Criteria Established by 1999 TMDL

Chehalis Mainstem River Mile	Water Quality Standard
73.6	18.4
70.7	18.9
69.1	19.5
67.5	20.3
66.3	20.4

The period of record shows that dissolved oxygen frequently declined below the criterion of 8.0 mg/L (Figure C-19). Reported anoxic conditions near the bottom was one of the drivers for the 1994 TMDL which limited carbonaceous BOD and ammonia-N.

Total phosphorus has ranged from 0.01 mg/l to 0.38 mg/l over the period of record. The average and median TP concentrations were 0.08 and 0.05 mg/l, respectively. Average TP concentrations along the mainstem were only exceeded at Claquato. Concentrations of greater than 0.05 mg/l for flows into a lake-like area (such as the Centralia Reach) indicate a high likelihood of poor water quality (MacKenthun, 1973). TP loading based on instantaneous flows is depicted in Figure C-20. TP loading and yield based on 50% exceedance flows was not calculated, but may demonstrate a higher average annual TP yield than at other stations along the mainstem.

Ammonia-N and nitrate+nitrite-N averaged 0.06 and 0.47 mg/l, respectively during the 1990's. Pickett (1994a) reported that this stretch of river is nitrogen limited.

TSS concentrations in the 1990's ranged from 1 mg/l to 109 mg/l, with an average of 16 mg/l. TSS loading based on instantaneous flows is depicted in Figure C-20 for the period of record.

Fecal coliform concentrations are frequently above 100 cfu/100 ml as seen in Figure C-21. Although the geometric mean for the period of record is only 47.3 cfu/100 ml, fecal coliform concentrations equaled or exceeded 200 cfu/100 ml on 21% of the sampling occasions in the 1990's data set of measurements.

Other Studies

This river reach has received intensive study due to the continuing low dissolved oxygen concentrations in this stretch. Low dissolved oxygen and high bacterial levels were observed as early as 1969 (McCall, 1970). This author reported that the Centralia Reach experienced temperature and oxygen stratification, similar to a meso- to eutrophic lake or reservoir. Improvements in the quality of the discharge from the Chehalis Wastewater Treatment Plant in

1970 resulted in higher dissolved oxygen concentrations at the surface and lower bacterial levels. However, the deepest points in the Reach were anoxic in three separate areas (McCall, 1970).

A 1972 study indicated that although the water quality had been improved by the changes at the treatment plant and oxygen levels met the water quality standards for that reach of the river, problems remained (Devitt, 1972). This study specifically mentioned access by livestock to the river and garbage dumping in some areas. Other potential sources of these problems were identified in the Sewage Drainage Basin Plan (R.W. Beck, 1975) as: failing septic systems, poor animal waste management, poor forest practices, and specific industrial point source discharges from facilities such as wood products, food processing, and meat packing.

By 1980, reports by Houck (1980) and Yake (1980) noted that the conditions of the Centralia Reach may be attributed, in part, to its natural flow patterns. A travel time of 6.4 days was estimated from the Chehalis WTP to the Mellen Street bridge. Yake concluded that this stretch of river is deep, slow, and stratified. Algal growth and respiration (resulting in oxygen utilization) is controlled by the levels of inorganic nitrogen discharged by the Chehalis WTP (nitrogen downstream of the WTP plant was 2 to 6 times higher than upstream of the plant). Johnson and Prescott (1982) also observed substantial temperature stratification, oxygen depletion to levels less than 2.0 mg/L near the bottom. They commented that the temperatures were high enough to pose a threat to salmonids. This was reiterated by a 1982 US Fish and Wildlife Service study of conditions in the Centralia Reach for chinook salmon.

An intensive survey and modeling effort of this reach of the river was conducted in 1982. Again the low velocity of the river (0.04 to 0.07 feet per second at low flow), coupled with the nutrient loading from the WTP stimulating algal growth, were identified as predominant factors contributing to depressed dissolved oxygen concentrations. It was suggested that as Salzer Creek entered the river, heterotrophic bacterial activity may have been the cause of additional oxygen depletion, rather than algal photosynthesis (Joy, 1987). To evaluate the potential impact of an increased discharge by Darigold under their NPDES permit, (Joy, 1987) modeled the additional BOD loading to the river. He concluded that no significant reduction in dissolved oxygen would results from the proposed increased load by Darigold. However, his model did not account for the impacts of nutrient loading and stimulation of algal growth on the dissolved oxygen levels in the river.

Dillenbaugh Creek

In 1986, WDOE performed an intensive survey of this creek that discharges into the Newaukum River near its mouth. The purpose of the 1986 survey was to investigate point and non-point sources of pollution to the creek that may have resulted in low dissolved oxygen levels (Pickett, 1992). The investigators found a wide variety of sources including: farming activities, including a dairy feedlot (thought to be the primary cause of low oxygen concentrations), failing septic systems adjacent to the creek (considered the major source of bacterial contamination), and industries in the Chehalis Industrial Park which contributed to temperature violations.

This creek was also included in the TMDL study (Pickett, 1994a). Flows in the creek were reported between 0.3 and 1.4 cfs during the dry season. Only one instance of a temperature exceedance of the water quality standard was recorded during the study. Noteworthy was one pH reading higher than 8.0 which was postulated to be associated with discharges from the Chehalis Industrial Park (Pickett, 1994a).

Dillenbaugh Creek has relatively high turbidity and TSS. The BOD and TOC were the second highest of any natural tributary to the mainstem; Pickett (1994) also reported that TP, TN, and chloride were also relatively high, but fecal coliform levels were low. Because elevated fecal coliform levels were measured in the upper creek, Pickett indicated concern about the rapid die-off. He hypothesized that pentachlorophenol from the American Crossarm and Conduit Superfund site adjacent to the creek may be "disinfecting" the creek near the mouth. It was recommended that additional monitoring and source control be performed as pentachlorophenol is a growth inhibitor for yearling sockeye salmon (Pickett, 1994a). In addition, he recommended a number of restoration and protection activities to improve the water quality in the creek.

Other Studies on the Mainstem below Skookumchuck

Enviroshpere Company (1982) monitored the stretch of the Chehalis between river mile 23.9 and 13.5 during the preparation for the Washington Public Power Supply System. They reported that the criteria were met for dissolved oxygen, turbidity, and temperature, except during the summer when temperatures in this section of the mainstem exceeded 18^{o}C.

Thurston County Environmental Health conducted sampling and analysis of the Chehalis River near Grand Mound during the low flow season in preparation for the proposed Grand Mound WTP. Samples were analyzed for dissolved oxygen, pH, conductivity, nutrients, BOD, TSS, and fecal coliform bacteria. All parameters met the water quality standards, except temperature. In late August 1989, temperatures between 18^{o}C and 19^{o}C were measured at two stations. Noteworthy were a dissolved oxygen concentration of 8.2 mg/L and a pH of 8.4 at the Prather Road bridge - barely meeting the standards. Nitrate+nitrite-N tended to increase in the downstream direction, while total phosphorus tended to decrease ranging between 0.1 and 0.2 mg/L (TCEH, 1989).

Landuse Impacts on Water Quality

Landuse in the Chehalis River mainstem subbasin near the cities of Centralia and Chehalis is more equitably spread across the major categories: forest lands comprise 64% of the subbasin, agricultural practices represent 20.1% of the landuse. Six percent of the subbasin is urbanized and industry and commerce represent 1.7% of the area.

Data Gaps

The river is well-studied in the subbasin and there were no apparent data gaps at this location. However, TP, IN, and TSS loadings and yields should be calculated based on median monthly (50% exceedance) flows. This would allow prioritization of activities designed to reduce pollutant loadings among the subbasins. The ambient station at Centralia should continue to be monitored for water quality parameters.

Subbasin Conclusions

This subbasin has been recognized as having an abundance of water quality problems, including elevated summer temperatures, fecal coliform levels, and low dissolved oxygen attributed to BOD and nutrient loading. Average TP and ammonia-N concentrations were among the highest along the mainstem. These water quality problems, coupled with the slow flowing conditions of the Centralia Reach, create conditions observed in a eutrophic lake or reservoir. As such it has been included in the two TMDL studies. Recommendations from these TMDLs should be implemented. While increased shading along the mainstem alone may not provide sufficient cover of the river to improve conditions due to its width, increased riparian shade along the upstream tributaries will likely improve summer temperature conditions.

Actions to improve water quality should include reductions in the oxygen depleting constituents and nutrients through revised permit conditions and implementation of agricultural and stormwater BMPs. Reductions in fecal coliform levels should be realized coincidentally with BMP implementation.

SUBBASIN 11. BLACK RIVER

Historical Studies

The Black River subbasin has been the subject of extensive study since a large fish kill occurred in August 1989 (hundreds of adult chinook were found dead in the Chehalis River near Oakville) (Pickett, 1992). Toxic materials were suspected, but never detected in significant amounts. Temperatures in the lower Black River (below RM 10) were found to exceed the water quality criteria of 18^{o}C at the surface. Dissolved oxygen concentrations below 8 mg/L were widespread (Pickett, 1992). Portions of the river were reported to support dense beds of aquatic macrophytes, which elevated levels of dissolved oxygen during midday. Total phosphorus concentrations in the lower river were in excess of 0.1 mg/L, EPA's desired goal for the prevention of nuisance plant growth in rivers. Pickett reported alternating locations of nitrogen and phosphorus limitation on plant growth in the upper river, but a strongly phosphorous limited condition in the lower river.

A water quality screening study was conducted cooperatively between the Chehalis Confederated Tribes and WDOE, between November 1989 and June 1990 (Dickes, 1990). Dissolved oxygen concentrations did not meet the standard in November, December, and June (Dickes, 1990). The pH standard was violated between March and May falling below 6.5 (Dickes, 1990). Numerous fecal coliform exceedances were detected during wet weather months, which ultimately lead to a wet weather TMDL for fecal coliform. Total suspended solids and turbidity levels were high during a storm event in January (Dickes, 1990).

A subsequent water quality study was conducted cooperatively between the Black River Watch and Thurston County Environmental Health in 1990 and 1991. Six stations were sampled from mid-July through October, and monthly through March 1991. During this study, temperatures reached a high of 23.5^{o}C in August. Thermal stratification was identified at three stations, where dissolved oxygen near the bottoms reached a low of 0.5 mg/L. Dissolved oxygen was below the standard at all stations on several sampling events. Fecal coliform level also exceeded criteria at all stations, except the most upstream location.

TMDL Studies

The results of the water quality monitoring studies focused attention on this watershed and lead to the development of both wet and dry season TMDLs. The wet season TMDL was conducted to evaluate and recommend a plan to remediate elevated fecal coliform concentrations. The TMDL (Coots, 1994) identified land use as dominated by crop and pasture in the main basin supporting almost 9,000 head of diary cows and numerous non-commercial farms. Although five aquaculture facilities were present in the basin, only one discharged directly to the Black River. Thus, conclusions of the study were that fecal coliform exceedances were attributed primarily to poor farm practices. Study recommendations included a 92% load allocation reduction in Beaver Creek (tributary to the Black River), and between 49% and 60% load reductions in the middle reach of the Black River (river mile 11.8 to 15.2); providing assistance to local farmers through the conservation district. Other recommendations were establishment of a local watershed management committee, and identify location of the pollutant loading sources along the middle reach (Coots, 1994).

Thurston County Environmental Health (TCEH) Division has continued to monitor Beaver Creek and the Black River. The results of wet season monitoring of Beaver Creek at Highway 121 (creek mile 0.1) indicate a decrease in the fecal coliform following TMDL implementation. A geometric mean of 1,285 cfu/100 ml for wet season data from December 1992 through March 1996, versus 461 cfu/100ml for December 1996 through March 1997 (TCEH reports for water years 92-93 through 96-97) (Figure C-22). Although water quality standards were still not being met in 1997, water quality was improving. Overall, in both wet and dry seasons, TCEH reported fewer fecal coliform exceedances of the second portion of the standard (i.e., no more than 10% exceeding 200 cfu/100 ml). In the 1992-93 water year, 75% of the samples exceeded the 200 cfu/100 ml limit, while in water year 96-97 only 25% of the samples exceeded the limit.

BMP implementation plans for farms on the Black River were in place by January 1995 (Sargeant, 1996). TCEH monitored the Black River at Moon Bridge (river mile 7.1) once in March of 1996 and monthly from December 1996 through March 1997 resulting in a geometric mean of 50.48 cfu/100 ml. Fecal coliform levels were well within the compliance limits. WDOE data indicate that the geometric mean of fecal coliform during the wet season decreased from 54 prior to BMP implementation, to 36 cfu/100 ml at this station following BMP implementation, with no exceedances of the 200 cfu/100ml standard following BMP implementation.

The dry season (defined as May 1 through October 31) TMDL was also issued in the summer of 1994 (Pickett, 1994b). Numerous pollutant issues were identified during the study. The upper river (upstream of river mile 15.3) was found to be strongly influenced by extensive wetlands. In this area, dissolved oxygen was low, and organic compounds were relatively abundant, giving the river its characteristic dark color (Pickett, 1994b). In the middle slow flowing and deeper portion of the river, water quality is affected by nutrient loading (in some instances from unidentified sources) and verges on eutrohpic. Just upstream of the confluence with Mima Creek, historical releases of pollutants from the Black River Ranch had severely affected water quality in that stretch of river. The study noted that waste management practices had been improved at the ranch, resulting in improvements in the water quality by 1992. In the lower reaches of the river, the proliferation of phytoplankton (a result of nutrient loading) was reduced. Instead dense beds of macrophytes were found downstream of river mile 9.1. Parameters of concern were identified as dissolved oxygen, total phosphorus, and temperature.

A new standard for dissolved oxygen by river mile was established based on background conditions, with no significant degradation of DO allowed from any new development of point or non-point sources (i.e., no new sources of BOD loading) (Pickett, 1994b). A limit on total phosphorous was applied to the middle Black River to protect this section of the river from further deleterious effects of eutrophication (Pickett, 1994b). A load capacity, defined as the daily average TP concentration of 0.05 mg/L, was applied from river mile 9.6 to 15.1. A TP load allocation was also recommended for the Swecker Salmon farm (Pickett, 1994b). To remedy the temperature exceedances, protection and replanting of shade trees in the riparian zone from RM 10 to the mouth was proposed (Pickett, 1994b). BMP implementation and monitoring were also recommended (Pickett, 1994b). The subsequent temperature TMDL for the Upper Chehalis (Butkus and Jennings, 1999) also recommended 31% additional shade for the Black River and a 62% reduction in the wide-to-depth ratio. Implementation details of the temperature TMDL were remanded to the Chehalis Basin Partnership for development in a Detailed Implementation Plan (Butkus and Jennings, 1999).

Following the dry season TMDL implementation, changes in ammonia-N, TP, and dissolved oxygen might be expected. Figures C-23 through C-25 provide the dry season monitoring data at river mile 7.1 for pre- and post-TMDL implementation for these parameters. Although the average DO has increased slightly and the maximum TP concentration measured since December 1995 is not as high as that measured previously, significant improvements are not immediately apparent. However, data collection has been limited since the original study, and BMP implementation generally requires a number of years.

Ambient Monitoring Station Data

A long-term ambient monitoring station has been maintained on the Black River at the Moon Bridge crossing (river mile 7.1). Water quality data was collected monthly from 1990 through 1997. These data are used in the following discussion of water quality. While no flow data were available, temperature, dissolved oxygen, pH, total phosphorus, ammonia-N, total suspended solids, and fecal coliform data are available.

As seen in Figure C-26, temperature and dissolved oxygen frequently do not meet the water quality criteria of 18^{o}C and 8.0 mg/L, respectively.

Total phosphorus at this station ranged between the detection limit of 0.01 mg/l and 0.17 mg/l. The average concentration was higher than any other tributary (and equaled that of the South Fork Chehalis River (Table C-7). The maximum TP concentration was substantially higher than the EPA maximum recommended concentration of 0.1 mg/L for the prevention of nuisance plant growth in rivers, although the average concentration was 0.05 mg/l.

Ammonia-N concentrations were measured at the Moon Bridge station and averaged 0.03 mg/l-N with a maximum concentration of 0.16 mg/l. Nitrate+nitrite-N and total nitrogen have not been measured at this station. However, summer season nitrate+nitrite-N was measured during the 1991 and 1992 water years (Pickett, 1994b). The average concentrations at the Howanut Bridge station for ammonia-N was 0.02 mg/l, and for nitrate+nitrite-N, 0.92 mg/l. Total N was reported as an average of 1.08 mg/L. The TN:TP ratio (>34) during the summer at Howanut

Road Bridge would indicate that the river is strongly phosphorus limited. However, Coots (1994) reported that some segments of the river are nitrogen limited.

Total suspended solids averaged 3 mg/l, with wet season peaks of 12 mg/l. Fecal coliform levels routinely exceeded the water quality criterion. Of the 61 station measurements, 15 (~25 %) were equal to or greater than 100 cfu/100 ml, even though the geometric mean for the time period was only 39 cfu/100 ml. Most of these excursions, were associated with the wet season.

Landuse Impacts on Water Quality

Landuse impacts on the water quality of the Black River subbasin have been well documented. While a high percentage of the land (68.8%) is considered forestland, agriculture and rangeland activities represent 14.2% and 3.7% of the landuse, respectively. Wetland areas comprise 5.5% of the subbasin, some of which are immediately adjacent to the river. Urban residential, and industrial and commercial, landuses represent less than 3% of the basin. Agricultural activities have had the most profound and well-documented impacts on the water quality of the river. Fecal coliform and TP levels have been elevated from farm practices. Fecal coliform levels may also reflect failing septic systems. These impacts are being remediated through implementation of the TMDL (Pickett, 1994b). Temperature is naturally elevated by the slow meandering course of the river, but is also affected by the clearing of land for agriculture and urban development. Increased shading, recommended in the temperature TMDL should assist in reducing the temperatures of the river.

Data Gaps

The Black River subbasin has received intensive study. However, establishment of a USGS gage station at the Moon Road or Howanut Road is highly recommended. This station would provide flow data for calculation of TP, IN, and TSS yields, allowing subbasins with higher yields to receive higher priority for activities to reduce pollutant loading.

Subbasin Conclusions

The water quality in the Black River subbasin is impaired. Excursions of temperature, dissolved oxygen, and fecal coliform criteria have been commonplace. The wet and dry season TMDLs for this river and the Upper Chehalis temperature TMDL recommended non-point loading allocations and recommend actions to improve water quality. Resources in this subbasin should focus on implementing the recommended actions. Post-implementation monitoring should be directed toward identification of water quality improvements.

SUBBASIN 12. CEDAR CREEK

No ambient monitoring station is located in this subbasin. Information from the TMDL (Pickett, 1994a) is summarized here. This tributary to the mainstem enters at river mile 38.8, just upstream of the Porter ambient monitoring station. Summer flows for this creek ranged between 11 and 14 cfs, representing 3 to 5 % of the flow on the mainstem at Porter (Pickett, 1994a). Water quality in this subbasin was considered to be good. Temperatures remained below the criterion and dissolved oxygen concentrations remained well above the criterion. Only one fecal coliform measurement was greater than 100 cfu/100 ml. The low observed fecal coliform levels were attributed to the fact that there is little livestock access to the stream. The TP concentrations were never above the detection level of 0.010 mg/l. TN concentrations were also low, averaging 0.27 mg/l throughout the low flow study period (Pickett, 1994a). This creek is also phosphorus limited as evidenced by the estimated TN:TP ratio of 27.

Landuse Impacts on Water Quality

Forestlands dominate landuse within this 39 mi^2 subbasin, representing 96.1% of the area. Range land represents 2.4% of the drainage and the only agricultural activities. Wampler (1993) noted that this subbasin had one of the lowest identified percentages of streambank with livestock access impacts (Wampler, et al., 1993). The lack of agricultural and urban development may be one factor contributing to the high water quality.

Data Gaps

This subbasin has no ambient water quality monitoring station. Long-term data are needed, although limited resources may focus on post-TMDL implementation monitoring until higher priorities have been achieved.

Subbasin Conclusions

While there is limited data on the Cedar Creek subbasin, extant data indicate that the Cedar Creek subbasin had generally high water quality, with one instance of elevated fecal coliform. Future actions in this basin should focus on maintaining its water quality.

SUBBASIN 13. CHEHALIS RIVER MIDDLE REACH 2

An ambient water quality monitoring station has been maintained at Porter (RM 33.3) since 1970, and continues to be monitored on a monthly basis. Temperature excursions have occurred at this station (Figure C-27) routinely over the period of record, and frequently exceeded 20^o. During development of the temperature TMDL, it was acknowledged that natural temperature conditions in the reach were higher than the standard, and thus, the water quality criterion was adjusted to 21^oC at this location (Butkus and Jennings, 1999). It was also estimated that 28% additional shade would still be required to meet this higher temperature standard (Butkus and Jennings, 1999). However, additional shading alone the mainstem of the river along may not result in the needed temperature reduction during critical summer periods.

Dissolved oxygen over the period of record has rarely fallen below the standard (Figure C-27). However, dissolved oxygen excursions have been observed in other studies, which lead to a TMDL. Point and nonpoint wasteload allocations were recommended to reduce loading of oxygen depleting substances to the river (Pickett, 1994a). Wasteload allocations for ammonia-N and carbonaceous BOD are anticipated to be implemented through NPDES permits or other Clean Water Act mechanisms (Pickett, 1994a). Non-point source loadings of ammonia-N and carbonaceous BOD were recommended to be limited to background conditions above the confluence of the Skookumchuck River. No load allocations were recommended for future growth (Pickett, 1994a).

Total phosphorus ranged from 0.1 to 0.52 mg/l over the period of record and averaged 0.054 mg/l. Average TP concentration in the 1990's was 0.05 mg/l (Table C-3). Figure C-28 indicates that TP routinely approaches, and occasionally exceeds the recommended level of 0.1 mg/l

(MacKenthun, 1973). TP loading was calculated using the 1990's data and median monthly flows. Both wet and dry season TP loadings were within the continuum along the river, increasing from the headwaters to the mouth. Average annual TP yield was calculated for the river basin drainage to river mile 33.3 and found to be 0.13 tons/year-mi^2, within the range of Puget Sound rivers reported by Embry and Inkpen (1998) (Table C-5).

Ammonia-N concentration over the period of record averaged 0.054 mg/l. The average and maximum concentrations for the most recent decade are higher than for the period of record (Table C-3). Nitrate+nitrite-N concentration averaged 0.68 mg/L in the 1990's, which was higher than any other mainstem station. The inorganic nitrogen yield was calculated from the 1990's data and median monthly flows. IN yield was found to be 1.92 tons/year-mi^2. This value is within the increasing continuum from the headwaters to the mouth of the Chehalis. It is also within the range reported for Puget Sound rivers (Table C-5). Both TP and TN were measured for the 1994 TMDL study; and a TN:TP ratio of more than 20 was calculated, indicating a strongly phosphorus limited segment.

TSS was not routinely measured until after 1982. Concentrations ranged from below detection to 130 mg/l, and averaged 12.8 mg/l over the period of record. TSS yield was calculated (Table C-6) for wet and dry seasons. The wet season TSS yield was within the range of that found for the Prather Road and Montesano stations (Table C-6). Dry season TSS yield was less than the other mainstem stations. The average annual TSS yield was calculated and found to be 48.9 tons/year-mi^2, which is between the Prather Road and Montesano station levels (Table C-6).

Fecal coliform concentrations at the Porter station were not routinely measured until late 1982. Fecal coliform routinely exceeds 100 cfu/100 ml (Figure C-29). Although not statistically significant, the number of exceedances of 100 cfu level appears to be decreasing in the 1990's. The geometric mean for the 1990's is 29 cfu/100 ml.

Landuse Impacts on Water Quality

Within this subbasin, landuse is less dominated by forest lands than in other subbasins, representing only 76.5% of the landuse. Agriculture represents 12% and urban, residential, commercial, and industrial less than 2%. However, the impacts of landuse in the Chehalis River at Porter are reflective of the watershed as a whole above the Porter gage. Thus, the landuse in the upper watershed (WRIA 23) also needs to be considered. Basin-wide to the Porter station, landuse consists of 80.4% forest, 13% agricultural, and represent 1% of rangelands. Urban residential landuses comprise 1.7% of the upper watershed and commercial and industrial activities represent 0.6% of the land use. Water quality has been degraded by many of these activities. Agricultural practices contribute to the elevated nitrate+nitrite-N concentrations and fecal coliform levels. Urban development contributes nutrients, BOD, and TSS in the form of wastewater discharges, stormwater run-off, and improperly functioning septic systems.

Data Gaps

The ambient water quality monitoring station at Porter has the longest and most complete water quality data record. Data gaps are not apparent.

Subbasin Conclusions

Water quality at the Porter station is a reflection of the activities and water quality of the Upper Basin (WRIA 23). Water quality has been degraded by human activities resulting in violations of the water quality standards for temperature and dissolved oxygen. TP yield was within the range of other Puget Sound basins, although IN yield was higher than the values reported by Embry and Inkpen (1998). Implementation of TMDL recommendations is anticipated to result in the compliance with water quality criteria for dissolved oxygen, fecal coliform, and temperature (Pickett, 1994a). Collaborative efforts of local agencies and citizens, as well as the state and federal agencies, will be needed to reduce nutrients and oxygen depleting pollutants. Similarly, implementation of the increased shading for the tributaries and mainstem will require collaboration.

SUBBASIN 14. CLOQUALLUM CREEK

Cloquallum Creek is a 70 square mile subbasin that discharges to the mainstem of the Chehalis River near Elma (RM 25.2). An ambient monitoring station was located at river mile 3.0. However, water quality data on this creek are limited and not recent. The period of record for ambient flow data span three water years (71-72, 74-75, and 75-76) and includes bimonthly samples during the 71-72 water year and monthly samples thereafter. Water quality data were obtained consistently for temperature, DO, pH, ammonia-N, TP, and fecal coliform, but only the first water year for nitrate+nitrite-N; no TSS data were obtained.

Available data indicate that temperature and dissolved oxygen were well within the criteria for the Class A stream. However, the creek experienced pH excursions on five of the 72 sampling dates.

Phosphorus was generally low, but elevated a number of times, possibly associated with storm events. The TP concentration averaged 0.039 mg/l (including these two events at 0.28 mg/l and 0.29 mg/l). The average concentration is less than that recommended to prevent eutrophication. TP loading (based on instantaneous flows) also fluctuated seasonally (Figure C-30). Ammonia-N concentrations were relatively constant, except on one occasion (a peak of 0.3 mg/l) and averaged 0.07 mg/l. Fecal coliform concentrations were routinely less than 100 cfu/100 ml, with occasional wet season peaks between 260 and 420 cfu/100 ml.

Wildcat Creek

Wildcat Creek is a tributary to Cloquallum Creek. It is the receiving water for the McCleary wastewater treatment plant. A number of special studies and investigations were conducted on this creek between 1969 and 1987. Elimination of discharges from the Simpson Door plant and an upgrade of the McCleary WTP have eliminated most of the problems observed in previous studies. Kendra (1987) noted that excessive inputs of nitrogen and phosphorus had lead to eutrophication of the creek, which deserved further study. A TMDL was approved in 1993 for chlorine, fecal coliform, ammonia-N, and BOD. Following the plant upgrade and subsequent permit revisions, the previous water quality problems have been eliminated (Jennings, 1996).

Landuse Impacts on Water Quality

The Cloquallum Creek subbasin is predominated by forest which represents 89% of the landuse. Agriculture and urban activities represent only 3.2 and 2.0%, respectively. Earlier studies and TMDL implementation have reduced the previously identified sources of water quality degradation.

Data Gaps

In the 1970's, water quality data were obtained consistently for temperature, DO, pH, ammonia-N, TP, and fecal coliform, but only for one year for nitrate+nitrite-N; and no TSS data were obtained. Although this subbasin is small, water quality monitoring should be conducted to obtain data on current conditions.

Subbasin Conclusions

Current conditions are unknown. Water quality monitoring should be re-established at least on a rotating basis to ensure more adequate information on which to assess water quality. Such monitoring would ideally provide data for TP, IN, and TSS yield for comparative priority setting.

SUBBASINS 15 THROUGH 18. SATSOP RIVER AND TRIBUTARIES

The Satsop River drainage is comprised of four of the subbasins used in this study: the East Fork Satsop, Middle Fork Satsop, Decker Creek, and the Satsop River. The combined drainage of these four basins is 299 square miles. A long-term ambient water quality monitoring station is located 2.7 miles upstream of the confluence with the Chehalis River. The period of record at this station extends from October 1970 until September 1993.

Temperature generally met water quality standards, although occasional excursions have been documented (Figure C-31). Dissolved oxygen concentrations were above 8.0 mg/l for the period of record (Figure C-31).

The average TP concentration for the 1990's was 0.02 mg/l. This was the lowest concentration of any tributary to the mainstem. Only the Hoquiam River had a lower average TP concentration. The average inorganic nitrogen concentration was 0.24 mg/l, also the lowest of the rivers discharging directly to the mainstem.

Total suspended solids concentrations ranged from a wet season high of 840 mg/l to a dry season low of 1 mg/l. The maximum TSS concentration is higher than any of the other tributaries discharging to the mainstem and was exceeded only by the maximum TSS concentration of the Humptulips River. TSS loading was calculated based on instantaneous flows and is depicted in Figure C-32. Differences in wet and dry season TSS loadings were almost two orders of magnitude, indicative of high solids associated with precipitation events.

Fecal coliform concentrations were generally within the water quality standards for the period of record. The geometric mean of the fecal coliform concentrations in the early 1990's was substantially below the water quality standard at 15 cfu/100 ml, only one sample was over 100 cfu/100 ml. Prior to the 1990's, only three samples equaled or exceeded 100 cfu/100 ml. However, the Grays Harbor TMDL indicates that fecal coliform loading from the Satsop River is adding to the loading in the harbor (Pelletier, 2000). The TMDL recommended a 29% reduction in the load allocation from non-point sources in this basin.

Landuse Impacts on Water Quality

The Satsop River subbasin is dominated by forestlands, representing 95.3% of the landuse. The basin also supports agriculture a (2.2% of the landuse). Urban residential and commercial and industrial landuses combined only represent 0.3% of the basin. The high wet season TSS loading may be attributable to forest practices in the basin.

Data Gaps

The Satsop River subbasin does not have a long continuous record of water quality data. Monitoring should be continued on at least a rotational basis in this subbasin for all the conventional parameters discussed in this report. In addition, median monthly flow data should be developed to calculate TP, IN, and TSS yields. Such calculations would provide a technical basis for prioritization of actions to improve water quality.

Subbasin Conclusions

Ambient data indicate that water quality in the Satsop subbasin is in compliance with the water quality standards. Nutrient concentrations are generally lower than in other tributaries. However, TSS concentrations indicate the need for improvements during periods of high runoff. Forest practices may be the sources of these elevated loads. Specific source sites should be identified and practices to reduce pollutant loading should be implemented. The issue of fecal coliform allocation reductions should be further examined in light of the low concentrations indicated by the ambient monitoring data.

SUBBASIN 19. CHEHALIS RIVER LOWER REACH 1

This subbasin includes the stretch of the river which extends from Porter (river mile 33.3) to Satsop (river mile 20). No long term ambient water quality monitoring stations have been maintained in this river segment. However, the Montesano monitoring station is approximately seven miles further downstream. Results from that station are provided in the discussion of Subbasin 30.

SUBBASIN 20. WYNOOCHEE RIVER

Data from the Wynoochee River were available from an ambient monitoring station at river mile 13.6. Water quality data were obtained bi-monthly for water years 1972-1974 and 76-77. Water quality was generally good for the period of record, but may not represent current conditions. During the period of record, temperature exceeded the water quality criterion on only two sampling dates in July 1973 and September 1974. Dissolved oxygen was consistently above the water quality criterion.

Total phosphorus concentrations remained below 0.1 mg/l on all dates sampled, and averaged 0.026 mg/l. Ammonia-N averaged 0.07 mg/l over the period of record. Nitrate+nitrite-N measurements were obtained only on six dates during one water year and averaged 0.14 mg/l. TSS data were not obtained at this monitoring station. Fecal coliform levels were obtained only during the 76-77 water year. During that year, fecal coliform levels were well below the water quality criteria, ranging between 2 and 70 cfu/100 ml. The recently published TMDL for Grays Harbor did not recommend reduction of the fecal coliform load allocation in this subbasin (Pelletier, 2000).

Landuse Impacts on Water Quality

Landuse in this subbasin is dominated by forestland, representing 94.5% of the land cover. Agriculture represent 3.2% of the landuse, and only a minor amount of landuse comprised the urban and residential category (0.4%). The activities in this subbasin had not adversely affect water quality in the 1970's.

Data Gaps

No recent data were identified for this subbasin. The ambient monitoring station in this subbasin needs to be re-established to obtain recent water quality data. Collection of data should include consistent collection of the major water quality parameters discussed in this study.

Subbasin Conclusions

Conclusions about the current water quality conditions cannot be determined because no recent data were available. Re-establishment of a monitoring station is recommended to provide an understanding of current water quality conditions.

SUBBASIN 21. WISHKAH RIVER

Data for the Wishkah River are minimal and not recent. Water quality and flow data were gathered at an ambient station at river mile 12.3 for water year 1976-77. Temperature, dissolved oxygen, pH, total phosphorus, and ammonia-N data were gathered in water years 72-73 and 73-74. Water quality in the Wishkah River was relatively good in the 1970's. Temperature exceeded the water quality criterion only on one sampling event in the three years of collected data. Dissolved oxygen remained high. The TP ranged from 0.02 mg/l to 0.11 mg/l and averaged 0.02 mg/l. Ammonia-N concentrations ranged from 0.02 to 0.09 mg/l and averaged 0.04 mg/l as N. Nitrate+nitrite-N data were not collected. TSS data were not collected. Fecal coliform data were collected only for water year 76-77 and exceeded 100 cfu/ 100 ml on one occasion. The geometric mean for the year was 19.4 cfu/100 ml. However, the recently published TMDL for Grays Harbor (Pelletier, 2000) indicated that fecal coliform from the Wishkah River was one of the more significant contributors of fecal coliform loading to the harbor. A reduction in the load allocation for this tributary of 62% was recommended.

Landuse Impacts on Water Quality

Landuse in this subbasin is dominated by forestland, which represents 91% of the land cover. Wetlands represent 3.2% of the landcover, which is greater than the 1% in agricultural use and 2.1% in urban residential use.

Data Gaps

The ambient monitoring station in this subbasin needs to be re-established to obtain recent water quality data. Collection of data should include the inorganic nitrogen species of nitrate+nitrite-N, and TSS for which there were no data gathered previously.

Subbasin Conclusions

There are not recent data and limited historical data on the Wishkah River subbasin. The recent TMDL, however, indicates the need for fecal coliform reductions from non-point sources. However, given the very low bacteria concentrations measured at this site, this reduction goal needs to be re-examined. Future actions in this basin should focus on re-establishing ambient water quality monitoring and identifying and reducing the sources of fecal coliform contamination.

SUBBASIN 22, 23, AND 24. HOQUIAM RIVER

The subbasins the East Fork, Middle Fork, and Hoquiam Rivers are represented by the ambient station at river mile 9.3 on the West Fork Hoquiam River. Although this station is below the confluence of the Middle Fork Hoquiam, and above the confluence with the East Fork Hoquiam River, it represents the best available data. Some water quality data were gathered at this monitoring station bi-monthly in water years 1972 through 1974, and monthly in water year 1993-1994.

Water quality in this subbasin is very good. Temperature, dissolved oxygen, and pH met or exceeded the water quality criteria established for a Class A stream. Total phosphorus data were gathered during all sampling events. Total phosphorus ranged between 0.01 and 0.14 mg/L and averaged 0.02 mg/l, which is well below recommended levels. They were lower than any other subbasins in this study.

Ammonia-N concentrations were also low ranging from 0.01 to 0.07 mg/l as N. Ammonia-N averaged 0.02 mg/l as N in water year 93-94. Nitrate+nitrite-N were measured in the 93-94 water year and averaged 0.13 mg/l as N. IN concentrations were lower in the Hoquiam River than in any other subbasin, except the Humptulips River.

TSS concentrations were very low ranging between 1 and 4 mg/l and averaging 2 mg/l during water year 93-94. TSS load was also lower than in any other river within the watershed (Table C-8).

Fecal coliform data were obtained only during the 93-94 water year. Results indicated extremely low fecal coliform. The geometric mean of all months was 10.2 cfu/100 ml and did not exceed 51 cfu/100ml. However, the recently released fecal coliform TMDL for Grays Harbor indicates that fecal coliform from the Hoquiam contributes adversely to the quality of the harbor (Polluter, 2000). The TMDL recommended a 58% reduction in load allocation near the mouth and load allocations reduction of 37% and 14% for the West Fork Hoquiam River and East Fork Hoquiam River, respectively.

Landuse Impacts on Water Quality

This subbasin is less highly forested that its adjacent subbasin, the Humptulips, with 88.9% of the land categorized in forestlands. Much of this land was and continues to be actively logged. Wetlands represent the second highest category of landuses, comprising 5.4% of the subbasin. Agricultural uses are minimal, and represented only as range land (0.2%). Urban landuses comprise approximately 3%, combining urban residential and commercial and industrial landuses.

Data Gaps

Although this basin does not have a long continuous record of water quality data, monitoring has been conducted in the early 1990's. Monitoring at the ambient station should be updated and should be continued on at least a rotational basis in this subbasin for the parameters discussed in this report.

Subbasin Conclusions

Water quality at the Hoquiam River monitoring station was within the water quality standards, and nutrient levels were among the lowest measured. However, fecal coliform within the Hoquiam subbasin has been identified as a contributor to the degraded conditions of Grays Harbor. However, given the very low bacteria concentrations measured at this site, this reduction goal needs to be re-examined. Monitoring at the ambient station should be continued at least on a rotating basis and median monthly flows should be derived to calculate TP, IN, and TSS loads and yields.

SUBBASIN 25. HUMPTULIPS RIVER

The water quality monitoring station on the Humptulips River is at river mile 23.6 representing approximately 130 square miles of the 244 square mile drainage. Data have been gathered at the ambient water quality monitoring station since the early 1970's, providing a nearly continuous record for most of the water quality parameters of interest. Early in the record, data were gathered bimonthly from 1971 through 1974. The record was interrupted from 1974 until 1979; thereafter, water quality data were obtained on a monthly basis.

Water quality standard exceedances have occurred in the Humptulips River. The temperature at the monitoring station is generally less than the 18^{o}C criterion, but excursions are not uncommon (Figure C-33). An apparent downward trend in the 1990's is indicated in the figure by the 12-month moving average. Farther upstream in the watershed a TMDL to reduce stream temperature is being undertaken as part of a collaborative watershed analysis (Dieu, pers. comm.).

Dissolved oxygen at the monitoring station has consistently been above the Class A water quality criterion of 8.0 mg/L (Figure C-33).

Total phosphorus concentrations varied seasonally with wet season events producing higher TP concentrations. The mean TP concentration in the 1990's was 0.02 mg/l with peak concentrations as high as 0.29 mg/l and low concentrations at 0.004 mg/l. The average concentration is lower than those found in other subbasins with recent data, except for the Hoquiam River. TP loading based on instantaneous flows is plotted for the period of record in Figure C-34. Seasonal variations are large; the average wet season TP loading was more than 14 times that of the dry season during the 1990's (Table C-8). Average annual TP yield for the 1990's was 0.20 tons/year-mi^2, the highest of all the station in the Chehalis River system for which TP yields were calculated (Table C-4 and C-8). However, this yield may be an artifact of the extremely high wet season flows.

Ammonia-N was monitored throughout most of the period of record. More recently (during the 1990's), ammonia-N concentrations averaged 0.01 mg/l and ranged as high as 0.04 mg/l. Recent nitrate+nitrite-N concentrations ranged from the detection limit (0.01 mg/l) to 0.34 mg/l and averaged 0.11 mg/l. Average annual inorganic nitrogen yield for the 1990's was 1.15 tons/year-mi^2, lower than the Newaukum River and lower than the other Chehalis mainstem stations. The average annual IN yield for the upper portion of this watershed was within the range reported by Embry and Inkpen (1998) (Table C-5).

TSS concentrations in the 1990's data set at this monitoring station ranged from 1 mg/l to 344 mg/l showing wide variations with season. The TSS loading based on instantaneous flows is depicted for the period of record in Figure C-34. While TSS loading appears to decline with time, no statistical differences were found. The TSS yields provided in Table C-8 indicated that the Humptulips River had the highest TSS yield of any of the tributaries to the Chehalis River system.

Fecal coliform data also show wide seasonal variations (Figure C-35). There are many exceedances of the 100 cfu/100 ml standard, but few excursions over the 200 cfu/100ml criterion. The geometric mean for data gathered in the 1990's was 8 cfu/100 ml, while for the entire period of record, the geometric mean is 7 cfu/100 ml. Although fecal coliform levels at the monitoring station were low, fecal coliform loading from this river was determined to represent the most significant impact to Grays Harbor, second only to the mainstem of the Chehalis River (Pelletier, 2000). The TMDL requires a 67% reduction in load allocation from non-point sources in this basin.

Landuse Impacts on Water Quality

This subbasin is highly forested with 95.7% of the land categorized in forestlands. Only subbasins 2 (Elk Creek) and 12 (Cedar Creek) have higher percentages of forestlands. Agricultural and urban landuses comprise less than 2% combined. Much of this land was and continues to be actively logged. Removal of trees and development and use of logging roads may contribute to this subbasin having the highest TSS yield of all the segments of the Chehalis River system. The elevated TP yield may be a consequence of the elevated TSS; phosphorous is often sorbed to particulates in freshwater systems.

Data Gaps

This river has a long continuous record of water quality data from a station in the central portion of the subbasin. This station should be maintained and continue to be monitored.
As resources allow water quality in the lower basin could be monitored on a rotational basis.

Subbasin Conclusions

Water quality in the Humptulips, has been adversely affect by human activities, predominantly logging. In the Upper Humptulips a temperature TMDL is in progress. The elevated TSS yield in this subbasin indicates that logging activities may be degrading water quality. Because this subbasin had the highest TSS yield of any of the Chehalis River tributaries, it should be a high priority for implementing BMPs that will reduce the TSS load. TP yield was also highest among those stations analyzed, but may be an artifact of the extremely high wet season flows. This hypothesis needs to be investigated. Because fecal coliform loading from this river represents a significant impact to Grays Harbor, sources should be identified and eliminated.

SUBBASINS 26 THROUGH 29 - ELKS RIVER, JOHNS RIVER, NEWSKAH CREEK, AND CHARLEY CREEK

No water quality data were identified from these subbasins

SUBBASIN 30 CHEHALIS RIVER - LOWER REACH 2

An ambient water quality monitoring station is maintained on the mainstem at river mile 13.15 near Montesano. This station represents the water quality in the stretch below the confluence with the Satsop River, but just above the confluence with the Wynoochee River at river mile 13. Water quality at this station is somewhat influenced by the estuary, but best represents the cumulative effects of upstream activities. This station was monitored once or twice a month from November 1970 until September 1971, then monthly from October 1977 until September 1992. Generally consistent data are available for temperature, dissolved oxygen, and pH. TP and TSS samples were collected somewhat less continuously; flow, nitrogen species, and fecal coliform data were collected sporadically. In the subsequent discussions, data are presented as individual measurements in figures, and as wet season, dry season, and annual averages over the last decade.

The temperature and dissolved oxygen for the '77 to '92 period of record are plotted in Figure C-36. Numerous exceedances of the Class A water quality criterion for temperature are evident from the figure. Dissolved oxygen, however, did not decline to less than the 8.0 mg/l criterion during the same period (Figure C-36).

Total phosphorus concentrations are depicted graphically in Figure C-37. It is noteworthy that the concentration of TP varied over one and a half orders of magnitude, averaging 0.045 mg/l, but peaking at 0.17 mg/l. TP loadings and yields were calculated based on the median monthly flow (50% exceedance flow). Wet season TP loading (3,779 lb/day) was higher than any other mainstem station (Table C-4). Dry season TP loading was also higher at the Montesano station (Table C-4). The TP yield was calculated assuming that half of Subbasin 30 drainage was represented at this station. The average annual TP yield was 0.18 tons/year-mi^2, which represents the highest mainstem yield. This yield compares favorably with the lower TP yields found for the major rivers systems in Puget Sound by Embry and Inkpen (1998) (Table C-5).

Results of monthly samples of ammonia-N concentrations are also depicted in Figure C-37. As with TP, ammonia-N is quite variable. Average ammonia-N and nitrate+nitrite-N were within the range of other mainstem stations. The average annual IN yield is higher than any other upstream station and is slightly higher than the range reported by Embry and Inkpen (1998) (Tables C-4 and C-4).

TSS concentrations in the 1990's ranged between 1 and 131 mg/l and averaged 14 mg/L. Wet and dry season TSS yields were determined for the most recent data. Wet season yield was approximately three times the dry season yield (Table C-6). Average annual TSS yield was calculated to be 48 tons/year-mi^2, similar to that estimated for the Porter station.

Fecal coliform samples were obtained on most sampling dates between 1977 and 1992. While the geometric mean was less than the criterion, numerous exceedances of the 100 cfu/100 ml standard were evident over the 1977 to 1992 sampling period (Figure C-38).

Landuse Impacts on Water Quality

Urban landuse comprises a relatively high percentage (10.5%) of the subbasin immediately surrounding the ambient monitoring station, with forestlands representing only 58.8%. However, because water quality at this station represents the cumulative impacts of all activities upstream, landuse in the entire basin above this station important. Forestland comprises the largest percent of the landuse in the basin at 82.7%, with agricultural uses only representing an average of 10.7% of the use and urbanized areas representing less than 2% of the area.

Data Gaps

Water quality monitoring at the Montesano station was relatively complete until the early 1990's. Monthly monitoring at this station should be re-established to evaluate efforts to improve water quality throughout the watershed. Establishment of a USGS monitoring station coincident with the water quality monitoring station would assist in data analysis.

Subbasin Conclusions

Exceedances of the water quality standard have been observed in this subbasin for temperature and fecal coliform. In addition, nutrient yields were higher than other mainstem stations. Because this subbasin represents the cumulative impacts of all the upstream subbasins, activities to improve water quality in those subbasins should improve the water quality in this subbasin as well. However, sources of evaluated fecal coliform, total phosphorus, and inorganic nitrogen within the drainage surrounding the station could include stormwater from urban areas, septic systems, and agricultural runoff. Specific sources should be identified and eliminated.

WATER QUALITY IMPAIRMENT UNDER CWA

Water quality is impaired in the Chehalis River watershed. Under the Clean Water Act (CWA), WDOE biennially publishes a state-wide list of all water bodies that have impaired water quality, commonly referred to as the 303(d) list. Water quality is impaired in 25 segments of the Chehalis River watershed (Table C-11). The most prevalent cause of impairment is elevated fecal coliform levels. Nineteen of the segments are listed as impaired for this reason. Low summer dissolved oxygen concentrations and elevated summer temperatures have resulted in the listing of 11 and 9 segments, respectively.

Table C-11. 303(d) Listed Water Segments in the Chehalis River Watershed

Water body Segment No.	Name	Subbasin #	Parameters Violating Water Quality Standards			
			Fec. Coli.	DO	Temp.	Other
WA 23-1108	Elk Creek	2	x			
WA 23-1106	South Fork Chehalis River	3	x		x	
WA 23-1104	Bunker Creek	4	x	x		
WA 23-1102	Stearns Creek	4		x		
WA 23-1100	Chehalis River	4	x	x	x	
WA 23-1080	Newaukum River, North Fork	6	x			
WA 23-1070	Newaukum River	7	x		x	
WA 23-1028	Berwick Creek	10	x			
WA 23-1027	Dillenbaugh Creek	10	x	x	x	
WA 23-1024	Coal Creek	10	x	x		
WA 23-1023	Salzer Creek	8	x	x		
WA 23-1020	Chehalis River	10	x	x	x	
WA 23-1019	Lincoln Creek	10		x		
WA 23-1018	Scatter Creek	13	x		x	
WA 23-1017	Independence Creek	13		x		
WA 23-1014	Garrard Creek	13		x		
WA 23-1015	Black River	11	x	x	x	
WA 23-2021	Littlerock Ditch	11	x			
WA 23-2020	Beaver Creek	11	x			
WA 23-2010	Mima Creek	11	x			
WA 22-4040	Chehalis River	19	x		x	
WA 22-1010	Humptulips River	25	x		x	
WA 22-9030	Duck Lake	30				TP
WA 22-0030	Inner Grays Harbor	30	x			pH

POINT AND NON-POINT SOURCES OF POLLUTANT LOADING

NPDES permitted discharges within the basin were provided from the Water Permit Life Cycle Permit System (WPLCS) database. These are listed with locations in Table C-12. Based on permitted limits and assumptions made by Embry and Inkpen (1998), the total phosphorus loadings from NPDES permits to the mainstem at Porter and Montesano were calculated. The median total phosphorus concentration estimated for municipal wastewater treatment plants in Puget Sound of 4.2 mg/l (Embry and Inkpen, 1998) was applied to the average design flow from WPLCS to calculate loading contributions of municipal plants. Loadings were summed for discharges above the Porter station and above the Montesano station. The cumulative permitted TP loading to mainstem at Porter is 377 lb/day. While this represents only 13% of the wet season TP loading, it represents more than 100% of the average dry season TP loading. Similarly, at Montesano, the cumulative TP loading from the municipal and industrial wastewater treatment plants is 427 lb/day (16% of the total wet season load and almost three times the dry season load). These NPDES contributions to the TP loads represent the potential for plants discharging at design capacity year-round and over estimate actual contributions. They were calculated based on discharging at design capacity and regional median concentrations. Despite this caveat, a more accurate evaluation of cumulative TP loading may be useful in improving water quality of the river, which is generally phosphorus limited (Pickett, 1994a).

Table C-12. Municipal and Industrial NPDES Dischargers to Chehalis Basin and Estimated, Permitted TP Loading

Facility Name	WRIA	Latitude	Longitude	Flow (MGD)	TP (mg/l)	TP Load (lb/day)
Municipal						
Pe Ell STP	23	46° 43'38"	123°18'7"	0.12	4.2[a]	4.0
Cedar Creek DOC STP	23	46°53'1"	123°8'20"	0.07	4.2[a]	2.4
Centralia TP	23	46° 42'47"	122°58'34"	4.3	4.2[a]	150
Chehalis STP	23	46° 39'38"	122°59'2"	2[c]	4.2[a]	69.9
Ground Mound STP	23	47° 47'17"	123°1'57"	0.07	4.2[a]	2.4
McCleary STP	22	47° 3'18"	123°16'29"	0.75	4.2[a]	26.2
Elma STP	22	47° 0'2"	123°25'22"	0.33	4.2[a]	11.5
Montesano STP	22	46° 52'55"	123°36'3"	0.36	4.2[a]	12.6
Aberdeen STP	22	46° 57'57"	123°49'35"	8.75	4.2[a]	306
Hoquiam STP	22	46° 58'20"	123°55'19"	4	4.2[a]	140
Ocean Shores STP	22	46° 55'56"	124°9'28"	2.2[c]	4.2[a]	75.2
Westport STP	22	46° 54'23"	124°7'0"	1	4.2[a]	35.0
Industrial						
Lewis Co. Water Dist. 2	23	46° 34'23"	122°43'44"	0.08	ND	NC
Trans Centralia Generation	23	46° 45'21"	122°51'39"	4.82	ND	NC
Trans Centralia Mining	23	46° 45'32"	122°45'32"	NL	ND	NC
Domsea Rochester	23	46°49'23"	123°0'11"	3.86	ND	NC
NW Seafarms Black River	23	46° 50'29"	123°7'29"	3.77	4.2[a]	131.8
Gull Industries	23	46° 58'55"	123°53'12"	<0.01	ND	NC
Associated Seafoods Co.	22	46°57'5"	124°48'0"	0.22	ND	NC
Meroins Seafood	22	46°54'22"	124°6'28"	0.32	4.2[a]	7.6
Ocean Spray Markham	22	46°54'15"	123°59'50"	0.03	ND	NC
Quality Veneer & Lumber	22	47°0'0"	123°54'17"	0.03	ND	NC
Washington Crab	22	46° 54'30"	124°6'56"	0.17	ND	NC
Washington Crab & Bottomfish	22	46° 54'24"	124°26'27"	0.13	ND	NC
Westfarm Foods	22	46° 39'54"	122°58'32"	0.48	11.5[av]	45.9

a = assumption based on data of Embry and Inkpen (1998)
av = average limit
NC = No calculation able to be made
ND = No data
NL = No limit

Recognized non-point sources of pollution to the watershed include agricultural and forest practices, urban stormwater, and failing septic systems (Pickett, 1994a). Landuse within the basin is dominated by forestlands (82.7%). Logging activities in these areas can contribute suspended solids to the streams. The high TSS yield in the Humptulips subbasin is likely associated with such activities. This subbasin is dominated by forestlands (representing more than 95% of the landuse) which are heavily logged. Logging may also contribute to the elevated TSS yield in the Chehalis headwaters (above Dryad), which is approximately 95% forestlands and moderately heavily logged.

Intensive agricultural activities have been recognized contributors of fecal coliform, BOD, TP, and nitrogen loading to the mainstem and a number of tributaries. The high TP and IN yields at Montesano may be attributed to agricultural practices in the basin between Porter and Montesano. Likewise the elevated IN yield of the Newaukum River may be attributable, in part, to agricultural activities. Agricultural activities represented 17% of the landuse in this subbasin.

Water quality in the Black River, which is also agricultural (agricultural represents 20% of the landuse) had the highest average TP concentration. The Black River also had the highest maximum levels of fecal coliform, which can be attributed to agricultural as well as other activities.

Urbanized areas represent less than 2% of the watershed to its interception with estuary waters at Montesano. Urban activities can increase the suspended solids and TP and IN loading to the river. The TMDL in the Upper Chehalis (WRIA 23) identified the need to reduce ammonia-N and carbonaceous BOD from stormwater by 100% (Pickett, 1994a). In urbanized areas without municipal sewers, failing septic systems can result in fecal coliform and nitrate loading of a stream segment. Both the Black River and Upper Chehalis TMDLs (Coots, 1994 and Pickett 1994a&b) identified fecal coliform loading from urban and rural-residential landuses, such as failing septic systems, stormwater, and farming activities (hobby farms).

DATA GAPS AND LIMITATIONS

While the Chehalis River watershed is one of the more highly monitored basins in Washington, water quality data do not comprehensively represent all subbasins across the watershed. A number of the subbasins lack ambient water quality monitoring stations. These include the subbasins of the south shore of Grays Harbor (Elks River, Johns River, Newskah Creek, and Charley Creek), Cedar Creek, and Salzer Creek. Ambient monitoring stations are present in the other major river tributaries to the Chehalis, although a number of the tributaries to these subbasins are absent. For example, Decker Creek and the Middle Fork Satsop River, Middle and East Fork of the Hoquiam, and the North and South Forks of the Newaukum River have not water quality monitoring stations. Thus, water quality cannot be characterized in each of the subbasins.

In some of the subbasins, water quality data are sporadic and/or may not represent current conditions. For example, ambient monitoring station data have not been collected from the Wynoochee and Wishkah rivers since the 1970's. These stations should be re-established.

Likewise, monitoring at the Montesano station on the mainstem Chehalis River was interrupted in 1992. This station is particularly critical as it represents the cumulative impacts of activities upriver of most of the tidal influence.

Samples that were taken were not consistently analyzed for all of the major water quality parameters, most often TSS and nitrate+nitrite-N were omitted. Similarly, data needed to calculate loading were not always obtained simultaneously. If no USGS gage station exists in the vicinity from which median monthly flows (50% exceedances) could be calculated, yield comparisons among subbasins cannot be made. Both of these situations are evidenced in the time series figures presented in this study. For ambient stations in which sampling efforts have continued, the water quality parameter list has been augmented to include the formerly missing analyses. For example, TSS and the inorganic nitrogen species that were often lacking in past data collection efforts, have become more routine analyses in the past decade.

The water quality data collected is primarily in the form of “grab” samples that represent one point in time and not necessarily the range of conditions. Data sets with longer periods of record generally compensate for this lack. However, for parameters that experience a critical seasonal or diurnal fluctuation, data may be missing during periods of greatest concern. Data may also be missing during storm events, which would be useful for identifying specific problem times and areas.

Despite the data gaps and limitations, the trends observed in the basin are useful for prioritizing actions and accompanying verification monitoring to demonstrate improvements.

RECOMMENDATIONS

Water quality in the Chehalis River and its tributaries is impaired and has been recognized as such in numerous studies beginning in the early 1980's. Temperature and dissolved oxygen exceedances of water quality standards are common along the mainstem and tributaries from the headwaters to the Montesano station. Dissolved oxygen concentrations have been reduced by oxygen depleting pollutants (carbonaceous BOD and ammonia-N) along the mainstem and in tributaries above the Porter station. Contributions of TP and inorganic nitrogen, nutrients that limit the overabundance of algae and aquatic macrophytes, have been recognized here and elsewhere as contributors to the eutrophication of the Chehalis River stream segments. The information gathered and analyzed in this report is summarized in the subsequent narrative text in tabular form by subbasin in Table C-13.

Elevated temperatures, including exceedances of the water quality criteria, have been identified in the tributaries and along the mainstem above Porter. While the TMDL addresses the issue of temperature with broad increased shading recommendations, the details of implementing temperature improvement activities is left to the Chehalis Basin Partnership. Those subbasins and river segments requiring the highest percentage increase in shading should be prioritized for earliest action. In developing the Detailed Implementation Plan, the CBP may want to carefully consider the improvements of increased shading of the mainstem will provide. Due to the river's width, shading resources may be better focused along the tributaries. As the Humptulips TMDL comes to completion, its recommendations also should be implemented on a priority basis.

Table C-13. Summary of Parameters Evaluated and Next Actions Identified by Subbasin

Subbasin	Location	Temp	DO	TP	IN	TSS	FC	Yield	Mon./Gage	Next Actions
Mainstem										
1	Dryad	TMDL	TMDL	M*	L*	M*	V			I&C (TSS)
4	Claquato	TMDL	TMDL	H	M	M	V	N	UR	Calc Yields; I&C (TP, BOD, FC)
10	Centralia	TMDL	TMDL	H	H	M	V	N	UR	Calc Yields; I&C (TP, BOD, IN, FC); Shade
10	Prather Rd.	TMDL	TMDL	L*	L*	M*	V		U	I&C (BOD, FC); Shade
13	Porter	TMDL	TMDL	L*	M*	M*	V			I&C (BOD, FC); Shade
30	Montesano	V	C	M*	H*	M*	V		**U**	I&C (IN, FC)
2	Elk Creek	TMDL	TMDL	L	L	L	V	N	ER/G	Establish Monitoring
Tributaries										
3	S. Fork Chehalis	TMDL	TMDL	M	H	M	V	N	U	Calc Yields; I&C (IN); Shade
5-7	Newaukum	TMDL	TMDL	L*	H*	L*	V		U	I&C (IN); Shade
8	Scatter Creek	TMDL	TMDL	H	H	NI	V		ER	Control sources
9	Skookumchuck	TMDL	TMDL	M	H	L	V	N	U	Calc Yields; I&C (IN, FC)
11	Black	TMDL	TMDL	M	NI	L	V	N	U/G	Gage; I&C (TP, BOD, FC)
12	Cedar Creek	C	C	L	L	NI	C	N	E/G	Establish Monitoring
15-18	Satsop	C	C	L	L	M	V	N	U	I&C (FC)
20	Wynoochee	NI	NI	NI	NI	NI	C	N	**U**	Update Monitoring
21	Wishkah	NI	NI	NI	NI	NI	V	N	**U**	Update Monitoring; I&C (FC)
22-24	Hoquiam	C	C	L	L	L	V	N	UR	I&C (FC)
25	Humptulips	TMDL	C	M*	L*	H*	V			I&C (TSS, FC)
26	Elks River	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring
27	Johns River	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring
28	Newskah Creek	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring
29	Charley Creek	NI	NI	NI	NI	NI	NI	N	E	Establish Monitoring

NOTES:

TMDL = violations to be addressed per TMDL;
C = in compliance with standard;
V = violation of water quality standard;
H, M, L = high, moderate, low pollutant concentration, asterisk (*) indicates assessment based on yield;
N = yields based on monthly 50% exceedance flows need to be calculate;
E = establish monitoring;
ER = Establish monitoring on rotating schedule;
U = Update monitoring (if bold **U**, high priority);
G = USGS flow gage needed;
NI = no information;
I&C = Identification and control;
UR = Update monitoring on rotating schedule.

Dissolved oxygen concentrations of less than 8.0 mg/l are associated with elevated summer temperatures, as well as carbonaceous BOD and ammonia-N loading in WRIA 23. The TMDL has identified the need for point and non-point source controls and in some instances identifies specific point sources and non-point activities that will require control. Table C-13 summarizes the subbasins in which identification and controls are needed. For non-point sources, a collaborative effort among state and local entities will be required to effectively reduce pollutant loading.

Other than the Black River, there were no tributaries where both temperature and dissolved oxygen did not meet standards. However, this combination of high temperatures and low DO's existed throughout most of the mainstem of the river. This represents a critical set of conditions for fish health and survival.

The comparisons of pollutant yields at four mainstem stations and two tributaries can serve as a prioritization scheme on which to focus resources for actions that will reduce pollutant loading. TP yields were highest at the Montesano station on the Chehalis mainstem and in the Humptulips River. Although these yields were within the lower end of the range reported by Embry and Inkpen (1998), actions to identify and control sources in these drainages could prevent further degradation. Inorganic nitrogen yields were higher than the Embry and Inkpen ranges at the Montesano and Porter stations along the mainstem and in the Newaukum River. Ammonia-N loading has already been identified as one of the oxygen depleting pollutants of concern in the Upper Chehalis, above Porter (Pickett, 1994a), but elevated nitrogen yields in the Newaukum and along the mainstem drainage between Porter and Montesano could be used to focus resources in those two areas initially. Finally, TSS yields were substantially higher in the Humptulips River and somewhat elevated above Dryad. These results coupled with the 303(d) listing of many stream segments in the upper and lower basin indicate that actions to reduce pollutant loading are needed.

While data gaps exist in a number of subbasins, these gaps do not preclude implementation of water quality improvement activities. Trends observed in the basin are useful for prioritizing actions necessary to improve water quality. Thus, recommendations for a Level 2 watershed assessment are divided into three categories. First, TP, IN, and TSS yields should be calculated based on monthly 50% exceedance flows or estimated from available data. Second, a comparison of the yields among subbasins should be used to prioritize subbasins for identification and control of pollutant sources. The subbasins with the highest pollutant yields and identified sources (e.g. identified non-point sources in the TMDLs), activities to reduce pollutant loading should be undertaken. For example, in the Humptulips subbasin where TSS yield was substantially higher than other basins, resources should focus on reducing these pollutant sources. Actions identified in the TMDL recommendations should also be focused on those subbasins with the greatest yields. Where a problem has been identified in numerous previous studies (e.g., specific pollutant sources in Scatter Creek), actions should be assigned and implemented as soon as feasible. This is an adaptive management strategy that would focus resources on basins of more degraded water quality, while conducting targeted monitoring where no (or outdated) data exist.

An outcome of the Grays Harbor bacteria TMDL was recommendation for FC bacterial load reductions in rivers that already have quite low bacteria concentrations. These recommendations should be examined against other watershed priorities.

Monitoring should include the subbasins that discharge to the south shore of Grays Harbor, as well as updating water quality data for the Wynoochee and Wishkah Rivers. The Wynoochee and Wishkah Rivers may be more affected by human activities, making them a higher priority for monitoring. While the south shore subbasins are not highly developed, obtaining at least a minimal amount of baseline data is advisable. This targeted approach would ensure that basins with higher pollutant yields specified in this study are appropriately identified and prioritized for action. Where activities are implemented to improve water quality, follow-up monitoring should be conducted to ensure that actions resulted in the anticipated improvements and that water quality improvements are documented.

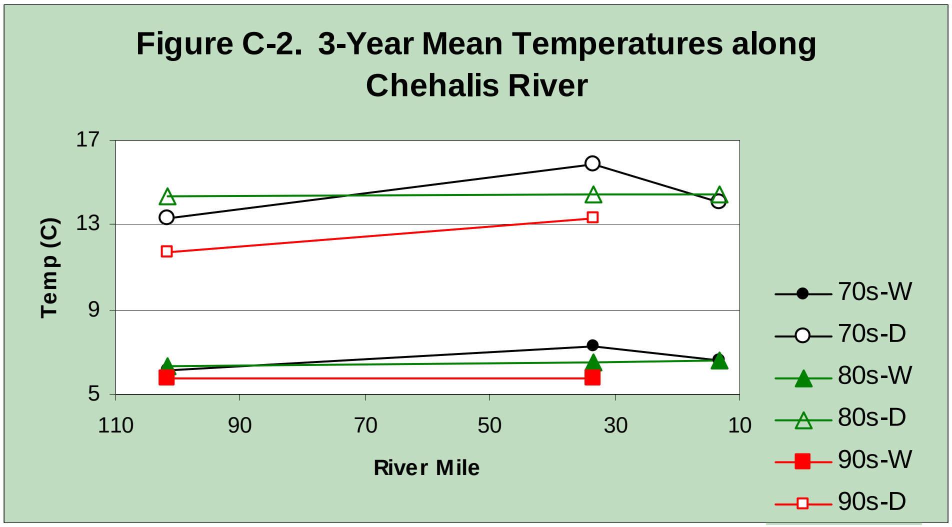


Figure C-2. 3-Year Mean Temperatures along Chehalis River
Temp (C)
17
13
9
5
110
90
70
50
30
10
River Mile
70s-W
70s-D
80s-W
80s-D
90s-W
90s-D

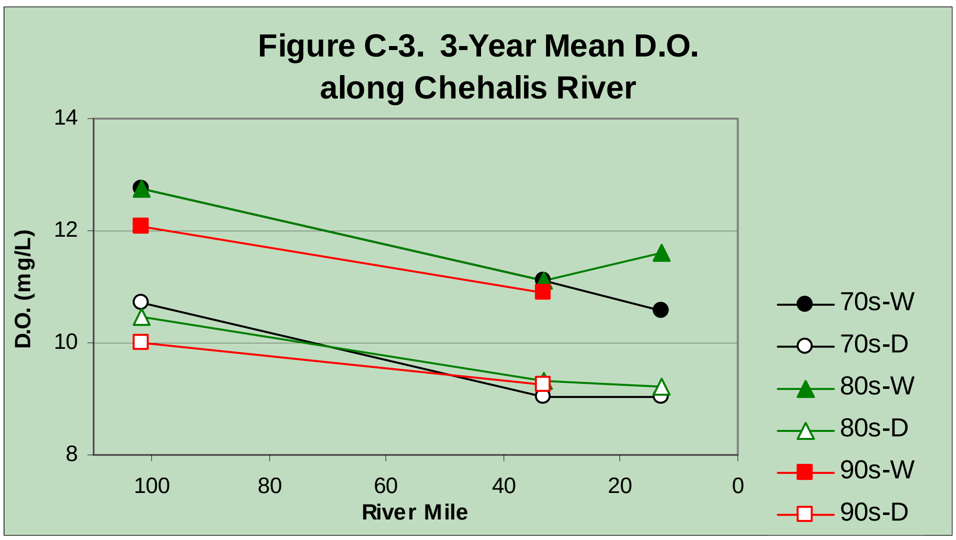


Figure C-3. 3-Year Mean D.O. along Chehalis River
D.O. (mg/L)
14
12
10
8
100
80
60
40
20
0
River Mile
70s-W
70s-D
80s-W
80s-D
90s-W
90s-D

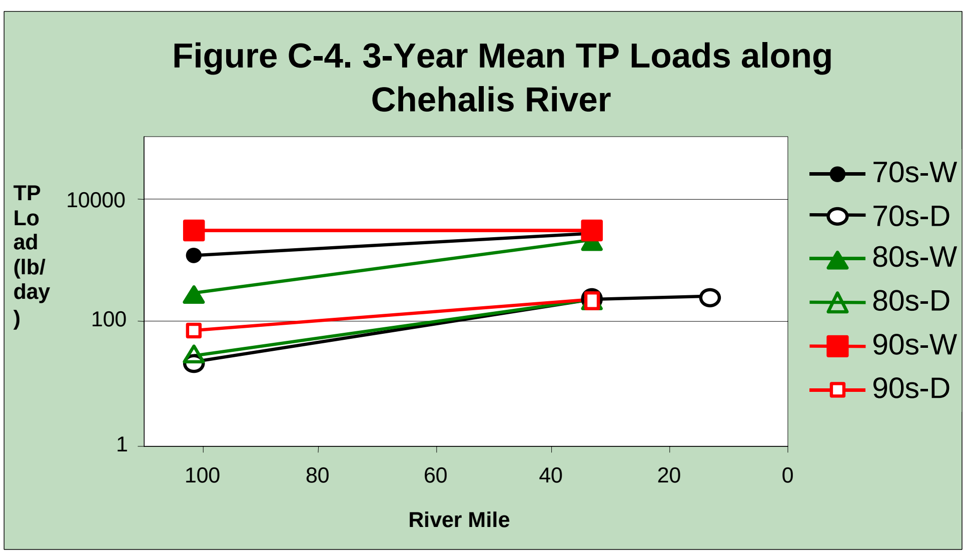


Figure C-4. 3-Year Mean TP Loads along Chehalis River
TP Load (lb/day)
10000
100
1
100
80
60
40
20
0
River Mile
70s-W
70s-D
80s-W
80s-D
90s-W
90s-D

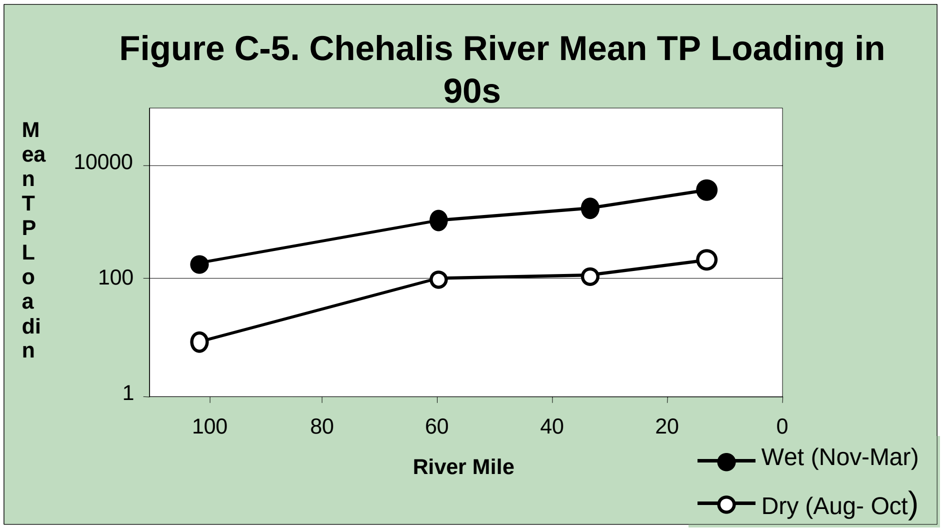


Figure C-5. Chehalis River Mean TP Loading in 90s

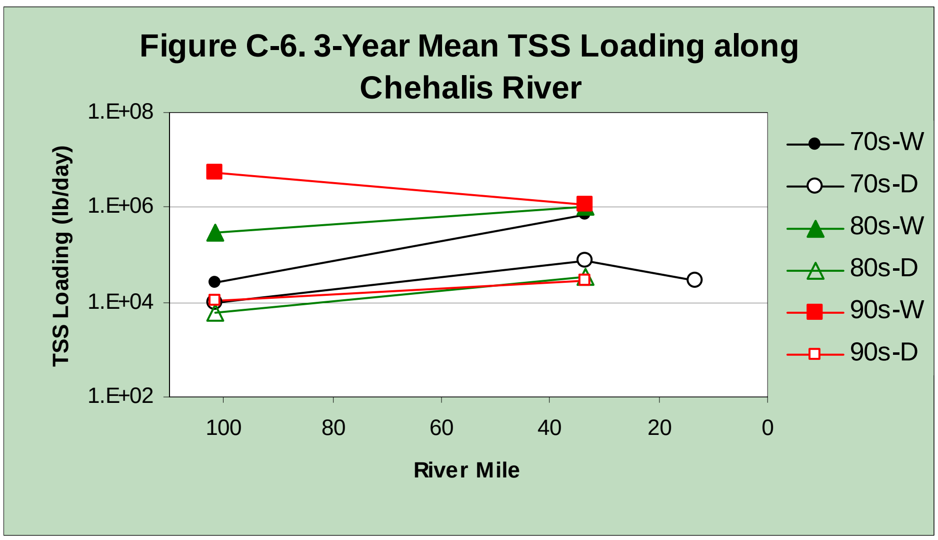


Figure C-6. 3-Year Mean TSS Loading along Chehalis River

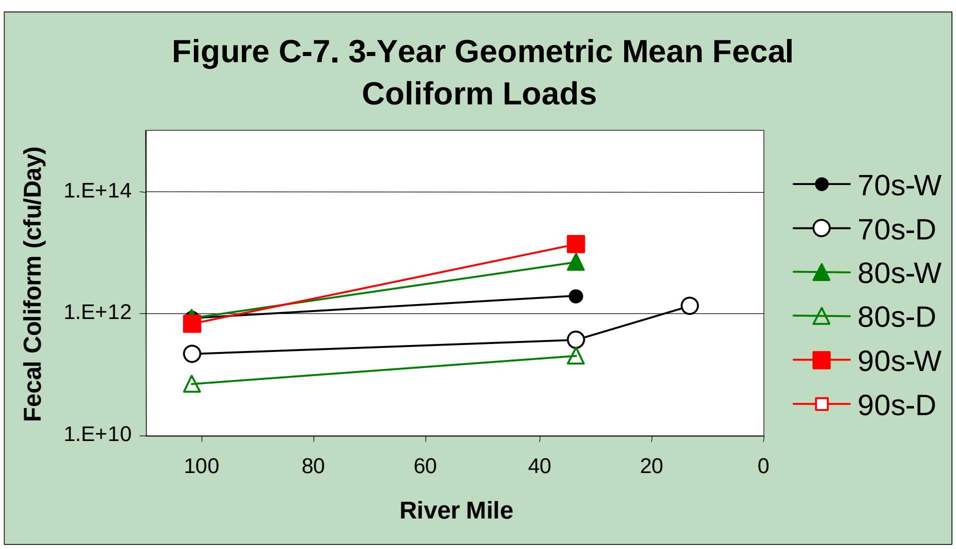


Figure C-7. 3-Year Geometric Mean Fecal Coliform Loads

Figure C-8. Chehalis at Dryad
Temperature & D.O.

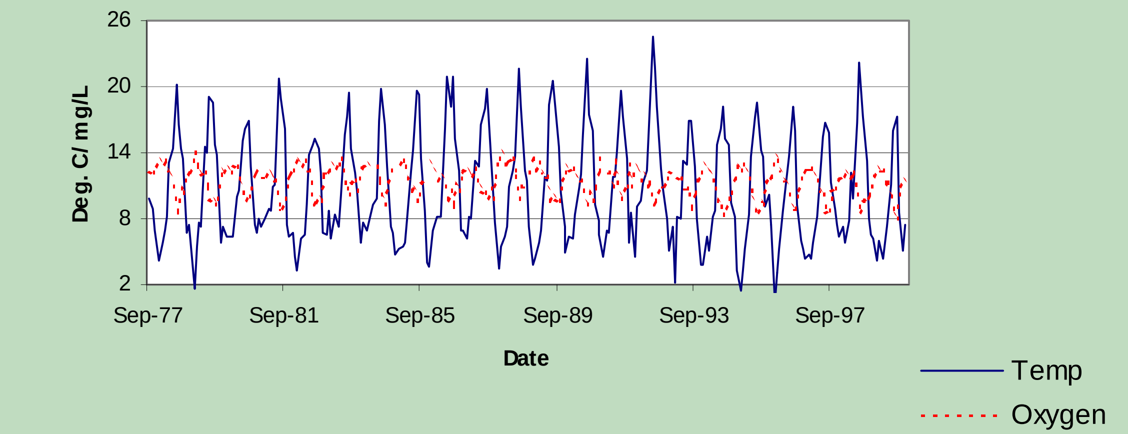


Figure C-9. Chehalis at Dryad
TP Loading

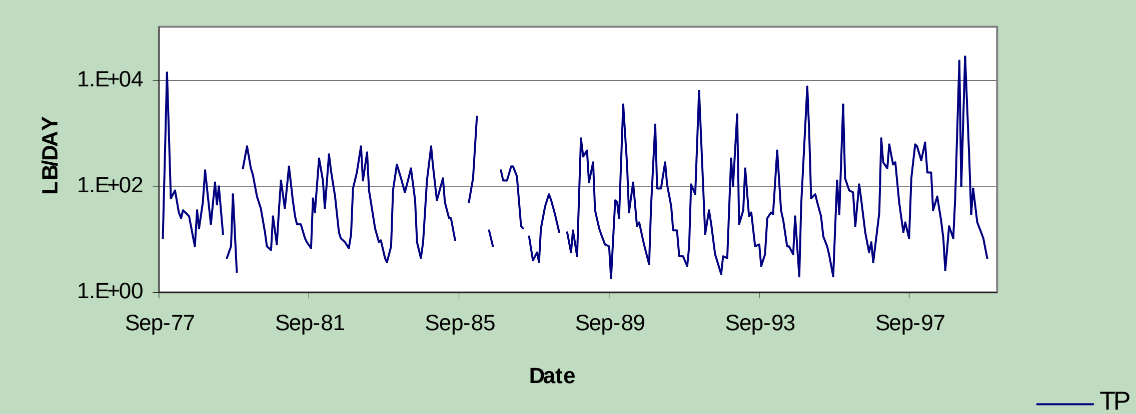
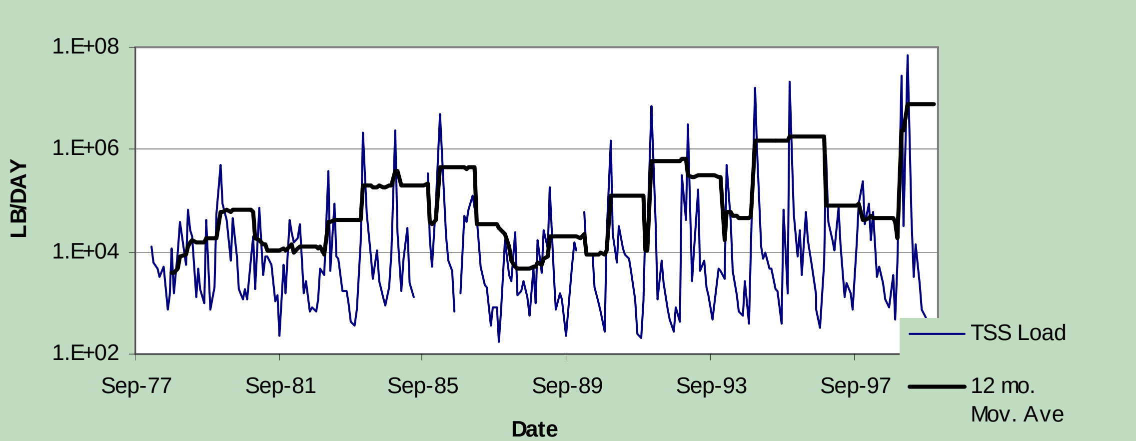


Figure C-10. Chehalis at Dryad
TSS Loading



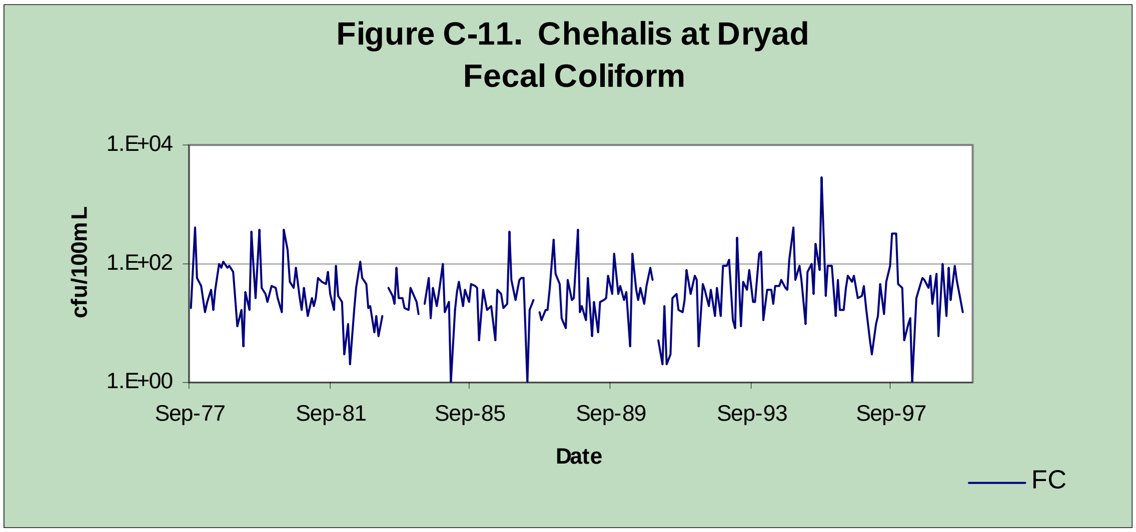


Figure C-11. Chehalis at Dryad
Fecal Coliform
1.E+04
1.E+02
1.E+00
cfu/100mL
Sep-77
Sep-81
Sep-85
Sep-89
Sep-93
Sep-97
Date
FC

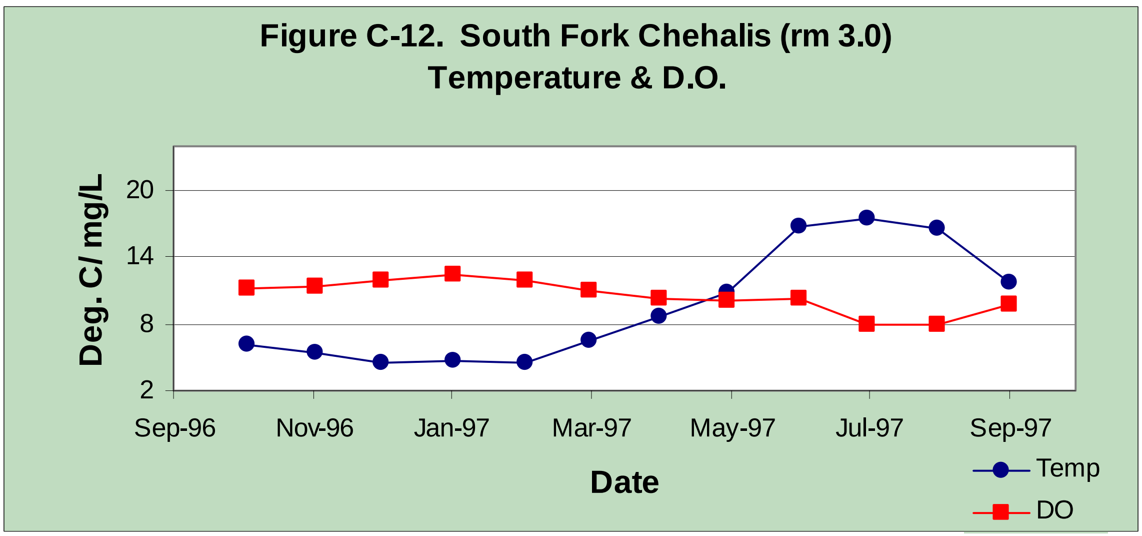


Figure C-12. South Fork Chehalis (rm 3.0)
Temperature & D.O.
20
14
8
2
Deg. C/ mg/L
Sep-96
Nov-96
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Date
Temp
DO

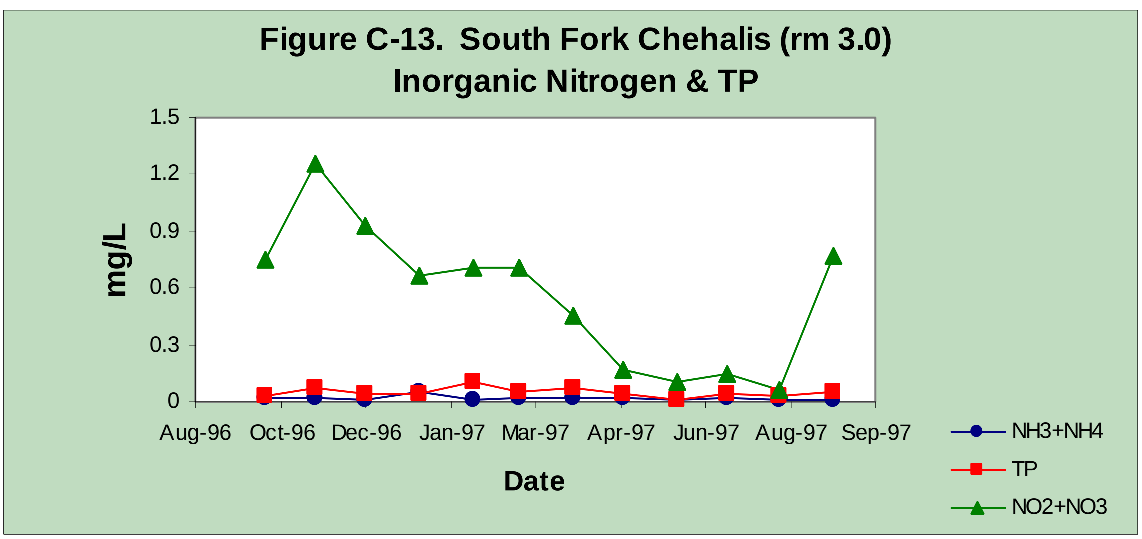


Figure C-13. South Fork Chehalis (rm 3.0)
Inorganic Nitrogen & TP
1.5
1.2
0.9
0.6
0.3
0
mg/L
Aug-96
Oct-96
Dec-96
Jan-97
Mar-97
Apr-97
Jun-97
Aug-97
Sep-97
Date
NH3+NH4
TP
NO2+NO3

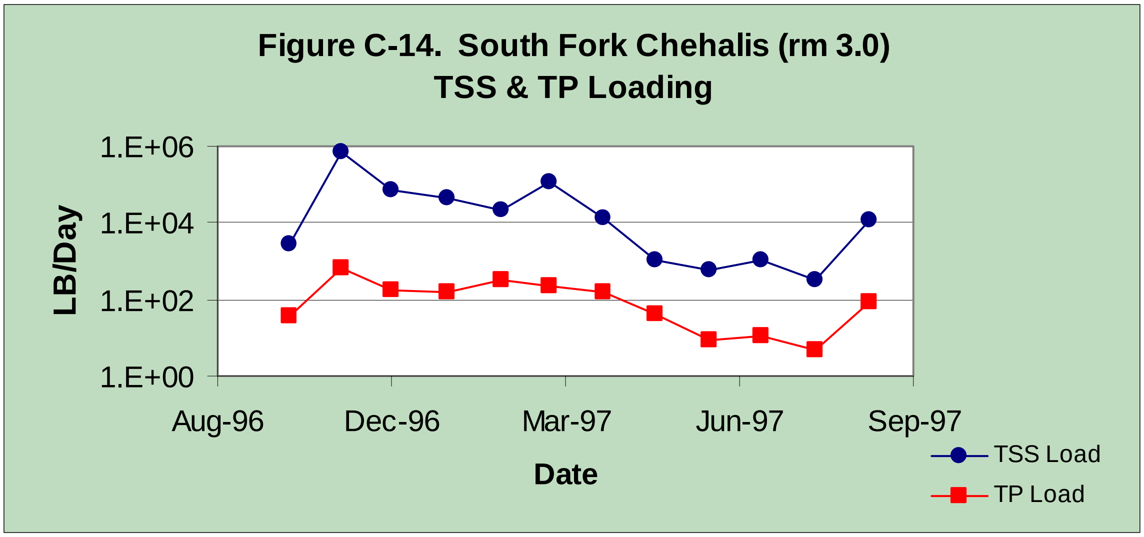


Figure C-14. South Fork Chehalis (rm 3.0)
TSS & TP Loading
LB/Day
1.E+06
1.E+04
1.E+02
1.E+00
Aug-96
Dec-96
Mar-97
Jun-97
Sep-97
Date
TSS Load
TP Load

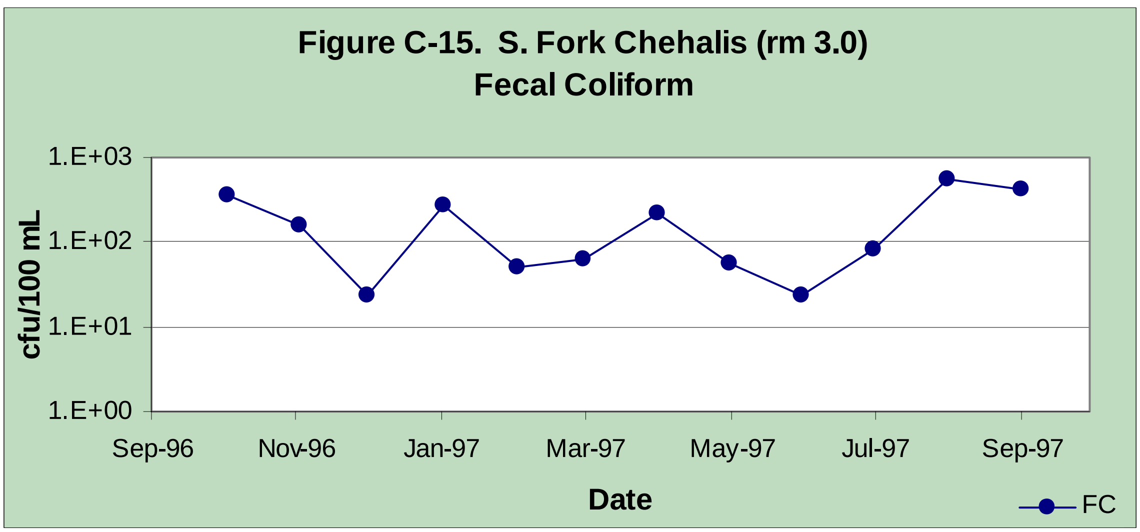


Figure C-15. S. Fork Chehalis (rm 3.0)
Fecal Coliform
cfu/100 mL
1.E+03
1.E+02
1.E+01
1.E+00
Sep-96
Nov-96
Jan-97
Mar-97
May-97
Jul-97
Sep-97
Date
FC

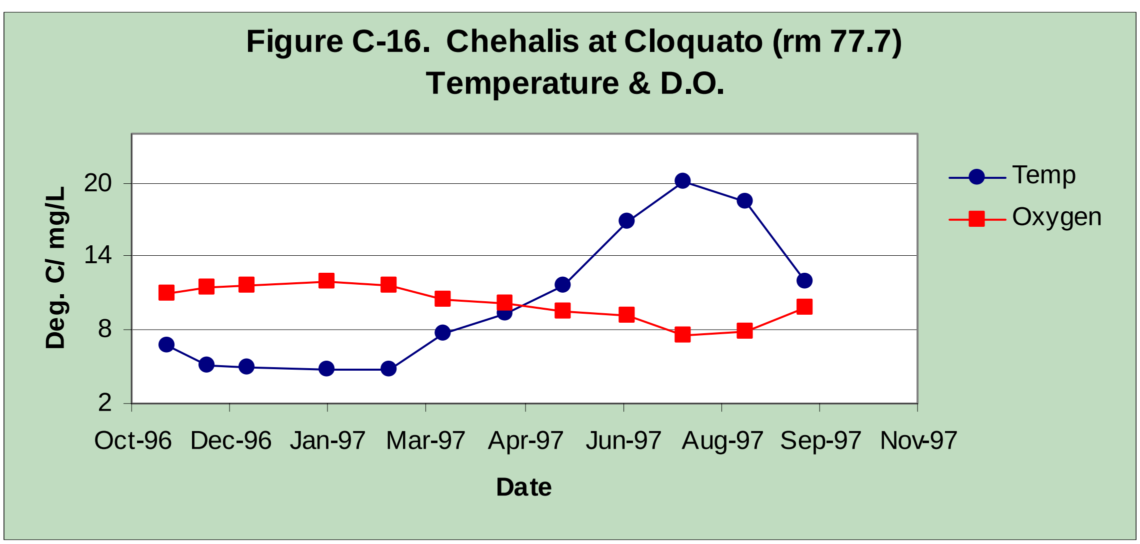


Figure C-16. Chehalis at Cloquato (rm 77.7)
Temperature & D.O.
Deg. C/ mg/L
20
14
8
2
Oct-96
Dec-96
Jan-97
Mar-97
Apr-97
Jun-97
Aug-97
Sep-97
Nov-97
Date
Temp
Oxygen

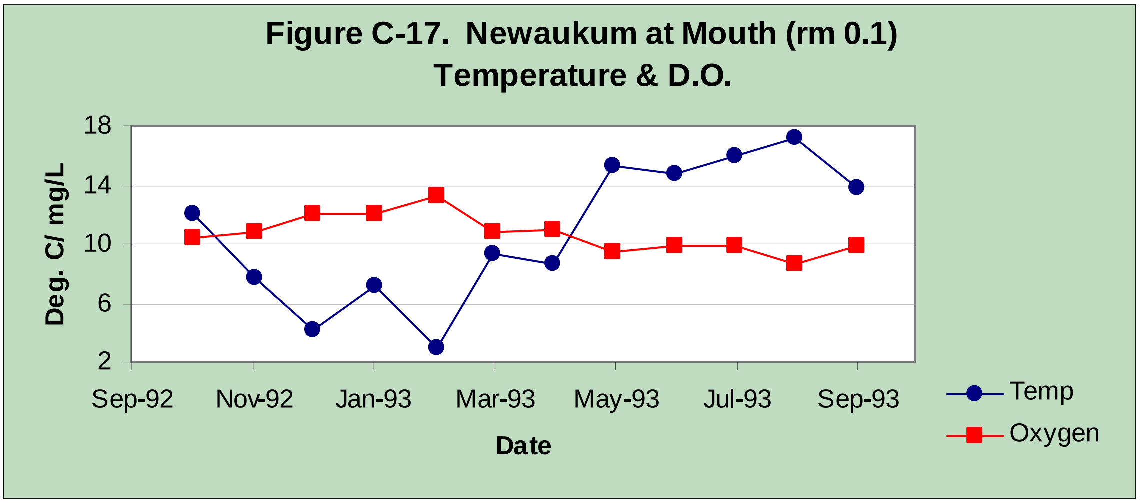


Figure C-17. Newaukum at Mouth (rm 0.1)
Temperature & D.O.
Deg. C/ mg/L
18
14
10
6
2
Sep-92
Nov-92
Jan-93
Mar-93
May-93
Jul-93
Sep-93
Date
Temp
Oxygen

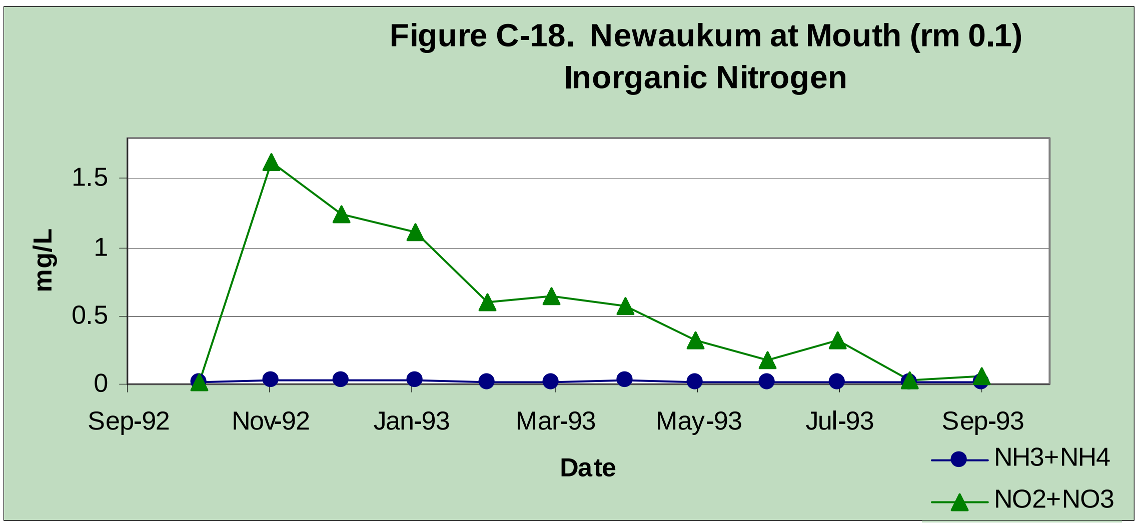


Figure C-18. Newaukum at Mouth (rm 0.1)
Inorganic Nitrogen
mg/L
1.5
1
0.5
0
Sep-92
Nov-92
Jan-93
Mar-93
May-93
Jul-93
Sep-93
Date
NH3+NH4
NO2+NO3

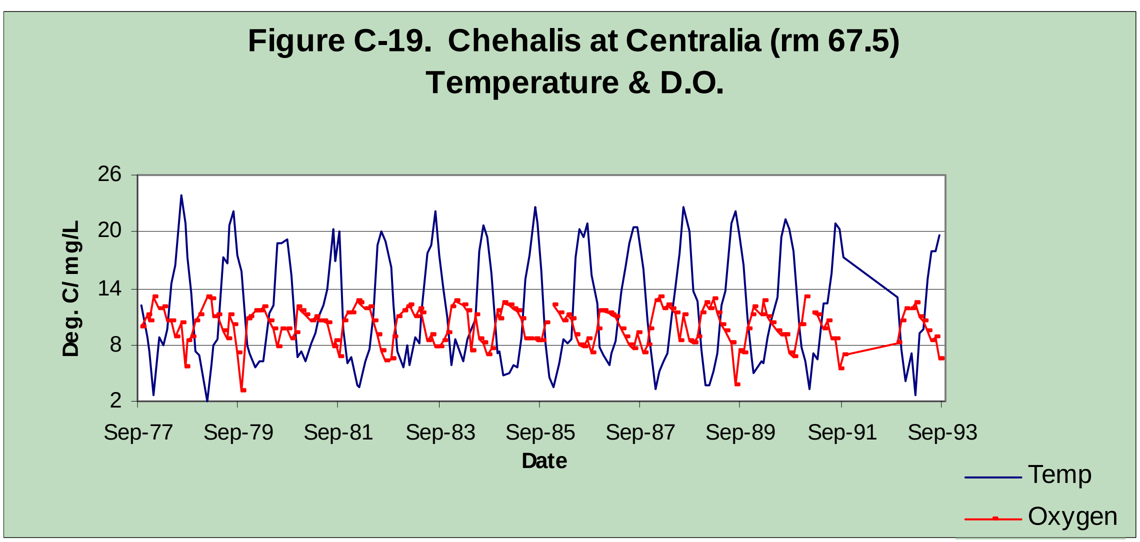


Figure C-19. Chehalis at Centralia (rm 67.5)
Temperature & D.O.
Deg. C/ mg/L
26
20
14
8
2
Sep-77
Sep-79
Sep-81
Sep-83
Sep-85
Sep-87
Sep-89
Sep-91
Sep-93
Date
Temp
Oxygen

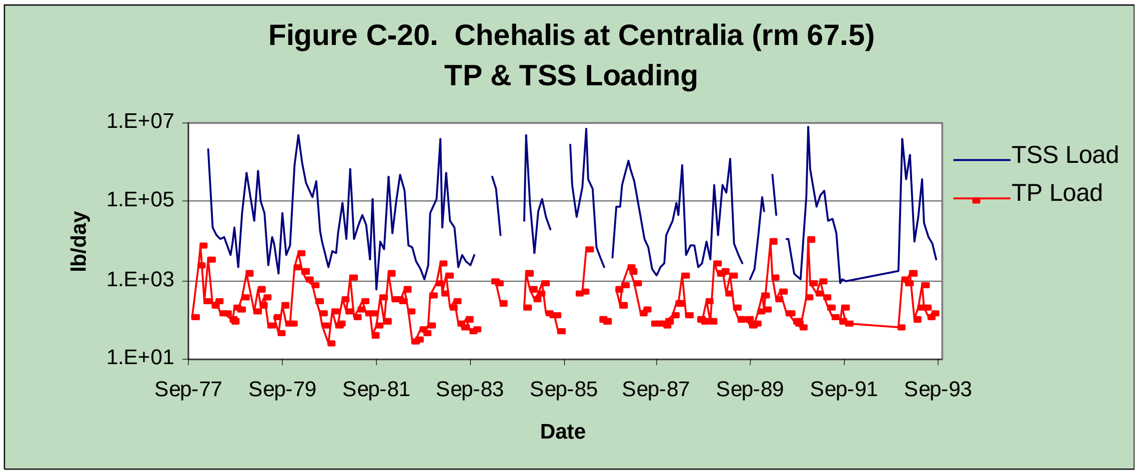


Figure C-20. Chehalis at Centralia (rm 67.5)
TP & TSS Loading
1.E+07
1.E+05
1.E+03
1.E+01
lb/day
Sep-77
Sep-79
Sep-81
Sep-83
Sep-85
Sep-87
Sep-89
Sep-91
Sep-93
Date
TSS Load
TP Load

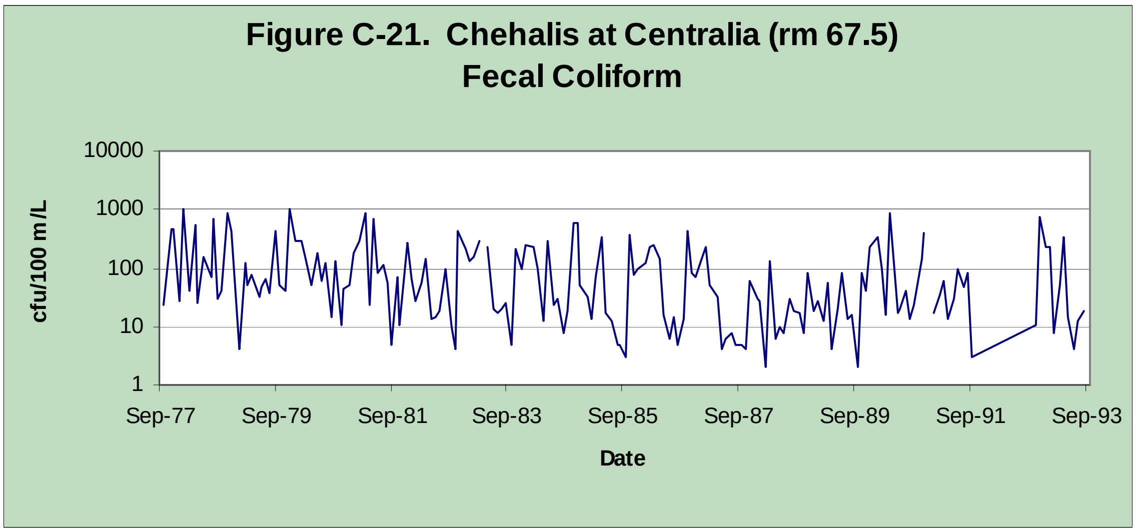


Figure C-21. Chehalis at Centralia (rm 67.5)
Fecal Coliform
10000
1000
100
10
1
cfu/100 m/L
Sep-77
Sep-79
Sep-81
Sep-83
Sep-85
Sep-87
Sep-89
Sep-91
Sep-93
Date

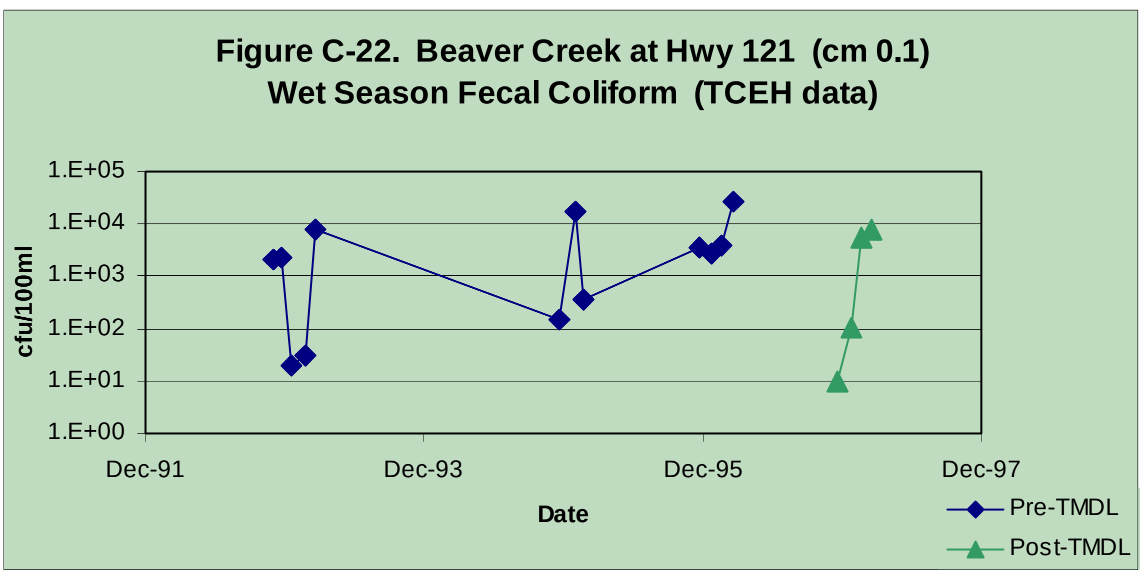


Figure C-22. Beaver Creek at Hwy 121 (cm 0.1)
Wet Season Fecal Coliform (TCEH data)
1.E+05
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
cfu/100ml
Dec-91
Dec-93
Dec-95
Dec-97
Date
Pre-TMDL
Post-TMDL

Figure C-23. Black River
Dry Season Ammonia

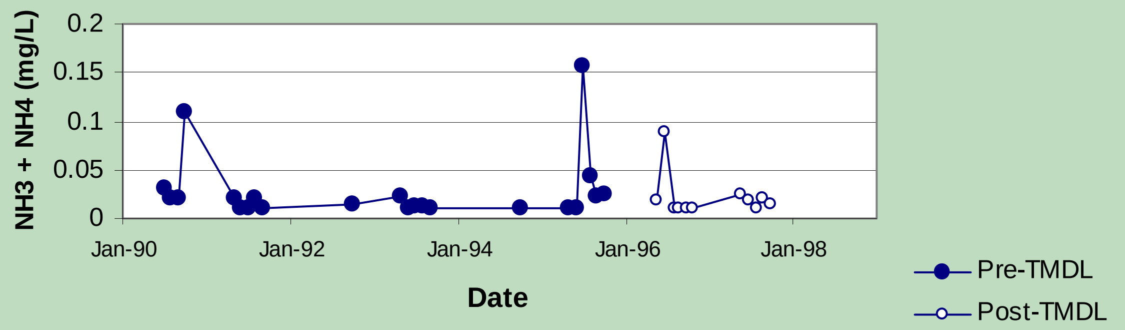


Figure C-24. Black River
Dry Season TP

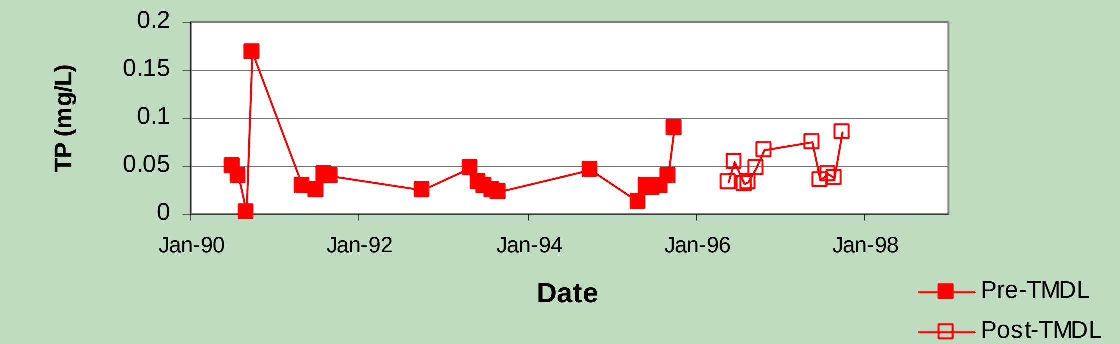
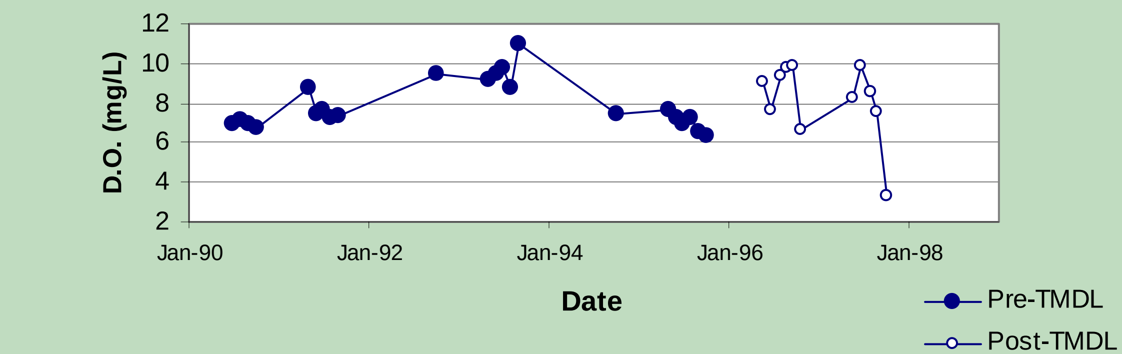


Figure C-25. Black River
Dry Season D.O.



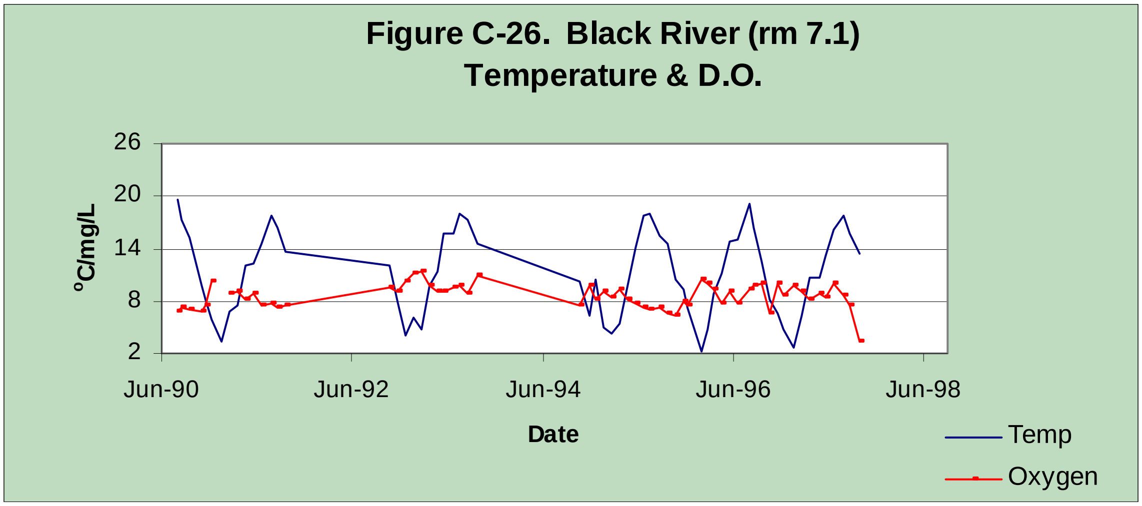


Figure C-26. Black River (rm 7.1)
Temperature & D.O.
°C/mg/L
26
20
14
8
2
Jun-90
Jun-92
Jun-94
Jun-96
Jun-98
Date
Temp
Oxygen

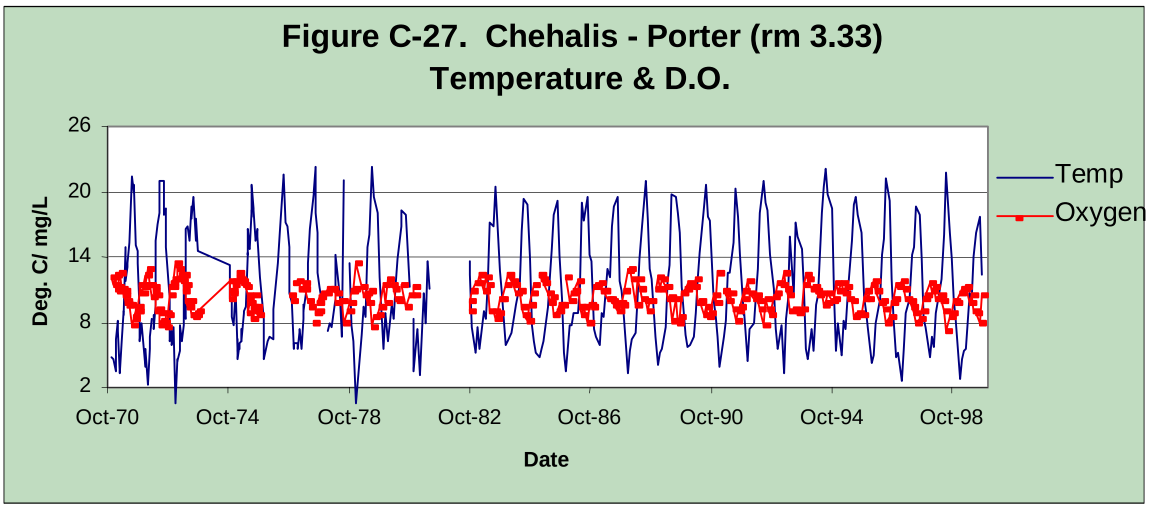


Figure C-27. Chehalis - Porter (rm 3.33)
Temperature & D.O.
Deg. C/ mg/L
26
20
14
8
2
Oct-70
Oct-74
Oct-78
Oct-82
Oct-86
Oct-90
Oct-94
Oct-98
Date
Temp
Oxygen

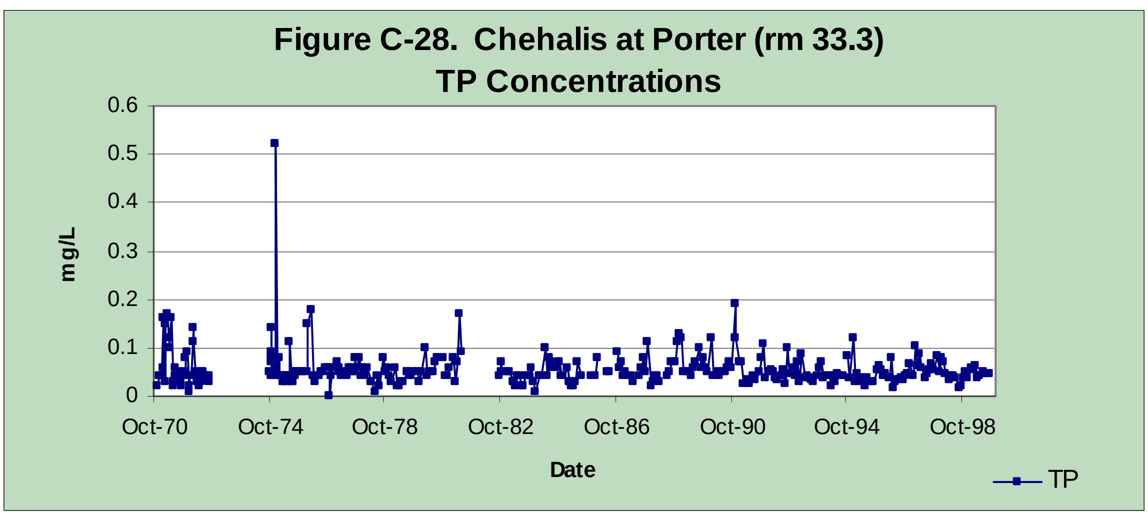


Figure C-28. Chehalis at Porter (rm 33.3)
TP Concentrations
mg/L
0.6
0.5
0.4
0.3
0.2
0.1
0
Oct-70
Oct-74
Oct-78
Oct-82
Oct-86
Oct-90
Oct-94
Oct-98
Date
TP

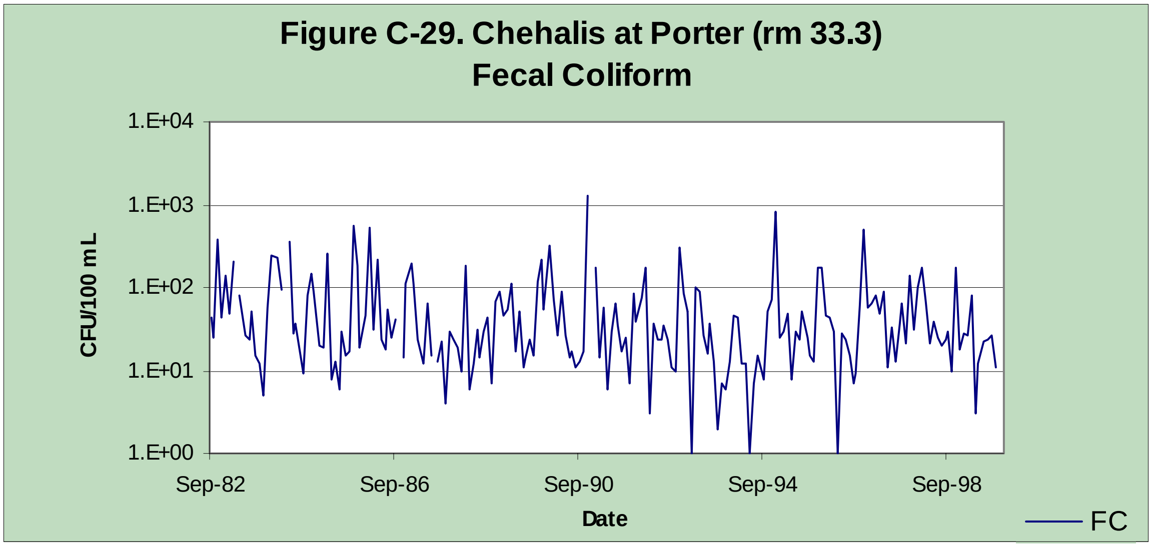


Figure C-29. Chehalis at Porter (rm 33.3)
Fecal Coliform
CFU/100 mL
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Sep-82
Sep-86
Sep-90
Sep-94
Sep-98
Date
FC

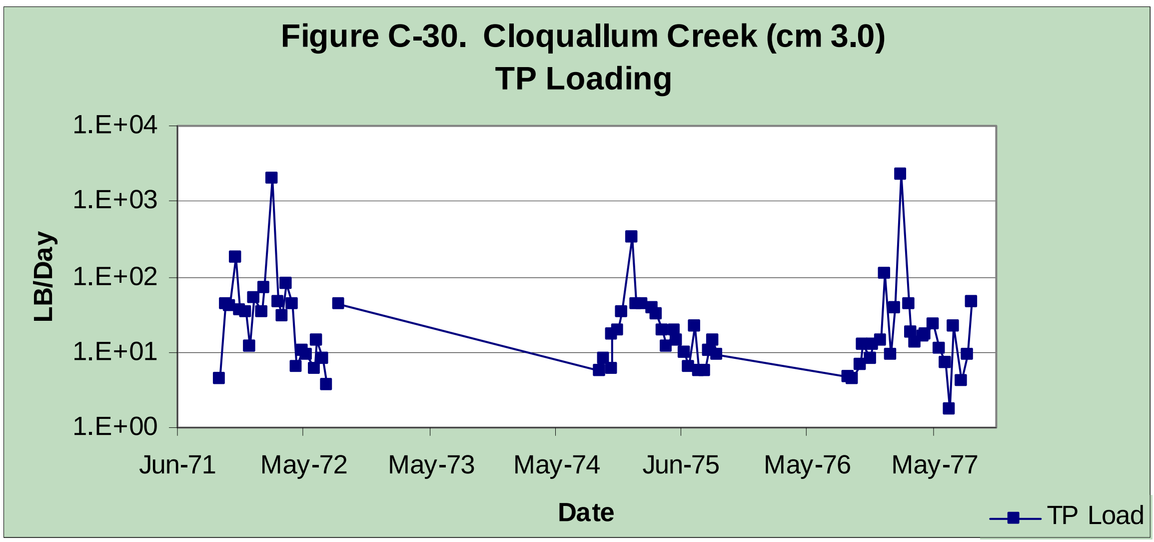


Figure C-30. Cloquallum Creek (cm 3.0)
TP Loading
LB/Day
1.E+04
1.E+03
1.E+02
1.E+01
1.E+00
Jun-71
May-72
May-73
May-74
Jun-75
May-76
May-77
Date
TP Load

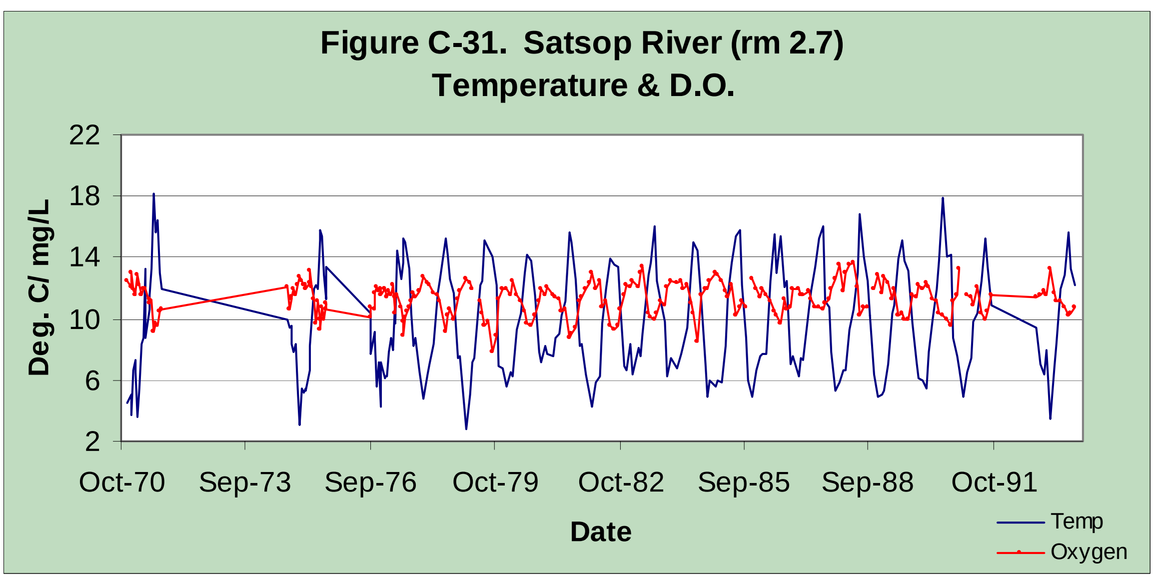


Figure C-31. Satsop River (rm 2.7)
Temperature & D.O.
Deg. C/ mg/L
22
18
14
10
6
2
Oct-70
Sep-73
Sep-76
Oct-79
Oct-82
Sep-85
Sep-88
Oct-91
Date
Temp
Oxygen

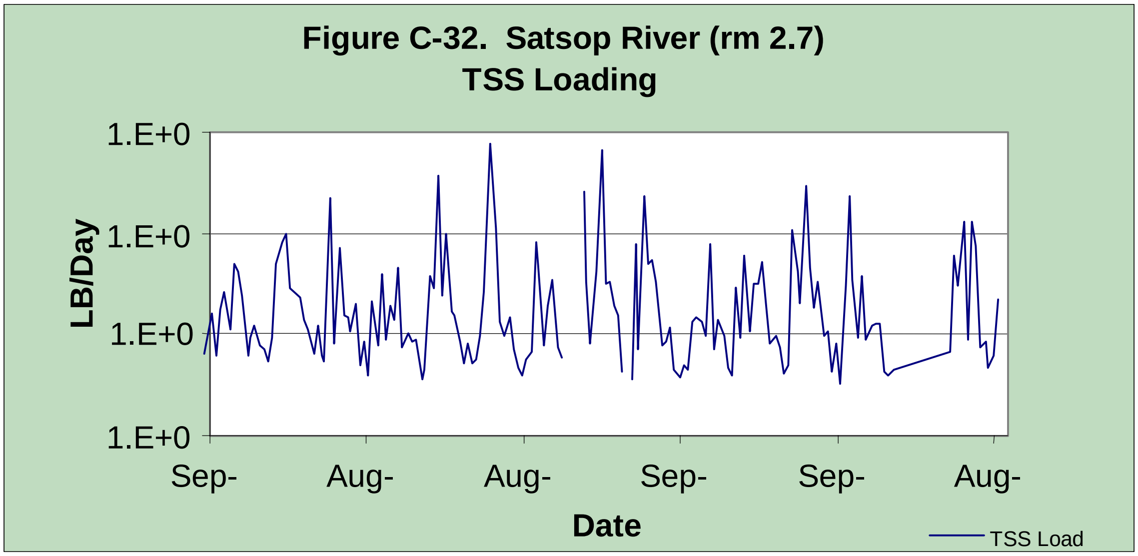


Figure C-32. Satsop River (rm 2.7)
TSS Loading
LB/Day
1.E+0
1.E+0
1.E+0
1.E+0
Sep-
Aug-
Aug-
Sep-
Sep-
Aug-
Date
TSS Load

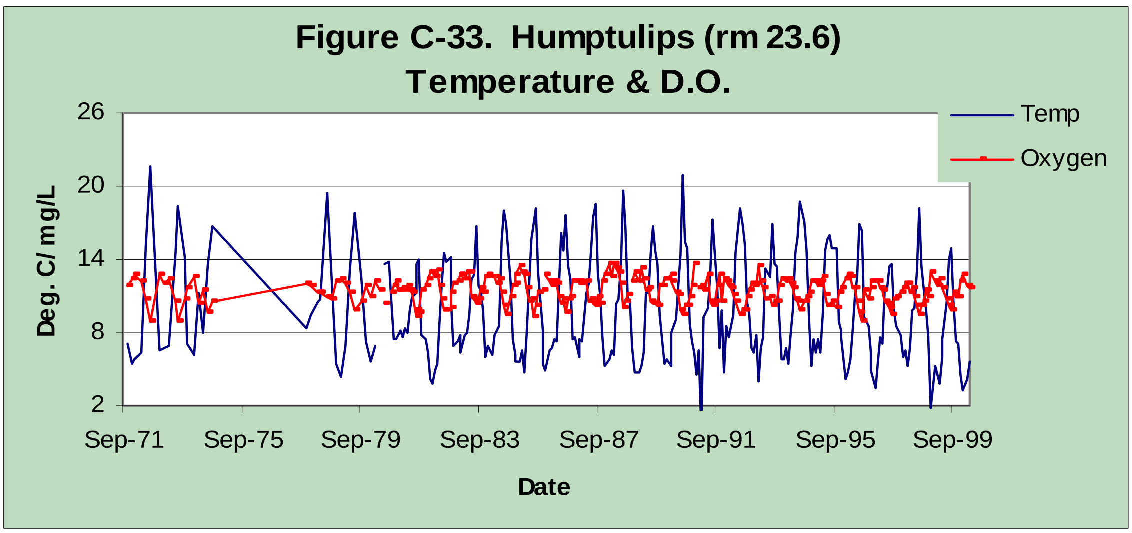


Figure C-33. Humptulips (rm 23.6)
Temperature & D.O.
Deg. C/ mg/L
26
20
14
8
2
Temp
Oxygen
Sep-71
Sep-75
Sep-79
Sep-83
Sep-87
Sep-91
Sep-95
Sep-99
Date

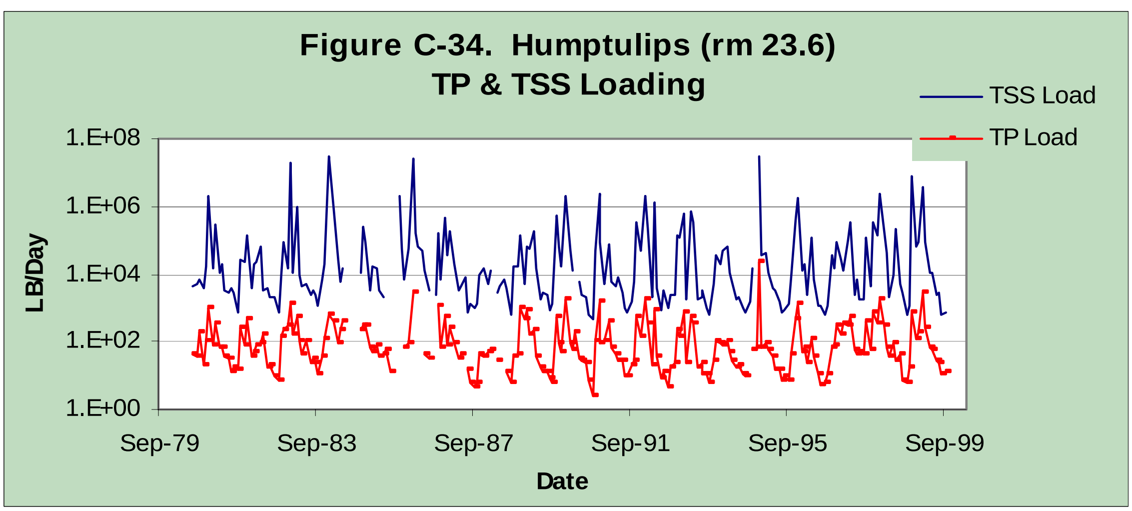


Figure C-34. Humptulips (rm 23.6)
TP & TSS Loading
LB/Day
1.E+08
1.E+06
1.E+04
1.E+02
1.E+00
TSS Load
TP Load
Sep-79
Sep-83
Sep-87
Sep-91
Sep-95
Sep-99
Date

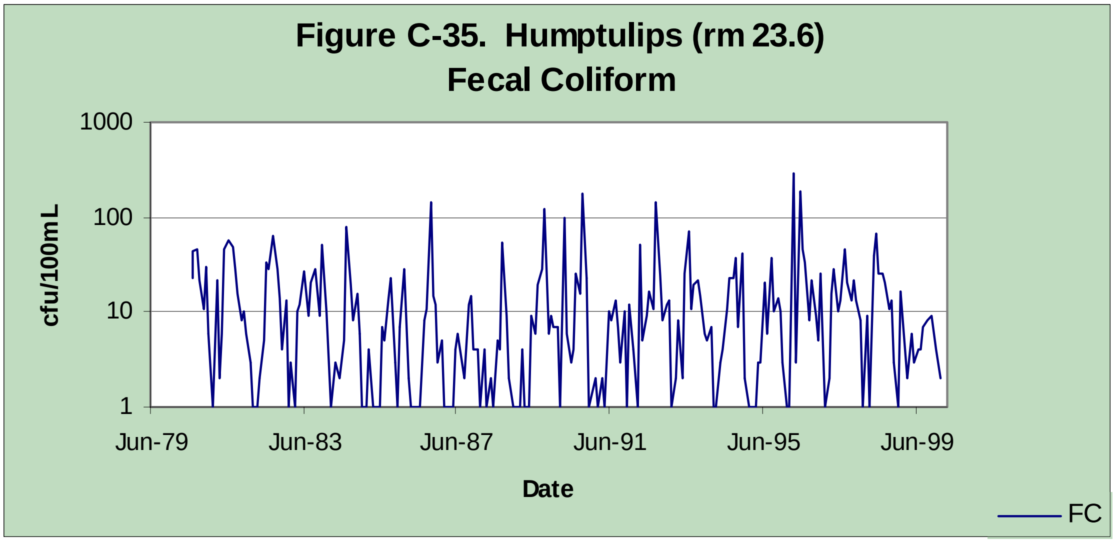


Figure C-35. Humptulips (rm 23.6)
Fecal Coliform
1000
100
10
1
cfu/100mL
Jun-79
Jun-83
Jun-87
Jun-91
Jun-95
Jun-99
Date
FC

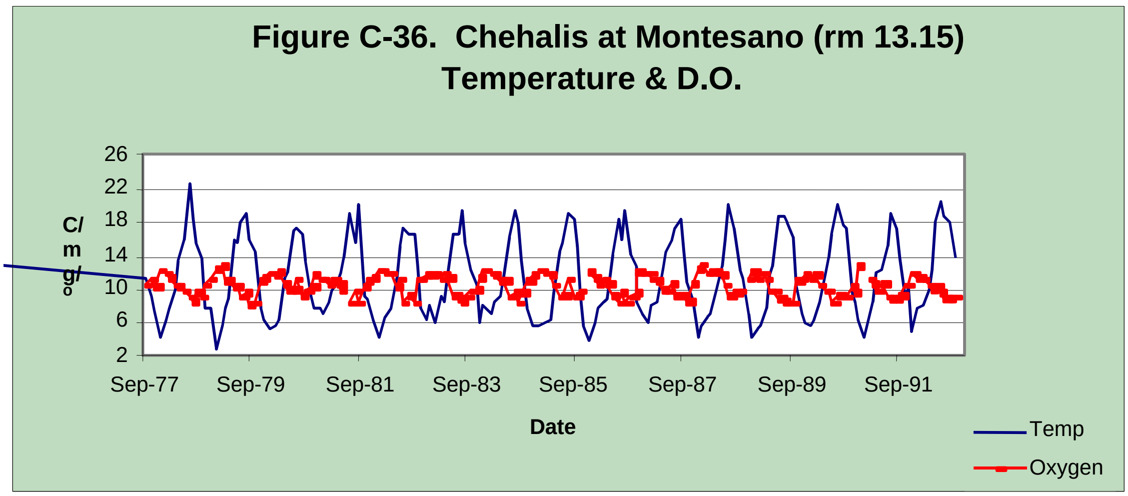


Figure C-36. Chehalis at Montesano (rm 13.15)
Temperature & D.O.
26
22
18
14
10
6
2
C/
m
g/
o
Sep-77
Sep-79
Sep-81
Sep-83
Sep-85
Sep-87
Sep-89
Sep-91
Date
Temp
Oxygen

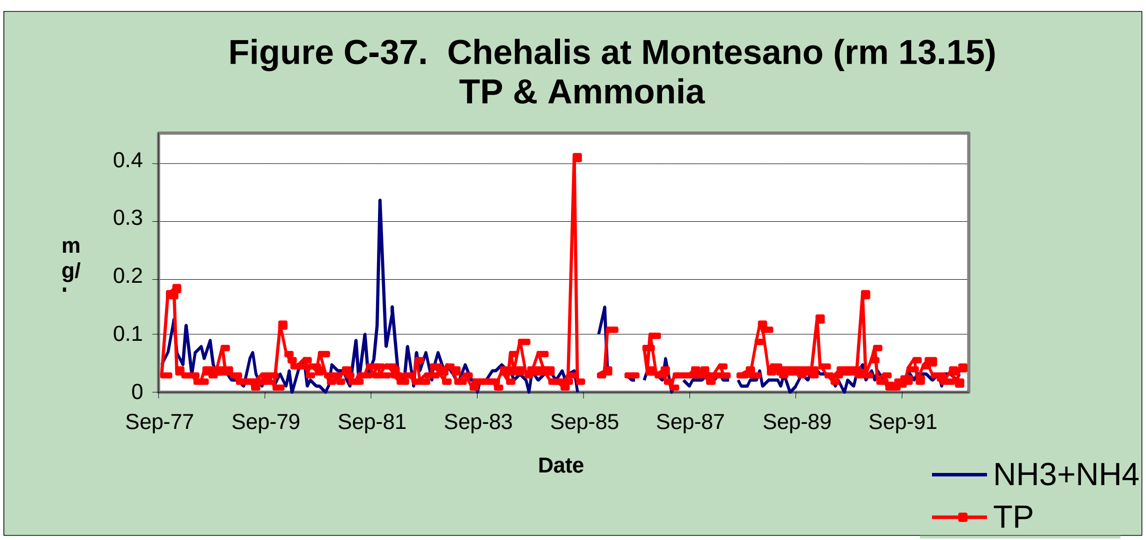


Figure C-37. Chehalis at Montesano (rm 13.15)
TP & Ammonia
0.4
0.3
0.2
0.1
0
m
g/
Sep-77
Sep-79
Sep-81
Sep-83
Sep-85
Sep-87
Sep-89
Sep-91
Date
NH3+NH4
TP

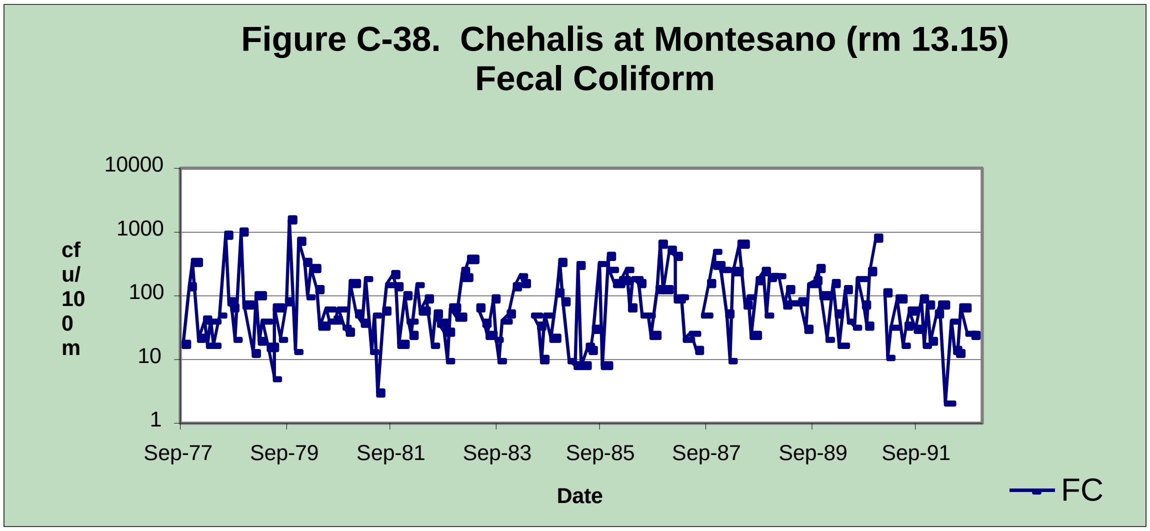


Figure C-38. Chehalis at Montesano (rm 13.15)
Fecal Coliform
cfu/100 m
10000
1000
100
10
1
Sep-77
Sep-79
Sep-81
Sep-83
Sep-85
Sep-87
Sep-89
Sep-91
Date
FC

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APPENDIX D: *FISH STOCK STATUS, HABITAT, AND HISTORIC DISTURBANCES*

FISH STOCK STATUS AND TRENDS

INTRODUCTION

This technical memorandum summarizes available information on the fish populations, stock status, and population trends of primarily salmonid fish in the riverine environments of the Chehalis River. Estuarine and salt water species, or saltwater lifestages of anadromous species, will not be addressed.

Information on fish populations and stock status within the Chehalis Basin has generally focused on salmon and trout, and is summarized in three reports developed by the Washington Dept. of Fish & Wildlife and the Western Washington treaty Indian tribes (SASSI, 1993; WDFW 1998a, 1998b). Since these reports summarize available information, stock status and trends will be discussed for chinook, coho, and chum salmon, steelhead trout, bull trout/Dolly Varden, and coastal cutthroat trout. Bull trout and Dolly Varden will be discussed as one species complex, since there is little information for this watershed with which to distinguish them (Table D-1) (WDFW, 1998b).

Table D-2 lists other native fish species, about which little basin-specific population information is known other than their presence in the fish assemblages of the Chehalis Basin, or within forested ecosystems of the Pacific Northwest (Wydoski and Whitney, 1979). In addition, two non-native trout species, brook trout and rainbow trout, have been introduced to some lakes and streams within the watershed. Little is known about their distribution and status, although populations appear to be small (Baxter, 1996; Baitis and Kuzis, 1999). These native and introduced species will not be discussed further.

Definitions used in the stock status reports are as follows:

A “stock” is the fish spawning in a particular lake or stream(s) at a particular season, which fish to a substantial degree do not interbreed with any group spawning in a different place, or in the same place in a different season. Stocks can be comprised of fish of native genetic heritage, non-native heritage, or mixed genetic heritage. Production (reproduction) can be in the wild (natural), supported by hatchery operations (cultured), or sustained by both artificial and natural reduction (composite).

“Critical stocks” are those that have declined in numbers to the point that the stock is in jeopardy of significant loss of in-stock diversity, or in the worst case, extinction.

"Depressed stocks" are those whose production is below expected levels, based on available habitat and natural variations in survival rates, but above the level here permanent damage to the stock is likely. The management intent is to restore these stocks to fishable levels.

"Healthy stocks" covered a wide range of conditions, from robust to those without surplus production for harvest. A healthy listing in this assessment does not mean that managers have no concerns, or that production levels are adequate (SASSI, 1993). It should be noted that, even with positive trends, most anadromous stocks present in the Chehalis Basin are far fewer than their historical numbers, and concerns about declines in fish habitat and fish production are not new (Hiss and Knudsen, 1992; Phinney et al., 1975). Conditions in individual streams will vary; problems and opportunities for restoration will vary as well.

"Escapement" is the number of fish that survive natural and human-caused mortality to spawn. A "run size estimate" is made by combining estimates of fishing harvest and escapement numbers.

STOCKS AND SUBBASINS

Stocks distinguished using genetic analysis are often named for the river(s) they are most commonly found in. In the Chehalis River watershed, fish spawning upstream of the Satsop River to the headwaters are generally grouped as one Chehalis stock, while the Humptulips, Hoquiam, Wishkah, Wynoochee, and Satsop stocks are generally distinguished from one another. This is not always the case, however. For instance, Skookumchuck/Newaukum winter steelhead are distinguished as a separate stock, bull trout/Dolly Varden are distinguished only as the larger "Grays Harbor/Chehalis" stock, and coastal cutthroat trout stocks are distinguished for the "Grays Harbor/Willapa Bay" distribution area. This is a function of the different levels of historic and current information available for different salmonid species.

STOCK STATUS AND POPULATION TRENDS

A total of two spring chinook stocks, seven fall chinook stocks, two chum stocks, seven coho stocks, two summer steelhead stocks, eight winter steelhead stocks, one bull trout/Dolly Varden stock, and two coastal cutthroat stocks have been identified in the Chehalis watershed. No pink salmon or sockeye salmon stocks were identified in this area (SASSI, 1993; WDFW, 1998a, 2000).

Some population trend information is available for some stocks but unknown for others. Trends in population identified by the SASSI report summarize information up to 1992 for most species. Trends in population identified for coastal cutthroat trout were summarized as of 1999, and for bull trout/Dolly Varden up to 1998 (WDFW, 1998, 2000).

Of the thirty-one stocks identified, stocks classed as “healthy” included:

- Chehalis spring chinook,
- Humptulips, Hoquiam, Wishkah, Wynoochee, Satsop and Chehalis fall chinook,
- Humptulips and Chehalis fall chum,
- all seven coho stocks in the watershed, and
- Humptulips, Hoquiam, Wishkah and Wynoochee winter steelhead.

Stocks classed as “depressed” included:

- Satsop summer chinook, and
- Satsop and Skookumchuck/Newaukum winter steelhead.

Stocks classed as “unknown” included: Johns/Elk fall chinook, Humptulips and Chehalis summer steelhead, South Harbor streams winter steelhead, and bull trout/Dolly Varden for the entire Grays Harbor/Chehalis area, and coastal cutthroat trout for both the Humptulips and Chehalis (SASSI, 1993; WDFW, 1998b, 2000).

One stock, Wynoochee spring chinook, was classed as “disputed”. During the development of the SASSI report, disputes arose between biologists. The main issue of dispute was the historical and current presence of six early-timed spring chinook stocks, including one in the Wynoochee River (SASSI, 1993). Nehlsen et al. (1991), using somewhat different criteria than used in SASSI, cited Wynoochee spring chinook as “at a high risk of extinction.”

Some population trend information was identified. A stable or positive population trend was identified for Chehalis spring chinook, all of the fall chinook stocks except Johns/Elk and South Bay tributaries.

Negative trends were identified for Satsop summer chinook, and Satsop and Skookumchuck/ Newaukum winter steelhead. These trends gave rise to the depressed classification for these populations.

Population trends of “unknown” were identified for Johns/Elk and South Bay tributaries fall chinook, Humptulips and Chehalis summer steelhead, South Harbor winter steelhead, Humptulips and Chehalis coastal cutthroat trout, and bull trout/Dolly Varden for the entire basin (SASSI, 1993; WDFW, 1998b, 2000). Wynoochee spring chinook were also identified as “unknown”, but the trend is probably negative, as discussed above.

No population trends were identified for the “healthy” Humptulips and Chehalis fall chum stocks; all seven coho stocks; and Chehalis, Humptulips, Hoquiam, Wishkah, and Wynoochee winter steelhead stocks (SASSI, 1993).

Table D-1. Stock origin, status and production type for salmon and char in the Chehalis watershed. (Sources include: SASSI, 1993; WDFW, 1998, 2000.) Population trends are listed where known, or defined as unknown by investigators.

Stock Name	Stock Origin	Production Type	Stock Status	Population Trend
Spring Chinook (Oncorhynchus tshawytscha)				
Chehalis	Native	Wild	Healthy	Stable or positive[1]
Wynoochee	Native	Wild	Disputed	Unknown
Summer Chinook				
Satsop	Mixed	Wild	Depressed	Negative [2]
Fall Chinook				
Humptulips	Mixed	Wild	Healthy	Positive [3]
Hoquiam	Native	Wild	Healthy	
Wishkah	Native	Composite	Healthy	
Wynoochee	Native	Wild	Healthy	
Satsop	Mixed	Composite	Healthy	
Chehalis	Mixed	Wild	Healthy	
Johns/Elk & S. Bay tributaries	Mixed	Wild	Unknown	Unknown
Fall Chum (O. keta)				
Humptulips	Native	Wild	Healthy	
Chehalis	Native	Wild	Healthy	
Coho (O. kisutch)				
Humptulips	Mixed	Composite	Healthy	
Hoquiam	Mixed	Composite	Healthy	
Wishkah	Mixed	Composite	Healthy	
Wynoochee	Mixed	Composite	Healthy	
Satsop	Mixed	Composite	Healthy	
Chehalis	Mixed	Composite	Healthy	
Johns/Elk & S. Bay tributaries	Mixed	Composite	Healthy	
Summer Steelhead (O. mykiss)				
Humptulips	Native	Wild	Unknown	Unknown [4]
Chehalis	Unknown	Wild	Unknown	Unknown [4]
Winter Steelhead				
Humptulips	Native	Wild	Healthy	
Hoquiam	Native	Wild	Healthy	
Wishkah	Native	Wild	Healthy	
Wynoochee	Mixed	Composite	Healthy	
Satsop	Native	Wild	Depressed	Negative [5]
Chehalis	Native	Wild	Healthy	
Skookumchuck/Newaukum	Mixed	Composite	Depressed	Negative [6]
South Harbor	Native	Wild	Unknown	Unknown[4]
Bull trout / Dolly Varden (Salvelinus confluentus/malma)				
Chehalis / Grays Harbor	Native	Wild	Unknown	Unknown
Coastal Cutthroat Trout (O. clarki clarki)				
Humptulips	Native	Wild	Unknown	Unknown
Chehalis	Native	Wild	Unknown [7]	Unknown

1. Annual escapements prior to 1992 were "hovering around the desired escapement goal of 1400 adults". (SASSI, 1993). In 1991, a positive trend in escapement compared to the 1970-1985 period was identified (Hiss and nudsen, 1993).
2. Stock status rating of depressed based on a long-term negative trend in escapement (SASSI, 1993).
3. In 1991, a positive trend in escapement compared to the 1969-1983 period was identified (Hiss and Knudsen, 1993).
4. Status and trends are unknown, stock comprised of a historically small number of steelhead. (SASSI, 1993)
5. Status is depressed based on chronically low wild spawner escapement (SASSI, 1993).
6. Status is depressed based on chronically low spawner escapement (SASSI, 1993).
7. Status is unknown, but is considered probably similar to the status of coho and winter steelhead, which is "depressed" (Johnson et al., 1999).

Table D-2. Fish species known or suspected to be present in the Chehalis watershed, other than the commonly studied salmonids. (Sources include Hiss and Knudsen, 1993; Wydoski and Whitney, 1979; WARIS/PHS database; Baitis and Kuzis, 1999; Parton et al., 1997).

Fish Species	Scientific name
Native Fish Species	
White sturgeon	Acipenser transmontanus
Green sturgeon	A. medirostris
American shad	Alosa sapidissima
Northern pikeminnow	Ptychocheilus oregonensis
Largescale sucker	Catostomus machrocheilus
Redside shiner	Richardsonius balteatus
Whitefish	Prosopium spp.
Reticulate sculpin	Cottus perplexus
Coast range sculpin	C. aleuticus
Torrent sculpin	C. rhotheus
Riffle sculpin	C. golosus
Prickly sculpin	C. asper
Pacific lamprey	Entosphenus tridendatus
River lamprey	Lampetra ayresi
Western brook lamprey	L. richardsoni
Longnose dace	Rhinichthys cataractae
Speckled dace	R. osculus
Redside shiner	Richardsonius balteatus
Olympic mudminnow	Novumbra hubbsi
Introduced species	
Brook trout	Salvelinus fontinalis
Rainbow trout	Onchorynchus mykiss
Largemouth bass	Micropterus salmoides

IMPACTS OF LAND USE ON HYDROLOGY, STREAM CHANNELS AND FISH HABITAT

INTRODUCTION

This section summarizes potential hydrologic effects, both surface and groundwater, associated with land and water use, and potential affects on fish habitat. These are summarized generally by land use, moving from hydrologic impacts to potential stream channel and fish habitat impacts.

As with most western Washington stream systems, the Chehalis has a land use history focused on timber harvest and agriculture. Many associated activities, such as splash damming and wood removal, have had an affect on hydrologic conditions and resultant channel/habitat conditions. The following sections present general information on the likely affects of land use and associated hydrologic changes within the basin.

For a general discussion of the role of fish habitat in healthy salmon populations, see Smith and Wenger (2000). For more technical discussions about impacts from specific land uses on hydrology and stream channels see Meehan et al.(1991), Beschta et al. (1995), Salo and Cundy (1987), and Dunne and Leopold (1978).

FORESTRY

The legacy

Fish populations and habitats in the Pacific Northwest are strongly affected by both current forest practices and by actions taken as part of past forest practices. Many of those forest practices, which were legal or unregulated at the time, may still have an affect on both current habitat conditions and on fish populations. Past practices included transporting logs using splash dams, stream channelization and removal of woody debris (LWD) (stream cleanouts), removal of riparian vegetation, road and railroad construction in stream channels and flood plains, and the hydrologic impacts discussed above. These actions either removed habitat features (LWD, side channels); increased peak flows, which caused channel downcutting; destabilized streambanks, which caused bank erosion; introduced sediment from bank erosion, road construction, and road failures; increased water temperatures from removal of riparian vegetation; and blocked migration with dams and log storage. Riparian areas that have been damaged or completely removed lower the potential for LWD inputs to the stream in the future, which will limit future habitat complexity until riparian vegetation returns.

The role of these past activities in defining current channel and habitat conditions is not entirely understood. Habitat conditions are likely improved from those of past years, but the combination of past and current activities still affects habitat conditions.

Timber harvest

This land use practice can affect both peak and low flow conditions. Peak flows may increase because less precipitation is intercepted by living trees, and because more snow may accumulate on bare ground. Increases are considered to be most likely at elevations where rain-on-snow precipitation events are likely. Increases in peak flows may affect stream channels (causing channel incision and removal of LWD), even after this potential impact has diminished as regrowth of trees occurs. Low flows have the potential to increase because of less precipitation interception. This could increase summer rearing habitat.

Roads and harvest practices

Peak flows may be affected because roads and drainage ditches reroute subsurface flows to surface runoff, which may enter the stream channel at a faster rate, and at a single point rather than by subsurface runoff. Skid trails also have the potential to route flows this way. Road ditches can extend the stream network, with occasional diversion of flows between basins. While the extent of this in the Chehalis is unknown, it is not uncommon in commercial forest land. Increases in peak flows would be associated with this condition. This could cause channel erosion/incision, and reduced water quality as sediments enter stream channels. Roads also generate sediment from their surface, as well as increasing the likelihood of mass wasting events. Watershed Analyses for forested regions in the headwaters of subbasins in the Chehalis indicate significant quantities of fines associated with roads and road related mass wasting events. These increases could lead to a reduction in the quality of spawning and winter rearing habitat.

AGRICULTURE AND RANGELAND

From a fish habitat perspective, agriculture differs from forestry in many ways. The primary one being that many of the changes in wetlands and stream channels are permanent, and maintained to keep an altered hydrologic condition (more drainage) or riparian changes (no trees). In a forested landscape there is the potential for the altered situation to recover, even though the recovery time may be hundreds of years long.

Drainage manipulation

Drainage manipulation can increase peak flows by delivering storm flows more efficiently to the stream channel. The channel response includes bank or bed erosion. Nearly all of the flood plains in the Chehalis valley have undergone some degree of drainage modification. Drainage modifications may also decrease low flows, and have the potential to lower the water table and reduce groundwater recharge. This reduces low-flow (summer) habitat, and can contribute to higher water temperatures. This also reduces flood storage capacity, which can cause channel incision. Channel complexity is reduced as channel length is shortened. Loss of fish access to wetland and off-channel habitats can reduce winter refuge habitat, as well as summer rearing area.

Crop production

Crop production has the potential to affect low flows as soil is tilled and transpiration rates are altered. Perhaps the most significant land use activity in the middle and lower portions of many subbasins is alteration of riparian vegetation. Coupled with drainage modifications, this contributes to bank erosion, reduces shade and channel complexity, and promotes channel downcutting. As recruitment of structural elements, such as LWD, is limited and channel complexity reduced, habitat value declines. In addition, irrigation water return has the potential to affect water quality (see below). Altered low flows can affect summer rearing habitat quality, and reduce water quality.

Cattle grazing

Cattle grazing has the potential to affect peak flow because compacted soils reduce infiltration and increase stormwater runoff. This has the capacity to cause channel incision. Cattle also remove riparian vegetation and break down streambanks, causing bank erosion, and increased levels of stream sediments. Unstable streambanks can cause channel widening or channel avulsion, reducing the quality of instream habitat due to lowered flows and less in-channel structure.

URBAN

Increases in impervious surface associated with urban landscapes, and the use of stormwater facilities change the timing and increase the magnitude of peak flows, since water is routed quickly to stream channels. Increased magnitude and volume of peak flows can cause bank erosion, channel widening or downward incision, and eventual disconnection of the channel from the former flood plain. Urban land uses also affect riparian corridor integrity where riparian corridors become fragmented, narrow, or disappear. These changes affect stream channels by removing sources of woody debris and shading, and potentially increasing the input of stormwater with degraded water quality (City of Olympia, 1999). As the Chehalis Basin is primarily forested and agricultural land, the impact of urban land uses is limited.

Structural features

In most cases, dams and diversions reduce the magnitude and frequency of high flows. As a result, stream channels downstream of a dam can become narrower as a result. Capture of sediments behind a dam can result in downstream channel erosion and bed armoring. Dams can also block migratory corridors, contributing to dewatering of downstream reaches, and release water with increased temperatures or sediment loads.

Channelization and construction of levees can change peak flow routing, reduce overbank flows, and isolate stream channels from their former flood plains and associated wetlands. The resulting channel constriction can cause downcutting. In addition, loss of connection between main-channel and off-channel or side-channel habitats will reduce rearing area and areas of refuge from high flows. In the Chehalis, bank protection efforts for road and railways have reduced the width of the channel migration zone by controlling meander movement. This can lead to channel erosion elsewhere in the basin as well as affect gravel deposition patterns.

Gravel mining

Gravel mining causes streambed disturbance, removes substrates, potentially changes groundwater interactions with surface waters, and could lower the water table. This removes or disrupts spawning and summer rearing habitats. Mining in the Humptulips, Wynoochee, and Satsop Rivers has altered channel bed elevations and substrate deposition (Collins and Dunne, 1986).

HUMAN WATER USE

Surface water diversions can deplete streamflow by consumptive use; and water used for irrigation can deplete streamflow between the point of diversion and the point of return.

Groundwater pumping had the potential to lower the water table. If groundwater discharge is critical to the maintenance of low stream flows, excessive pumping may affect streamflow. While a number of subbasins have the potential for this impact due to high pumping rates (Scatter Creek, Black River lower Newaukum), quantification of water budget variables has not been undertaken at this level. Areas with high groundwater withdrawal rates also possess the most productive aquifers in the basin.

Return flows have the potential to alter timing of low flows, and to change the surface water/groundwater interaction. They also may contribute to poorer water quality, higher temperatures, and higher sediment levels in the receiving stream.

SUMMARY

There is little doubt that land use activities have influenced basin hydrology and associated channel and fish habitat conditions. The degree to which this has occurred, however, is difficult to determine. In addition, the relative role of each land use activity in each subbasin varies. In general, increased peak flows associated with higher runoff rates and reduced low flows due to more efficient drainage systems are likely the prime hydrologic alterations. These changes, coupled with removal of riparian vegetation, has likely brought about an increase in channel bank and bed erosion throughout the basin. At this level, it is not possible to quantify the direct cause and effect relationship between specific land uses and hydrologic/channel/habitat changes.

Land use impacts on groundwater resources are poorly understood and very difficult to quantify. Alteration of groundwater recharge rates, ditching, and water withdrawals have influenced groundwater movement and availability, but the level of impact is not known

HISTORICAL DISTURBANCES IN THE CHEHALIS WATERSHED

This section follows the summary of impacts from various land use types on fish habitat, and summarizes historic watershed disturbances in the Chehalis watershed. Some topics are covered only briefly to not duplicate other ongoing assessment efforts. In those cases, the reader is referred to other documents for more detail than that presented here. For instance, the important topic of past and present Grays Harbor water quality, research results on the estimated impact on fisheries, and recent water quality improvement efforts are not extensively discussed (see Smith and Wenger, 2000).

"...The history of Chehalis Basin fish runs and habitats is one of pristine productivity, then gross degradation, followed by partial recovery..." (Hiss and Knudsen, 1993).

WILDFIRE & WINDSTORMS

Two of the largest watershed disturbances in the Chehalis watershed, prior to European-American settlement, were wildfire and windstorms. Of these, windstorms were probably a more common occurrence (Agee, 1993). Wildfire return intervals in Sitka-spruce dominated coastal forest are fairly long, on the order of 1,100 years. In other words, Sitka spruce forests rarely burn. In Western hemlock/Douglas-fir forests, which would have covered most of the Chehalis watershed outside of the coastal zones, fire return intervals are between 200 and 750 years, but should more correctly be classified as "episodic" (Agee, 1993). For example, a fire burned the headwaters of the South Fork Newaukum approximately 200 years ago (Weyerhaeuser, 1999). Some evidence exists for burning by humans prior to European-American settlement, especially in lowlands and prairie habitats where burning increases grassland habitats and plants (Agee, 1993).

After European settlement, fires were initially very common as a side effect of use of locomotives and donkey engines during logging, and the process of land clearing. Many of these fires could not be controlled, and were left to burn large tracts of timber (Van Syckle, 1981). Fire suppression was a major concern during both this period and more recent periods of road-based timber harvest. Since approximately 1950, suppression of wildfire has been public policy, so the occurrence of wildfires within the Chehalis watershed has decreased over the last 50 years. The practice of tree planting after harvest began in the early 1940's (Van Syckle, 1981). Slash burning as a management tool prior to tree replanting was used in the 1960's, 1970's, and 1980's, although, it is much less common now.

ESTABLISHMENT OF SETTLEMENTS AND AGRICULTURAL LANDS

River channel conditions prior to European settlement were very different than those seen today. Most low-gradient river channels in Western Washington and Oregon consisted of complexes of river, wetlands, beaver ponds, sloughs, logjams, and side channels, with both standing trees and instream wood very common and plentiful. On a list of rivers with their lower channels completely blocked by drift wood were "...most Grays Harbor rivers, the Chehalis, Black and Satsop Rivers..." (Dept. of Army reports 1875-1899, in Sedell and Luchessa ,1981). The Army Corps of Engineers cleared many streams of logjams and large boulders in the 1880-1905 period in this area.

Draining land for farming began early in the settlement period in Grays Harbor County, from the mid-1800's, and ditching and draining activities by individual landowners were very common in the 1880-1920 period (Van Syckle, 1981; Sedell and Luchessa, 1981). In order to consolidate the main channel, in many rivers, woody debris was not only cleaned out of the stream channel, but was also used to dike off sloughs and side channels. During the 1930's, when the Works Project Administration was active, many stream channels in agricultural areas were cleared of brush (Sedell & Luchessa, 1981).

Actions related to agriculture have been largely undocumented, although their impacts on fish habitat date back to the settlement of Hoquiam in 1857. The process of snagging, or log removal is discussed above. Many streams were diked, which eliminated winter cover and feeding areas, as well as increased channel scouring. Small streams were straightened in order to allow more convenient grazing and farming. Wetlands were drained or filled. These actions have resulted in a loss of habitat and habitat simplification, and are widespread over the agricultural lands in the watershed (Hiss and Knudsen, 1993).

RIPARIAN VEGETATION REMOVAL

One land use practice common on both lands used for timber harvest and agricultural lands was riparian vegetation removal. This was a side effect of (legal) timber harvest practices. Buffer strips of varying widths began to be left during the 1980's, and are now mandated. Therefore, while the historical disturbance was extreme, riparian areas in timber production land use can be considered in recovery from past practices, although, the recovery period may be as long as several hundred years.

This was also a result of agricultural practices, which are ongoing in the watershed. Riparian vegetation removal and degraded conditions have been documented widely throughout the watershed (Wampler et al., 1993 see Appendix D for a summary by subbasin). While this condition can be suspected to be changing for the better, from a fish habitat perspective, on forest lands, it is likely to be remaining a problem in agricultural lands.

In addition, current riparian areas over much of the watershed have been documented to have been removed, or to be in a damaged or degraded state. Resulting bank erosion has also been widely documented (Wampler et al., 1993).

TIMBER HARVESTING

Splash dams for timber transport

Splash dams were used to transport timber to tidewater mills during the 1882-1930 period. There were approximately 100 dams basin-wide. Some dams were built in a series moving downstream, such as those in the Humptulips watershed, and many were used daily. Impacts include: removal of sediments and spawning gravel downstream of dam, migration blockages, destabilized channels, stream cleanouts, and use of regular in-water blasting. Some splash dams in this region were in place for about 20 years, and it is estimated that when in place, splash dams effectively blocked 60 percent of the salmon streams tributary to Grays Harbor (Wendler and Deschamps, 1955).

An additional impact of splash damming was that sloughs, swamps, and low meadows were often blocked off, and wider stream sections had log cribbing added to their banks, to consolidate the main channel. Boulders and logjams were generally removed using dynamite, and small stream channels were often widened as a result of both the flooding from dam operations and erosion of streambed and streambanks by the logs themselves (Sedell and Luchessa, 1981; Van Syckle, 1981). The damage to fish populations as well as to erosion of streambanks was recognized, and splash damming began to be phased out during the 1930's, with many dams finally removed in the 1950's (Wendler and Deschamps, 1955).

Logging railroads and roads

Logging railroads started to be built around 1912 (Simpson Timber and Weyerhaeuser, 1996). A total of 1,095 miles of logging railroad were noted as historically present in Grays Harbor County (Van Syckle, 1981). Because railroad grades were generally restricted to 4% grade or less, they were often laid near or in stream channels. Steams channels were cleaned out and straightened using heavy equipment to protect culverts and trestles. Many railroad grades were eventually converted to road grades, and road networks were extended onto steeper ground (Simpson Timber and Weyerhaeuser, 1996). Stream channels then were at risk of sediment inputs from cut or fill slopes that failed, as well as from road surfaces.

Stream cleanouts for fish passage

Starting in the late 1940’s, and continuing until the 1970's, an additional effort was made in many streams and rivers in Washington and Oregon to remove both instream wood and logging debris. Starting somewhat as a response to damages noted in the splash dam era, these efforts were intended to remove barriers to fish passage (Sedell and Luchessa, 1981).

GRAVEL MINING

Instream gravel mining was most common in the lower reaches of the Chehalis, Humptulips, Satsop, and Wynoochee Rivers, although, it also occurred in many other streams in the watershed. This process started in earnest at the end of the splash dam era, when roads and railroads replaced water transport for logging, and continues today at lowered rates of removal (Hiss and Knusden, 1993). In 1986, it was estimated that in an average year, removal rates (in the four rivers noted above) were 10 times higher than the river's capacity to replenish gravels (Collins and Dunne, 1986). Gravel operations in the Satsop, South Fork Chehalis, Humptulips, and Wynoochee were identified in 1975 to have seriously reduced the available spawning areas for chinook. Operations elsewhere in the Chehalis, particularly in the Newaukum watershed, were felt to have severely affected both chinook and chum populations (Phinney et al., 1975).

DAMS AND DIVERSIONS

The two largest dams in the basin are the Skookumchuck Dam on the Skookumchuck River, and Wynoochee Dam at RM 48 on the Wynoochee River. Skookumchuck Dam was built in 1970, and is a barrier to anadromous fish migration. Steelhead are transported upstream of the dam to spawn (Herger, 1997). Anadromous fish are transported above Wynoochee Reservoir and have access to habitat upstream to Wynoochee Falls (RM 58) (Parton et al., 1997).

WATER QUALITY

This topic is only briefly summarized here. It is discussed in many sources (for example, Chehalis River Council, 1992), and Appendix C of this report.

Low dissolved oxygen levels are identified as a significant problem during warm weather and low flow conditions. The Chehalis River in the "Centralia Reach" and the Black River exhibit stratification, and low dissolved oxygen levels have been observed downstream of Porter (Chehalis River Council, 1992 Pickett, 1994).

While warm summer water temperatures may have been historically present in much of the Chehalis watershed due to low elevations, widespread human activities have removed riparian vegetation and reduced shading levels, thereby contributing to temperature increases (Hiss and Knudsen, 1993).

In addition to direct manipulations of stream channels (diking, ditching, draining), agricultural impacts to fish habitat have included runoff from animal operations and use of agricultural chemicals.

GRAYS HARBOR ESTUARY: HISTORIC AND CURRENT CONDITIONS

This topic is only briefly summarized here. For a more complete discussion, the reader should consult Smith and Wenger (2000), which summarizes research and monitoring changes in industrial discharges during the 1990's.

It has been suspected that water quality in Grays Harbor, particularly in the Inner Harbor, has contributed to poor salmonid population numbers in the past. Suspected or known problems include filling of eelgrass beds in the Inner Harbor (which removed juvenile rearing habitat), industrial discharge from pulp mills, municipal sewage discharge, and non-point source pollution. (Chehalis River Council, 1992). In addition, is it estimated that approximately 30% of the original estuary has been lost to fill (Smith and Wenger, 2000).

FISH HABITAT CONDITIONS SUMMARY

OBJECTIVES

This section presents and summarizes available fish habitat information in the Chehalis Basin. Analyses and conclusions presented are those of the original investigators. See Appendix E for a summary of habitat conditions for each subbasin.

DATA SOURCES

Four of the most important data sources are described below. Other data sources are presented and referenced in the appropriate sections.

Washington stream catalog

This reference, developed in 1975, describes the streams in WRIA 22 and 23, and discusses habitat conditions and problems in a general way (Phinney et al. 1975).

USF&WS/WDFW extensive survey

This report is a resource for ongoing rehabilitation and enhancement activities. The extensive survey identified specific habitat problems in a total of 1,518 stream miles throughout most of the subbasins in the Chehalis watershed upstream of the Humptulips River, and 111 miles of the Chehalis River mainstem. Problems were classified in two ways. A condition noted in a stream reach less than 20 feet long was recorded as a point occurrence, and a situation noted in a reach greater than 20 feet long was recorded as a distance value. Habitat problems were linked to land uses where known (generally harvest practices or agricultural practices), or classed as a situation with unknown causes. Some water quality problems were noted, as well as the presence of beaver dams and water diversions, and in some subbasins, instream woody debris (LWD). Subbasin delineation, and aggregation of data to present results, is similar to, but not always exactly the same as, the subbasin delineation used in this report. Results aggregated by subbasin are presented here as presented by the investigators (Wampler et al., 1993). The data set is archived within a GIS system, and information can easily be extracted for stream reaches of concern in a Level 2 analysis (Hudson, 1993).

The Humptulips, Hoquiam, and Wishkah Rivers and all of the South Bay tributary streams were not included in the extensive survey.

Federal and state watershed analysis reports

Watershed Analysis reports were available for the following subbasins: Chehalis headwaters, Stillman Creek, North Fork and South Fork Newaukum Rivers, West Fork Satsop, Wynoochee, East and West Fork Humptulips, and Wishkah Rivers. These reports are done to assist long-term planning for timber harvest, road, and riparian corridor management on forest lands. Fish habitat and stream channel information is collected by subsampling some stream reaches, and conclusions and recommendations are then drawn for groups of similar stream reaches within the watershed. In some cases, the level of detail of analysis on agricultural lands within the watershed is less than that on forested lands (Raines et al., 1992; Simpson Timber and Weyerhaeuser, 1996; Weyerhaeuser Co., 1994a, 1994b, 1997, 1999; US Forest Service, 1996; Rayonier and US Forest Service, 2000).

Fish habitat concerns identified in these reports were identified at the time of the analysis. One result of watershed analysis is the development of “prescriptions”, which are planning, operational, or remedial actions taken by the landowner to address the problems. It should be recognized that conditions may have changed in the watershed as a result of these prescriptions and the original report(s) be consulted for more information.

T/F/W Ambient Monitoring surveys

A few streams in forested portions of the Chehalis watershed have been surveyed as part of a state-wide data gathering project (T/F/W Ambient Monitoring Project, 1991, 1996). Data summaries and analysis of local and regional conditions have not yet been generated from this data set. Thus, no analysis of this data is presented here.

Washington Department of Ecology (WDOE) data collection

The Dept. of Ecology collected water quality information in the mainstem Chehalis River between Porter and Pe Ell, and a number of tributaries (Pickett, 1994) in support of eventual establishment of a total maximum daily load (TMDL) for several water quality parameters. Summer temperature and dissolved oxygen (DO) findings are summarized briefly here, with respect to general salmonid temperature and dissolved oxygen preferences. Because these samples were collected at different times of day, they cannot be described statistically (for example, as a daily maximum). They are, however, an indication of temperature within the daily range of temperatures. Dissolved oxygen (DO) levels measured are discussed with respect to the generally accepted minimum level of 5.0 mg/L for salmonid fish (Bell, 1991). Another important parameter for salmonids, with respect to DO, is the percent of saturation, which is a function of temperature. Water quality information is discussed in further detail in Appendix C.

WDFW culvert database

The Washington State Dept. of Fish and Wildlife, maintains a database of culvert surveys in each WRIA. Culvert information is standardized state-wide (WDFW, 1998a). WDFW also assesses the amount and quality of fish habitat upstream of many culverts in the database, in order to compare habitat gain with the expense of the culvert upgrade. Culvert status classifications include those that are not barriers, those that need repair, those that are fixed, and those that are barriers with insufficient upstream habitat gain to warrant repair.

In April, 2000 the database contained a total of 296 entries for WRIAs 22 and 23, although not all entries refer to culverts that are barriers. Any summary of this information presented at this point would be misleading. Culvert survey information known to have been collected during 1999 by Lewis County and the Washington Dept. of Transportation has not yet been added, since WDFW is still in their quality assurance and habitat assessment process (B. Benson, WDFW, pers. comm., 2000). This database is a "living document", which can be consulted at a subbasin level as habitat concerns and potential projects are identified, or as part of a Level 2 assessment.

Data Limitations

Problems and situations described in both the USF&WS/WDFW extensive survey and the Watershed Analysis reports are identified as of the date of the survey. Because restoration activities in the Chehalis watershed basin have been ongoing, it should be recognized that some situations may have changed since the survey was done.

SUMMARY OF HABITAT CONDITIONS

While situations vary to some degree between subbasins, some basin-wide patterns are clear. These patterns agree with the conclusions of previous analysts (Hiss and Knudsen 1993, Wampler et al., 1993). As a result of past and present land use practices, stream channels in the Chehalis watershed show a consistent pattern of riparian vegetation removal, shade reduction, and reduction in bank stability leading to erosion and instream sediments. While few measures of existing woody debris levels were found, comparison to historic information and past legal stream cleaning practices point to instream LWD levels to be either non-existent or much lower than historic levels. Information about loss of side channel and wetlands habitats is more anecdotal. However, patterns of timber harvest and agricultural practices have left stream channels in a more simplified state than in pre-settlement periods with less streambank stability, lowered shading levels, and simplified instream habitats with fewer, or no, side- or off-channel habitats available. While summer water temperatures in much of the Chehalis watershed may have been historically high (above preferable for salmonid fish, but sublethal) due to relatively low elevations of many of the stream channels in the basin, riparian vegetation removal, lowered shading levels, and degradation of streambank stability have most likely contributed to increases in the magnitude and range of this problem.

Because of the size of the Chehalis watershed, watershed-wide conclusions are necessarily very general. A more appropriate level of detail is the subbasin level. In some situations, habitat conditions may be in some partial recovery from past damages; this is most likely on forested lands managed under federal or state forest practices where protection of riparian corridors has become the rule during the last few decades. Because little change in protection or restoration of riparian corridors on agricultural lands has occurred in the last few decades, riparian conditions in those land uses rely primarily on the individual landowner's discretion. In those land uses, riparian and stream habitat conditions will vary widely, and no estimation of the amount of recovery of riparian function can be made at this level.

CHEHALIS RIVER MAINSTEM

This summary covers parts of Subbasins, 4, 10, 13, 19 and 30. It is presented separately here because of the importance of this data summary.

USFWS/WDFW extensive survey

The survey summarized here covered 111 river miles from the mouth to the confluence with the Elk Creek and Crim-Rock Creeks subbasins. The lower mainstem survey included Stevens and Elizabeth Creeks, as well as portions of Peel's, Preachers, and Blue Sloughs. The most important habitat problems identified were: for the "lower mainstem" (mouth to the Black River confluence), stream canopy reduced by agriculture (upstream 3/4 of the lower mainstem, stream canopy reduced by other causes), (downstream 1/4 of lower mainstem), and bank erosion (middle 1/3 of lower mainstem); for the "upper mainstem" (Black River confluence to Elk Creek confluence), stream canopy reduced by agriculture (middle ½ of the upper mainstem), streamside vegetation loss, cause unknown (upstream 1/4 of upper mainstem), and bank vegetation destruction by livestock (middle 1/3 of upper mainstem).

Summary of the most important degradations are given for the entire reach surveyed:
reduced tree canopy from agriculture, forest practices and other causes (9 points and 104.1 miles), livestock access (1 point and 7.7 miles), bank vegetation destruction or loss from agriculture and unknown causes (52 points and 22.2 miles), damage from livestock access (7.74 miles), bank erosion (69 points and 24.1 miles), riprap, dumping, and artificial bank protection (65 points and 8.1 miles), and excessive instream sediments (7.4 miles).

In the lower mainstem, beaver dams were noted in Stevens and Elizabeth Creeks. A total of 40 known and suspected water withdrawals were also noted. One waste-water outfall and 7 miscellaneous pollution input sources were noted (Wampler et al., 1993).

Off-channel habitat survey

A 7-mile stretch of the lower Chehalis River floodplain, from the Wynoochee to the Satsop Rivers, was surveyed to identify and inventory off-channel habitats with potential for restoration for juvenile coho overwintering habitat, by reconnecting to the river(s) (Ralph et al., 1994). The lower five miles of the Satsop and Wynoochee Rivers were also surveyed. The large tidal sloughs in the lower 12 miles of the Chehalis mainstem were not evaluated as part of this survey. A total of 28 potential restoration sites were identified. Summaries include general site description, characters of ponded areas, riparian vegetation, aquatic vegetation, inlets and outlets, and restoration and enhancement recommendations (Ralph et al., 1994).

Collins and Dunne (1986) estimate that the rate of gravel removal in the reach between RM 2-11 exceeded the replenishment rate for the three decades prior to 1986, by a factor of 10. Channel downcutting was estimated to be 0.1 foot/year.

WDOE surveyed the mainstem Chehalis River from the Porter Bridge upstream to Pe Ell during 1991 and 1992. Previous studies had documented areas of low dissolved oxygen in the "Centralia Reach" (between the Newaukum and Skookumchuck Rivers). Surveys showed that thermal stratification was present during the summer months in the Centralia Reach, and that deeper waters contained very low, or no, dissolved oxygen (Pickett, 1994). For this study, a total of 45 mainstem sites, between River Mile (RM) 33.8 and RM 108.2, were sampled and are summarized in Table D-3. Summer temperatures were often above the water quality standard of 18 ^{o} C, and in places were found to be 26.6 ^{o}C (Pickett, 1994). While this lower value is tolerated by most salmonid fish, the higher value is above the upper lethal limits of 24.4 - 25.5 ^{o}C for many salmonid species. In addition, low dissolved oxygen levels in some cases are below generally acceptable limits (5 mg/L) (Bell, 1991). In addition, sublethal impacts of warmer summer temperatures can include higher predation success by warmwater species (such as bass) on salmonid juveniles.

Table D-3. Summary of range of water temperatures sampled in the Chehalis River during summer 1991 and 1992 by WDOE. For further information consult the source (Pickett, 1994).

Sampling site (RM)	Temperature range sampled (^oC)	Dissolved oxygen range sampled (mg/L)	Comments
108.2	16.4-17.7	9.4-10.7	@ Pe Ell water intake
106.3	14.4-18.1	9.2-10.8	SR 6 bridge
100.5	15.4-22	8.3-10.6	@ Elk Cr. Rd. nr Doty
97.9	17.8	8.5-10.3	@ Dryad
94.4	18.1-18.2	9.3	Meskill Br.
90.1	18.0-20.12	7.5-9.0	Above Ceres Rd. Br.
90.0	15.8-22.5	7.5-8.8	@ Ceres Rd. Br.
81.0	16.8-20.3	8.1-8.7	@ Adna, SR 6 Br.
77.6	19.9-21.2	7.3-9.1	@ SR 603 Br. nr Claquato
74.9	22.6-23.4	8.2-8.5	Ab. SR 6 Br. nr Chehalis
74.6	16.8-22.3	7.1-8.7	@ SR 6 Br. nr Chehalis
73.6	17.4-25.5	0.5-9.0	
72.5	17.9-25.7	6.9-8.8	Ab Golf Course intake
72.3	17.4-23.4	6.1-9	Blw Golf Course intake
70.7	17.6-25.9	0.1-8.6	North of airport
69.6	17.2-24.4	0.1-8.5	
69.1	13.1-24.4	0.1-8.8	Blw Salzer Cr.
68.6	17.3-24.4	2.6-9.9	
67.5	18.7-26.2	0.1-10.3	@ Mellen St. Br.
64.2	17.1-20.4	6.6-9.3	@ Galvin Rd. Br.
59.9	15.9-23.2	6.9-10.0	Nr Grand Mound (Prather Rd.)
54.2	15.8-21.3	8.3-10.2	@ Independence Br.
44.0	21.4-22.5	8.5-11.5	@ Sickman Ford Br.
33.8	17.3-20.0	7.9-10.6	@ Porter Rd. Br.

SUBBASIN 1. CHEHALIS RIVER HEADWATERS

USFWS/WDFW extensive survey

Two USFWS/WDFW survey summaries lie within this subbasin. A total of 28 stream miles were surveyed in their **"Upper Chehalis"** subbasin, including the upper Chehalis mainstem, upstream of the Rogers Creek confluence, the East and West Forks, Thrash and Cinnabar Creeks. The most important problems identified were: stream canopy and streambank vegetation loss from forest practices (8 points and 13.9 miles) (West Fork, East Fork, and mainstem Chehalis), bank erosion (56 points and 7.8 miles) (Cinnabar Creek, EF Chehalis River), and debris torrent inputs to stream channels (6 points). Few beaver dams were found at the time of the survey. Three water withdrawals were noted (Wampler et al., 1993).

A total of 42 miles were surveyed in their **"Crim-Rock"** subbasin, including the mainstem Chehalis from Rogers Creek downstream to Rainbow Falls, Crim, Big, Rock, and McCormick Creeks. The most important problems identified were: bank erosion (124 points and 19.6 miles) (lower Chehalis, McCormick Creek, Rock Creek, upper Crim Creek), streamside vegetation loss from agriculture and unknown causes (39 points and 12.1 miles) (lower Chehalis River, lower Rock Creek, lower McCormick Creek, mid-Crim Creek), and streamside canopy reduction from forest practices (7 points and 6.3 miles) (Crim Creek, Big Creek, upper Chehalis River). Beaver dams were noted in upper Rock and McCormick Creeks. A total of ten water withdrawals were noted as well as 3 miscellaneous pollution input sources (Wampler et al., 1993).

A portion of this subbasin was included in the **Chehalis Headwaters Watershed Analysis** (Weyerhaeuser Co, 1994). The analysis area included 44,920 acres in the Chehalis River headwaters, upstream of the Town of Pe Ell (Weyerhaeuser Co., 1994). Prior to 1930, splash dams were operated on the mainstem Chehalis above Fisk Falls, and below Crim Creek (Wendler and Deschamps, 1955). Between the 1960's and the 1970's, stream cleaning operations removed LWD from most of the larger streams in this subbasin, except Cinnabar Creek (Weyerhaeuser Co., 1994).

Habitat concerns identified in the watershed analysis include the potential for warm summer temperatures to create adverse conditions for holding spring chinook in the mainstem Chehalis, as well as the potential for legal and illegal fishing to reduce numbers of adult chinook in the same reach, waiting to spawn. Nearly half of the stream channels (47%) had canopy closures lower than that estimated to protect water temperature, including all of the mainstem Chehalis River, and portions of the East Fork, West Fork, and reaches of Crim, Thrash and Cinnabar Creeks. (The lower mainstem is wide enough to limit the degree to which riparian canopy can contribute to thermal reduction.)

Warm summer temperatures also reduce the quality of summer rearing habitat for juvenile fish. Riparian conditions were fairly good over most of the watershed, with mature, dense stands of mixed conifers and hardwoods present over much of the basin. At this time, tree sizes along some of the larger streams are too small to function effectively as LWD, although long-term prospects are good. There is a general lack of in-channel LWD in this subbasin, which limits refuge habitat, holding pool frequency, and depth. This was identified as a problem in areas used by chinook, as well as in areas used by coho and steelhead (Weyerhaeuser Co., 1994).

T/F/W Ambient Monitoring Survey

A stream survey was done in Sage Creek (23.1195) (0.3 miles), Thrash Creek (23.1186) (0.3 miles), Big Creek (23.1179) (0.2 miles), and the mainstem Chehalis River (RM 120.9) (T/F/W Ambient Monitoring, 1996).

SUBBASIN 2. ELK CREEK

USFWS/WDFW extensive survey

A total of 43 stream miles were surveyed in their **"Elk Creek"** subbasin, including the mainstem of Elk Creek and portions of Nine, Seven, Eight, Ludwig, Smith, Swem, Fourth, and Little Elk Creeks. The most important habitat problems identified included: bank erosion (89 points and 27.7 miles) (Elk, Nine, Swem and Smith Creeks), stream canopy reduction from forest practices (6 points and 11.6 miles)(Elk, Smith and Ludwig Creeks), and excessive levels of instream sediments (11 pointsand 9.9 miles) (Ludwig, Eight, upper Nine, and mid-Elk Creeks). Most of the beaver dams noted in the survey were in upper Elk, Smith, and Swem Creeks. A total of 7 water withdrawals and one waster water outfall were noted (Wampler et al., 1993).

WDOE recorded summer temperatures in Elk Creek in the 14 - 17 ^{o}C range, within the preferred range for most salmonid fish (Pickett, 1994; Coutant, 1977). DO levels were good, in the 9.0 - 10.7 mg/L range (Pickett, 1994).

SUBBASIN 3. SOUTH FORK CHEHALIS

USFWS/WDFW extensive survey

A total of 113 stream miles were surveyed in their **"South Fork Chehalis - Stillman"** subbasin, including the mainstem South Fork; Lake, Barney, and Deep Creeks; Beaver, Lost Valley, Halfway, Keller, Slide, Stillman, and Raccoon Creeks; and Cedar, Laughin, Black, Trout, Deer, and Hanlan Creeks. The most important habitat problems identified were: bank erosion (291 points and 55.9 miles) (mid- and upper South Fork, Stillman and Halfway Creeks), streamside vegetation loss or destruction and stream canopy reduction (153 points and 36.6 miles) (mid-and lower South Fork, lower Stillman Creek tributaries, mid-Lake Creek), excessive instream sediments (12 points and 37.2 miles) (northern half of subbasin), and impacts from livestock access to streams (12 points and 23.4 miles) (mid-South Fork, mid-Lake Creek, lower Stillman Creek tributaries). Impacts were seen within both forested and agriculture land uses. Beaver dams were present in low numbers throughout the basin with the exception of Lake Creek, where they were more numerous. A total of 31 known or suspected water withdrawals were noted, as well as 14 miscellaneous pollution input sources (Wampler et al., 1993).

WDOE recorded summer temperatures in the SF Chehalis in the 17 - 20 ^{o}C range. At 20 ^{o}C, some salmonid fish exhibit avoidance behavior, if cooler water is available ("avoidance temperature") (Coutant, 1977). DO levels were good, in the 6.8 - 8.5 range (Pickett, 1994).

For this analysis, we have grouped lower Stillman Creek into Subbasin #4, Upper Chehalis River.

SUBBASIN 4. UPPER CHEHALIS RIVER

This subbasin includes the Chehalis River mainstem, as well as Stearns, Lake, lower Stillman, Bunker, Capps, Absher, Markesian, Dell, Garrett, Prairie, Deep, Van Ornum, Mill, Coal, and Scammon Creeks. Information for the Chehalis River mainstem is presented above. Information for tributary streams is presented here and in other sections. USFWS extensive survey results for Stillman Creek are summarized as part of the South Fork Chehalis subbasin (#3).

USFWS/WDFW extensive survey

Two USFWS/WDFW survey summaries lie within this subbasin. A total of 20 stream miles were surveyed in their **"Stearns"** subbasin, including Stearns and West Fork Strearns Creeks, and several unnamed tributaries. The most important habitat problems identified were: streamside vegetation loss, unknown causes (17.5 miles) (widespread in subbasin), bank erosion (43 points and 11.8 miles) (Stearns Creek, WF Stearns), bank vegetation destruction (48 points and 0.04 mile) (WF Strearns, tributary 0943), and livestock access to stream (3 points and 5.1 miles) (WF Strearns, tributary 0943). Some beaver dams were noted in the subbasin, mostly in the west fork and in two headwater tributaries. Four known or suspected water withdrawals were noted, as well as 1 miscellaneous pollution input source (Wampler et al., 1993).

A total of 47 stream miles were surveyed in their **"Scammon"** subbasin, including portions of Hope, Absher, Copps, Dunn, Marcuson, Dell, Garrett, Bunker, Deep, Van Ornum, Mill, Coal, and Scammon Creeks. The most important habitat problems identified included: streamside vegetation loss, agriculture and unknown causes (46 points and 28.3 miles) (Bunker, Deep, Marcuson, Mill Creeks), livestock access to streams (2 points and 12 miles) (Deep, Marcuson, Bunker and Mill Creeks), and bank erosion (100 points and 22.9 miles) (Bunker, Hope and Deep Creeks) Beaver dams were noted in Bunker, Deep, Garrett, Dell, Marcuson, and Hope Creeks at the time of the surveys. A total of 27 known or suspected water withdrawals and 2 miscellaneous pollution input sources were noted (Wampler et al., 1993).

WDOE recorded summer temperatures in Bunker Creek in the 15 -17.5 ^{o}C range, within the preferred range for most salmonid fish. Temperatures in Stearns Creek were in the 15 - 19 ^{o}C range; the upper end of this range is above salmonid preferred temperatures. Scammon Creek temperatures were recorded as 17.4 ^{o}C (Pickett, 1994; Coutant, 1977). DO levels in Bunker Creek were poor, ranging from 3.3 - 5.4 mg/L. DO levels in Stearns Creek were good, ranging from 6.5 - 7.4 mg/L. DO levels in Scammon Creek were also poor, with one measurement of 5.6 mg/L.

A portion of this subbasin was included in the **Stillman Creek Watershed Analysis (**Weyerhaeuser Co., 1994b). The analysis area included Stillman Creek upstream of the confluence with the South Fork Chehalis. Habitat conditions identified included good spawning habitat in lower Slide, Keller, Halfway, and upper Stillman Creek upstream of Racoon Creek; and less abundant spawning habitats elsewhere. Illegal fishing, especially of holding spring chinook, was also identified as a problem. LWD is in short supply throughout most of the

WAU, contributing to a low pool frequency, although, pool percentages were high. Pool habitat was generally shallow and lacking in overhead cover. Near-term recruitment potentials for LWD were poor to fair. Potential concerns with water temperature exist for 37% of this subbasin, where existing shading is less than desired. The majority of these areas are located in the northern third of the watershed, where land use is agricultural. Lost Creek is known to experience extreme low summer flow problems. In 1972, 1986, and 1990 large floods deposited substantial quantities of logs and debris in jams along the lower portion of the Stillman Creek mainstem (Weyerhaeuser Co., 1994b).

SUBBASINS 5,6,7. SOUTH FORK NEWAUKUM, NORTH FORK NEWAUKUM, NEWAUKUM RIVERS

SFWS/WDFW extensive survey

A total of 125 stream miles were surveyed in their **"Newaukum"** subbasin, including Newaukum Creek; South Fork Newaukum, Lost, Kearney, Beaver, Bernier, and Frase Creeks; the Middle Fork Newaukum; the North Fork Newaukum, Lucas, and Mitchell Creeks. The most important habitat problems identified were: streamside vegetation loss from unknown causes (5 points and 42.9 miles) (Newaukum, NF Newaukum, Lucas Creek, SF Newaukum), bank erosion (302 points and 28.8 miles) (Newaukum, MF Newaukum, NF Newaukum, SF Newaukum), stream canopy reduction and bank vegetation loss from forest practices (28 points and 17.23 miles) (upper NF Newaukum tributaries, Lucas Creek, SF Newaukum tributaries), and bank vegetation reduction and other damage from livestock (78 points and 13.9 miles) (SF Newaukum tributaries, MF Newaukum, lower North Fork Newaukum, Allen Creek). Beaver dams were noted in Lucas Creek, portions of the middle Fork and in some South Fork tributaries, but were not common in other subbasin streams at the time of the survey. A total of 33 known or suspected water withdrawals were noted, as well as 11 miscellaneous pollution input sources (Wampler et al., 1993).

WDOE recorded summer temperatures in the South Fork Newaukum in the 15.8 - 19.1 ^{o}C range, and in the 15.5 - 19.2 ^{o}C range in the North Fork Newaukum. The upper end of this range is above salmonid preferred temperatures (Pickett, 1994; Coutant, 1977). Summer temperatures in the Newaukum River at the mouth were recorded in the 16.6-21.2 ^{o}C range. The upper end of this range is at the upper avoidance temperature reported for salmonid fish (Coutant, 1977). DO levels in both forks and the mainstem of Newaukum Creek were good, ranging from 8.3 - 10.3 mg/L (Pickett, 1994).

A portion of this subbasin was included in the **Upper North Fork and Upper South Fork Newaukum Watershed Analysis** (Weyerhaeuser Co., 1999). Analysis area included: the upper North Fork and upper South Fork Newaukum Rivers (50,235 acres). Lowered amounts of in-channel LWD were noted, primarily due to past management practices. Current shading levels were found to be on target for protection of water temperatures, except for the agricultural areas in the lower North Fork subbasin. Thirteen potential fish passage barriers at culverts were identified, as well as natural passage barriers in steeper sections of the main stems and their tributaries. Lack of in-channel LWD in some stream reaches has produced lowered pool depths and frequency, and lack of cover. Future recruitment potential for LWD was good over much of these basins, and was identified as a problem in 20% of the riparian areas. Pool filling and deposition of fine sediments was noted in some channel types, and much of the watershed has fine sediments delivered from road erosion, and potentially delivered from areas with high hazard ratings for landslides.

SUBBASIN 8. SALZER CREEK

USFWS/WDFW extensive survey

A total of 37 stream miles were surveyed in their **"China- Centralia"** subbasin, including Dillenbaugh, Berwick, Salzer, Coal, and China Creeks. The most important habitat problems identified were: livestock access to stream (2 points and 24 miles) (Salzer, mid-Coal, lower Dillenbaugh, and lower Berwick), stream canopy reduced by agriculture, forest practices, and other causes (3 points and 34.2 miles) (upper China, upper Salzer, lower Dillenbaugh, lower Berwick), excessive streambed sediment (2 points and 16.8 miles) (upper China, Salzer, Coal), streamside vegetation loss or destruction (23 miles) (lower Salzer, Dillenbaugh), and bank vegetation destruction (42 points and 4.5 miles) (Salzer, mid-Coal, mid-Dillenbaugh, lower Berwick). A few beaver dams were noted during the survey, mostly in upper Salzer Creek. Nineteen known or suspected water withdrawals were noted, as well as 2 wastewater outfalls, 9 miscellaneous pollution input sources and one source of suspected poor water quality (Wampler et al., 1993).

WDOE recorded summer temperatures in Dillenbaugh Creek in the 14 - 16 ^{o}C range (at LaBree Road) and in the 17 - 18.6 ^{o} C range (above the mouth and near I-5). This latter temperature is above preferred temperatures, but below avoidance temperatures. Temperatures in Berwick Creek were recorded in the 15 - 16.6 ^{o} C range, and Coal Creek temperatures in the 14 - 16 ^{o}C range. Temperatures in China Creek- 16.1 ^{o}C. These last three measurements are within the salmonid preferred temperature range. Temperatures in Salzer Creek (at Airport Road) were in the 15 - 19.2 ^{o} C range. The upper end of this range is at the upper avoidance temperature reported for salmonid fish (Pickett, 1994; Coutant, 1977).

DO levels in Dillenbaugh Creek at LaBree Road were good (9.3-9.4 mf/L), but were poor both at the mouth and at I-5 (2.1 - 3.1 mg/L). Berwick and Coal Creek DO levels were fair to good (6.3 - 7.9 mg/L and 6.7 - 8.3 mg/L, respectively). China Creek DO levels were good (10.3 mg/L). Salzer Creek DO levels, at Airport Road were very poor (<1 - 6.4 mg/L) (Pickett, 1994).

For this analysis, Coal, Dillenbaugh, and Berwick Creeks are part of Subbasin 10, Chehalis River Middle Reach 1.

SUBBASIN 9. SKOOKUMCHUCK RIVER

USFWS/WDFW extensive survey

A total of 110 stream miles were surveyed in their **"Skookumchuck"** subbasin, including the Skookumchuck River, Hanaford, North and South Hanaford, Packwood, Snyder, Coal, Salmon, Johnson, Thompson, Bloody Run, Baumgard, Plenty, and Eleven Creeks. The most important habitat problems identified were:

stream canopy reduced by agriculture (16 points and 45 miles) (lower ½ of subbasin), livestock access to streams and bank vegetation destruction (103 points and 53.6 miles) (lower ½ of subbasin), excessive instream sediments (11 points and 30 miles) (tributaries in lower ½ of subbasin), and bank erosion (180 points and 20.8 miles) (Thompson, Johnson and Salmon Creeks, upper Hanaford Creek). Beaver dams were fairly uncommon throughout the watershed, and were most common in Packwood, Hanaford, and Thompson Creeks. A total of 23 known or suspected water withdrawals were noted, as well as 15 miscellaneous pollution input sources or suspected sources of poor water quality (Wampler et al., 1993).

Summer temperatures in the Skookumchuck River above Hanaford Creek were recorded in the 14-18.6 ^{o}C range, and in the 17 - 20.4 ^{o}C range at the mouth. Hanaford Creek temperatures were in the 15.5 -19 ^{o}C range. The upper end of this range is above preferred salmonid temperatures and approaches the upper avoidance temperature reported for salmonid fish (Pickett, 1994; Coutant, 1977).

DO levels in the Skookumchuck River, both above Hanaford Creek and at the mouth, were good (8.9 - 11.0 mg/L). Hanaford Creek DO levels were fair to good (5.9-7.3 mg/L) (Pickett, 1994).

A portion of this subbasin was included in the **Upper Skookumchuck Watershed Analysis (**Weyerhaeuser Co., 1997). The analysis area included the area upstream of Skookumchuck Dam, including the reservoir. Most stream channels are fairly high gradient and confined. Rearing areas in the form of lowland areas, beaver ponds, and side channels are not common features in this WAU. Accumulation of fine sediments was rare, and not considered a problem in terms of pool filling or intrusion into redds. Local areas vulnerable to inputs from surface erosion or mass wasting have been mapped. Lack of LWD is common throughout this WAU. Habitat concerns at most life history phases are associated with the lack of LWD. Human-caused barriers included Skookumchuck Dam and culverts. Generally, water temperatures are not considered a problem. Approximately 1/3 of streams in the WAU have shading levels less than desirable: these streams include the lower mainstem and headwaters of the Skookumchuck, and portions of Laramie, Eleven, Three Deer, Drop, and Bigwater Creeks. One splash dam was operated in the past (1/2 mile upstream of the existing Skookumchuck Dam). The channel downstream of that location is now within the reservoir. The construction of Skookumchuck Dam in 1970 eliminated natural access of anadromous fish, and inundated historical spawning habitat for coho and chinook. Populations of steelhead above the dam are maintained by hauling adult fish above the dam (Weyerhaeuser Co., 1997).

SUBBASIN 10. CHEHALIS RIVER MIDDLE REACH 1

USFWS/WDFW extensive survey

A total of 63 stream miles were surveyed in their **"Independence-Lincoln"** subbasin, including portions of Independence, Lincoln, and Wildcat Creeks. The most important habitat problems identified included: livestock access to stream (2 points and 21.3 miles) (lower and mid-Lincoln Creek, independence Creek tributaries), streamside vegetation loss and bank vegetation destruction (60 points and 24.5 miles) (lower Lincoln Creek, Independence Creek and tributaries), bank erosion (112 points and 14.4 miles) (upper Lincoln Creek, Independence Creek tributaries), and excessive instream sediment (2 points and 11.7 miles) (lower Lincoln Creek, Independence Creek tributaries). Beaver dams were fairly widespread in Independence Creek at the time of the survey, only a few dams were noted in Lincoln Creek, mostly in the headwaters. A total of 20 known or suspected water withdrawals and 13 miscellaneous pollution sources were noted (Wampler et al., 1993). WDOE recorded summer temperatures in Lincoln Creek 15 - 19 ^{o}C range. Independence Creek temperatures were recorded in the 13.6- 17 ^{o}C range. Lincoln Creek high temperatures are above preferred salmonid maximums, while Independence Creek temperatures were mostly within the range of salmonid preferred temperatures (Pickett, 1994; Coutant, 1977).

DO levels in Lincoln Creek were poor (3.9-5.6 mg/L). Independence Creek DO levels were also poor (4.1-5.6 mg/L) (Pickett, 1994).

USFWS extensive survey results for Coal, Dillenbaugh, and Berwick Creeks are summarized with Salzer Creek (Subbasin #8).

SUBBASIN 11. BLACK RIVER

USFWS/WDFW extensive survey

A total of 88 stream miles were surveyed in their **"Black"** subbasin, including the Black River, Mima, Waddell, Dempsey, Salmon, Allen, and Beaver Creeks, and Blooms Ditch. The most important habitat problems identified were: livestock access to streams (6 points and 23.9 miles) (Beaver, Dempsey, Mima, and Allen Creeks, Blooms Ditch, and the Black River), streamside canopy reduced by agriculture (2 points and 18 miles) (lower Black River, lower Mima Creek, Beaver Creek, Allen Creek, Dempsey Creek), streamside vegetation loss from unknown causes (1 point and 16.7 miles) (Salmon and Allen Creeks, Blooms Ditch), bank erosion (82 points and 7.2 miles) (Waddell, Salmon and Mima Creeks), and bank destruction by livestock (73 points and 6.2 miles) (Mima Dempsey, Beaver and Allen Creeks, Blooms Ditch, lower Black River). Beaver dams were present throughout the basin, although, somewhat more common in Mima and Waddell Creeks. Twenty-eight known or suspected water withdrawals were noted, as well as 9 miscellaneous pollution input sources (Wampler et al., 1993).

WDOE recorded summer temperatures in the 15 -21 ^{o}C range in the Black River (at Howanut Road Bridge). The upper temperature measured is at salmonid avoidance temperatures, and is at a value where salmonid adult upstream migration has been seen to be blocked by temperature conditions (Coutant, 1977; Bell, 1991). DO levels measured were all in the good range (7.9-12 mg/L) (Pickett, 1994).

A stream survey was done in an unnamed tributary (23.0661) (0.3 miles) (T/F/W Ambient Monitoring, 1996).

SUBBASIN 12. CEDAR CREEK

USFWS/WDFW extensive survey

A total of 38 stream miles were surveyed in their **"Gibson- Cedar"** subbasin, including portions of Gibson, Thurston, Cedar, Shelton, and Sherman Creeks. The most important habitat problems identified were: livestock access to streams (2 points and 2.5 miles) (lower Cedar Creek), streamside vegetation loss from unknown causes (6 points and 2.2 miles) (Cedar, Shelton and Sherman Creeks), bank erosion (52 points and 0.6 miles) (Cedar and Sherman Creeks), and miscellaneous pollution input sources (12 points) (upper Cedar, Sherman, extreme lower Cedar Creek). Beaver dams were present in the subbasin, but not in large numbers during the survey. A total of three known or suspected water withdrawals were noted (Wampler et al., 1993).

WDOE recorded summer temperatures in Cedar Creek in the 14 - 15.6 ^{o}C range, within salmonid preferred temperatures (Pickett, 1994; Coutant, 1977). DO levels is Cedar Creek were good (9.2-10.4 mg/L) (Pickett, 1994).

A stream survey was done in Lost Valley Creek (23.0581) (0.3 miles), and two in Sherman Creek (23.0579)(0.5 miles) (T/F/W Ambient Monitoring, 1996).

SUBBASIN 13: CHEHALIS RIVER - MIDDLE REACH 2

This subbasin contains the mainstem Chehalis between Porter and just upstream of the Prairie Creek confluence, and includes Porter, Rock, Scatter, Prairie, and Garrard Creeks. Information collected in the mainstem Chehalis River is presented in a previous section. This section presents information for the tributary streams.

USFWS/WDFW extensive survey

Three USFWS/WDFW survey summaries lie within this subbasin. A total of 27 stream miles were surveyed in their **"Porter"** subbasin, including Porter, NF and SF Porter, and Marcy Creeks, and two unnamed tributaries. The most important habitat problems identified were: bank vegetation loss from forest practices (1 point and 2.9 miles) (mid-Porter, Marcy, tributary 0548), bank erosion (72 points and 2.6 miles) (Porter Creek, tributaries 0548 and 0547), streamside vegetation loss from unknown causes (2.1 miles) (lower 1/3 of subbasin), and bank vegetation destruction by livestock (23 points and 0.12 miles) (lower Porter Creek, tributary 0547). Beaver dams were not common in this subbasin at the time of the survey. Two water withdrawals were noted, and one miscellaneous pollution input source (Wampler et al., 1993).

A total of 31 stream miles were surveyed in their **"Scatter Creek"**subbasin, including Scatter and Prairie Creeks. The most important habitat problems identified were: stream canopy reduced by agriculture (1 point and 17.6 miles) (Scatter Creek), livestock access to stream (1 point and 11.7 miles) (Scatter Creek, upper Scatter Creek tributary 0719), excessive instream sediments (2 points and 8.5 miles) (mid-Scatter Creek, Prairie Creek), streamside vegetation loss (4 points and 13.2 miles) (Prairie Creek, lower Scatter Creek, tributary 0719), and bank vegetation destruction by livestock (34 points and 3.1 miles) (Scatter Creek). Some beaver dams were noted during the survey, mostly in mid-Scatter Creek. A total of 6 known and suspected water withdrawal were noted, as well as one pollution input source and one suspected source of poor water quality (Wampler et al., 1993).

A total of 53 stream miles were surveyed in their **"Rock-Garrard"** subbasin, including portions of Garrard, Bloomquist, Williams, Rock, and Gaddis Creeks. The most important habitat problems identified included: bank erosion (116 points and 11.5 miles) (upper Garrard, Williams and Gaddis Creeks), livestock access to streams (5 points and 9.4 miles) (Garrard and Williams Creeks), streamside vegetation loss, bank vegetation destruction, and reduced tree canopy (86 points and 8.2 miles) (mid-Rock Creek, upper Williams Creek, Garrard Creek), and excessive instream sediments (5 points and 9.6 miles) (Gaddis and Williams Creeks, SF Garrard Creek). Beaver dams were present in Gaddis and Upper Williams Creeks, as well as in Bloomquist Creek and another small Garrard Creek tributary, at the time of the survey. Twelve water withdrawals and 7 miscellaneous input or suspected pollution inputs were noted (Wampler et al., 1993).

WDOE measured summer temperatures in Scatter Creek in the 15 -21 ^{o}C range. The upper temperature measured is at salmonid avoidance temperatures, and is at a value where salmonid adult upstream migration has been observed to be blocked by temperature conditions (Coutant, 1977; Bell, 1991). Garrard Creek summer temperatures were measured in the 14 - 18.3 ^{o}C range. The higher temperatures observed are above preferred salmonid maximums. Rock Creek temperatures were 14.4- 14.7 ^{o}C, within salmonid preferred temperatures (Pickett, 1994; Coutant, 1977).

Scatter Creek DO levels, measured above the mouth, were good (11.9-14 mg/L), as were DO levels in Garrard Creek (6.4-8.3 mg/L). Rock Creek DO levels were good (8.2-8.4 mg/L) (Pickett, 1994).

WDOE recorded summer temperatures in Porter Creek in the13 - 14 ^{o} C range, within salmonid preferred temperatures (Pickett, 1994; Coutant, 1977). However, these are all morning samples and probably more indicative of mean or minimum temperatures than maximums. DO levels in Porter Creek were also good (9.6-9.7 mg/L) (Pickett, 1994).

Extensive survey results for Independence Creek are summarized with those for Lincoln Creek, in Subbasin #10. Results for Gibson Creek are summarized with Cedar Creek in Subbasin #12.

Thurston Conservation District habitat survey

Thurston Conservation District staff surveyed 4.26 miles of Scatter Creek during 1999, in order to describe fish habitat conditions as part of the development of a Habitat Conservation Plan. Data from that survey may be available by Fall, 2000 (J. Coffing, TCD, pers. comm., 2000).

SUBBASIN 14. CLOQUALLUM CREEK

USFWS/WDFW extensive survey

A total of 94 stream miles were surveyed in their **"Newman - Cloquallum"** subbasin, including Newman, Vance, Cloquallum, Wildcat, Bush, Mox-Chehalis, and Sand Creeks. The most important habitat problems identified were: streamside vegetation loss from unknown causes (1 point and 41.8 miles) (widespread), excessive instream sediments (12 points and 16 miles) (Vance, Sand, Bush and upper Newman Creeks), bank erosion (173 points and 10.5 miles) (Cloquallum, Mox Chehalis and Wildcat Creeks), and bank riprap/artificial protection or dumping (108 points and 2.2 miles) (Wildcat, lower and mid-Cloquallum and Vance Creeks). Beaver dams were present in the basin in moderate numbers at the time of the survey. A total of

22 known and suspected water withdrawals were noted, as well as 2 wastewater outfalls and 22 miscellaneous pollution input sources (Wampler et al., 1993).

Newman and Vance Creeks are grouped in our subbasin 19, below.

SUBBASIN 19. CHEHALIS RIVER LOWER REACH 1

This subbasin includes the mainstem Chehalis River between the Satsop River and Porter Creek, including Workman Delezene, Newman, and Vance Creeks. USFWS extensive survey data for the mainstem Chehalis River is presented above.

USFWS/WDFW extensive survey

A total of 42 stream miles were surveyed in their **"Workman Delezene"** subbasin, including portions of Workman, Delezene, and Eaton Creeks and two unnamed tributary creeks. The most important habitat problems identified included: stream canopy reduction from forest practices (1 point and 23.3 miles) (Workman, Delezene, Eaton Creeks), excessive sediments in streambed (1 point and 16.2 miles) (Workman, mid- and lower Delezene, upper Eaton Creeks), stream canopy reduction from agriculture (9 points and 5.3 miles) (upper Eaton, lower Delezene, lower Workman), and bank erosion (53 points and 0.3 miles) (Workman and Delezene Creeks). Beaver dams were fairly widespread across this subbasin at the time of the survey. A total of 4 known or suspected water withdrawals and 6 known or suspected pollution input sources were also noted (Wampler et al., 1993).

Habitat survey results for Vance and Newman Creeks are summarized with Cloquallum Creek, our Subbasin #14.

SUBBASIN 20. WYNOOCHEE RIVER

USFWS/WDFW extensive survey

A total of 160 stream miles were surveyed in their **"Wynoochee"** subbasin, including the Wynoochee River, Sylvia, Wedekind, Black, Helm, Anderson, Schafer, and Hell Creeks. The most important habitat problems identified were: bank erosion (219 points and 71.65 miles) (major tributaries from Black Creek to Schafer Creek and adjacent reaches of the mainstem Wynoochee), excessive instream sediments (17 points and 3.5 miles) (tributaries in lower 1/3 of basin), stream canopy reduced by forest practices (24 points and 28 miles) (Black, Wedekind and Sylvia Creeks), and beaver dams potentially partially passable (35 points) (tributaries in lower ½ of subbasin). Beaver dams were present throughout the basin at the time of the survey, and present in Black, Sylvia, and Wedekind Creeks in the highest numbers. Fifteen known and suspected water withdrawals were observed, as well as 5 miscellaneous pollution input sources (Wampler et al., 1993).

A portion of this subbasin was included in the **Wynoochee Watershed Analysis** (USFS, 1996). The analysis area included the watershed upstream of Save Creek. The analysts concluded that instream habitats have been simplified through reduced recruitment of LWD, removal of instream LWD, increased inputs of coarse and fine sediments, and road placement in or near stream channels and floodplains. Streams identified to be in moderate condition with stable or improving trends in habitat quantity and quality included Save Creek, Anderson Creek, Middle Wynoochee River tributaries, Upper Wynoochee, and Wynoochee Lake tributaries. Streams identified to be in fair to poor condition with unstable or declining trends in habitat quantity and quality: Trout Creek, Harris Creek, Big Creek, West Branch Wynoochee, and the North Fork West Branch Wynoochee (USFS, 1996).

A portion of this subbasin was included in the **Sylvia Creek watershed fish and habitat inventory** (City of Montesano, 1994, 1995). Sylvia Creek is accessible to anadromous fish for the first 4.7 miles. Resident fish are found upstream of this point. Lower Sylvia Creek was found to have predominantly pool habitat, with qualities that make for good rearing habitat. Little spawning gravels were found, and it was noted that native soils are gravel poor. The report notes that the East Fork /Sylvia Creek has “received protection from logging” for over the last 75 years, although the lower 1 mile was scoured in 1990 during a road fill failure. The West Fork has been logged in the past over a “a substantial portion” of its length (City of Montesano, 1994, 1995).

SUBBASIN 25. HUMPTULIPS RIVER

Fish habitat has been assessed in the East Fork and WF Humptulips Rivers upstream of their confluence as part of the **East/West Humptulips watershed analysis** (Dieu and Martin, 2000; Martin and McConnell, 2000). Spawning gravels were found in adequate amounts in the anadromous zones. Substrate embeddedness was found to be high in O’Brien Creek and the West Fork Humptulips. The relative amount of pool habitat available for summer rearing was high in both upper mainstems and in several tributaries with anadromous fish. Amounts of instream LWD were adequate in many tributaries, especially those upstream of historic splash dam locations. Instream LWD amounts were found to be low in portions of the West Fork and larger portions of the East Fork. Loss of LWD-associated habitat as a result of channel flushing and reduced inputs of LWD was identified to be of concern for the lower portions of the channel network. A reduction in the rate of bank erosion was also identified as a key objective in areas where the river channel is confined by terraces. Summer water temperatures were determined to cause risk to juvenile steelhead and chinook, especially in the lower reaches of the East and West Forks.

Collins and Dunne (1986) estimated that gravel removal in the Humptulips River between RM 16 and RM 28 between the late 1950's and 1985 caused the river bed to lower, with an estimated rate of 0.1 foot/year. Harvest rates in Grays Harbor County were adjusted after 1986, and the current gravel harvest rate is lower than the rate during that period. Also, WDFW now encourages gravel pit locations to be outside of active stream channels. Current gravel harvest rates, and currently acceptable instream locations, are not known.

A habitat survey was done in Brittain Creek 22.0079) (1.4 mi) and Elwood Creek (22.0079a) (1.6 miles (T/F/W/ Ambient Monitoring, 1991).

SUBBASIN 18. SATSOP RIVER

USFWS/WDFW extensive survey

A total of 246 stream miles were surveyed in their **"Satsop"** subbasin, including the Satsop, WF, MF and EF Satsop and Canyon Rivers, and Decker, Bingham, Cook, and Dry Creeks. The most important habitat problems identified were: bank erosion (428 points and 57 miles) (WF Satsop , MF Satsop, Canyon River, Dry Creek), streamside vegetation loss from unknown causes (2 points and 38.8 miles) (widespread in lower 2/3 of subbasin), stream canopy reduced from forest practices (12 points and 21 miles) (widespread in lower 2/3 of basin), and logjams with the potential to be whole or partial migration blockages (74 points) (upper 1/3 of basin). Beaver dams were present in moderate numbers at the time of the survey. A total of 14 known and suspected water withdrawals were noted, as well as 2 wastewater outfalls and 9 miscellaneous pollution input sources (Wampler et al., 1993).

A portion of the subbasin was included in the **West Satsop Watershed Analysis** (Simpson and Weyerhaeuser, 1996; Baxter, 1996). The analysis area included the West Fork upstream of the confluence. Habitat concerns identified include lower levels of LWD than those present historically. Lower than preferable wood levels were found in the West Fork Satsop, Canyon River, Lower Still Creek, West Satsop Junction, Middle West Fork, Save Creek, Lower Little River, and Lower Upper Canyon River subbasins. Open riparian canopy that might contribute to high water temperatures was noted in the much of the West Fork Satsop mainstem and Canyon River. A potential for gravel scour was noted in the mainstem West Fork Satsop, Canyon River, and lower portion of the Little River. Subbasins where a potential for fine sediment inputs (and little spawning gravel) included tributaries to the west work Satsop, Lower Still Creek, Upper Still Creek, Five Mile Creek, and Seven Mile Creek subbasins (Baxter, 1996).

Collins and Dunne (1986) estimated that, for the 10-20 year period prior to 1986, gravel harvesting removed more gravel than the annual replenishment rate in the Satsop River between RM 1 and RM 3 by a factor of more than 10. Channel downcutting of approximately 0.1 foot/year was estimated.

A stream survey was done in an unnamed West Fork tributary (22.0400) (0.95 miles) (T/F/W Ambient Monitoring, 1991).

SUBBASIN 21. WISHKAH RIVER

A portion of this subbasin was included in the **Wishkah Watershed Analysis.** The analysis area included the subbasin upstream of RM 28.5 (Wishkah Falls is at RM 29.4). Investigators noted that the small tributary streams tended to have good habitat complexity and instream structure. Deciduous-dominated riparian stands in the watershed limit future LWD recruitment. A lack of large instream wood was noted in the main stem Wishkah above the reservoir, and the analysts concluded that habitat conditions were apparently in the process of recovery from past land use actions (Raines et al., 1992). No other information was found for current fish habitat conditions in the Wishkah River watershed.

SUBBASINS 22, 23, 24. MF HOQUIAM, EF HOQUIAM, AND HOQUIAM RIVERS

Historic information found indicated that the Hoquiam River began to be logged early in the settlement period of Grays Harbor County, and records show that 8 splash dams in the basin operated during the 1880-1930 period (Wendler and Deschamps, 1955; Van Syckle, 1981). There is a diversion dam on the WF Hoquiam River, serving as the water supply for the City of Hoquiam. No other information was found about current fish habitat conditions in the Hoquiam River watershed.

SUBBASIN 26. ELK RIVER

Subbasin contains the Elk River, Andrews Creek, and Barlow Creek, as well as Redman, Beardslee, and Mallard Sloughs, and is the southern-most subbasin of the independent South Harbor tributaries. Because of location, the South Harbor tributaries were entered for timber harvest early in the settlement period of the Grays Harbor area (Van Syckle, 1981). No current information on habitat conditions in this subbasin was located.

SUBBASIN 27. JOHNS RIVER

This subbasin contains the Johns River and tributary streams. Five splash dams are reported to have been historically present in the Johns River subbasin, although the dates of building and removal are not known (Fairbairn, 1982). Because of location, the South Harbor tributaries were entered for timber harvest early in the settlement period of Grays Harbor (Van Syckle, 1981). No current information on habitat conditions in this subbasin was located.

SUBBASIN 28. NEWSKAH RIVER

This subbasin contains Newskah River and tributary streams. A total of five splash, pond, or roll dams evidently existed historically on the Newskah River, although no information on the year of building, location, or height is available. All of the dams are reported as out of the river by 1955 (Wendler and Deschamps, 1955). Because of location, the South Harbor tributaries were entered for timber harvest early in the settlement period of Grays Harbor (Van Syckle, 1981). No current information on habitat conditions in this subbasin was located.

In addition, no current information on habitat conditions in O'Leary, Stafford, Indian, Campbell, or Chapin Creeks was located.

SUBBASIN 29. CHARLEY CREEK

One splash dam was reported to have been historically present in Charley Creek, built prior to 1910 and washed out at an unknown date (Fairbairn, 1982). Because of location, the South Harbor tributaries were entered for timber harvest early in the settlement period of Grays Harbor (Van Syckle, 1981). No current information on habitat conditions in this subbasin was located.

A lack of information about habitat conditions in these systems would make it difficult to effectively target enhancement or rehabilitation efforts, should those be desired.

SUBBASIN 30. MAINSTEM CHEHALIS RIVER BELOW MONTESANO

Historical information about channel changes during the 1800's and early 1900's was available, and is summarized in a previous section. Water quality information was available and is summarized Appendix C. Extensive habitat survey information is summarized above.

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ATTACHMENT 1
MASTER LIST OF DOCUMENTS FOR THE CHEHALIS BASIN

Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
1989 Lakes and Reservoir Water Quality Assessment Program: Survey of Chemical Contaminants in Ten Washington Lakes. Ecology Report, May 1990		1990		Johnson, A. and D. Norton	Ecology
A preliminary Examination of Relationships Between Catchment Characteristics and Volumes of Infrequent Large Floods. UW Master of Science Thesis		1990		Balocki, J.B.	Thurston County
After action report for February 1996 Flood Event in Seattle District COE office, Seattle, Washington.		1996		ACOE	PIE
After action report for the February, 1996, flood event in the Seattle district, CENPS-EN-HH-WM. U. S. Army Corps of Engineers.				USACOE	NWGIS
An Analysis of Streamflows on the Olympic Peninsula in Washington State Department of Civil Engineering, WSU, Pullman, WA		1987		Amerman, K.S. and J. Orsborn	Jean Caldwell
An Evaluation of the Henry's Fork Watershed Council		1995		NW Policy Center	
Assessing the Effects of Gravel Harvesting on River Morphology and Sediment Transport – A Guide for Planners. WSDOE (contact report)		1987		Collins, B.D. Dunne, T.	Thurston County
Assessment of the Sources of Enrichment of Carlisle Lake and Possible Restoration Methods.		1985		Moore, B.C. W.H. Funk, K.E. Hartz, H.L. Gibbons, Jr., C.P. Larsen, R. Krishnaiah, S.K. Julin, J.P. Nyznyk, S.T.J. Juul, T.C. McKarns, E.E. Syms, S.E. Radcliffe	Ecology
Basin Water Monitoring Program Fish Tissue and Sediment Sampling for 1989		1991		Hopkins, B.	Ecology
Beyond Polarization: Emerging Strategies for Reconciling Community and the Environment		1993		NW Policy Center	
Biological Assessment of Small Streams in the Coast Range Ecoregion and the Yakima River Basin. WDOE		1999	99-302	Merritt, B. Dickes, and J.S. White	Jean Caldwell
Blooms of surf-zone diatoms along the coast of the Olympic Peninsula, Washington; 7, Variations of the carbon-to-nitrogen ratio in field samples and laboratory cultures of Chaetoceros armatum; Limnology and Oceanography, v.21, no.2		1976	V.21, no.2	Collos, Y., Lewin, J.	Thurston County
Changes in Flow and Temperature Observed in Wildcat Creek and Sam's Canal in August 1986. Memo to Greg Cloud.		1987		Kendra, W.	Ecology
Changes in the Consolidated Dairy Products (Darigold) Permit: Computer Model Simulations and Nutrient Evaluation. Memo to Chung Ki Yee		1987		Joy, J.	Ecology
City of Westport and South Beach Area – Groundwater Characterization Study		1994		Grays Harbor County	Ecology

Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
Community Stewardship – A Guide to Establishing Your Own Group		1995		Fraser Basin management Program	
Comprehensive planning for flood hazard management guidebook (first edition). Washington State Department of Ecology, document 91-44, Olympia, Washington.		1991	91-44	WADOE	State Library
Confederated Tribes of the Chehalis Reservation		1996			Thurston County
Data on selected lakes in Washington; Part 2: Ecology Water-Supply Bulletin 42, part 2 (1974), part 3 (1976), part 4 (1976), part 5 (1976), and part 6 (1980)			Bulletin 42	Bortleson, G.C.; Higgins, G.T.; Hill, G.W.	Thurston County
Draft – Report of the Technical Advisory Committee on the Capture of Surface Water by Wells. Recommended Technical Methods for Evaluating the Effects of Ground-Water Withdrawals on Surface Water Quantity. 1998		1998		Ross & Associates Environmental Consulting, LTD.	Envirovision
Effectiveness of best management practices for aerial application of forest pesticides. Washington Department of Ecology, Environmental Investigations and Laboratory Services, publication no. 93-81. Olympia, Washington.		1993	93-81	Rashin, E. and C. Graber. WADOE	mcm
Effectiveness of forest road and timber harvest best management practices with respect to sediment-related water quality impacts, interim report no. 2. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Watershed Assessments Section, publication no. 94-67. Olympia, Washington.		1994	TFW-WQ8-94-001	Rashin, E., et al. WADOE	mcm
Effectiveness of forest road and timber harvest best management practices with respect to sediment-related water quality impacts, interim report no. 1. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Watershed Assessments Section, publication no. 94-27. Olympia, Washington.		1993	94-27	Rashin, E., et al. WADOE	mcm
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Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
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Effects of Coal Mine Drainage on the Water Quality of Small Receiving Streams in Washington, 1975-77		1988		Packard, Frank A., et al	USGS, Tacoma Office
Effects of Leakage from Four Dairy Waste Storage Ponds on Ground Water Quality		1994		Erickson, Denis R.	Ecology
Effects of McCleary Wastewater Treatment Plant Effluent on Water Quality and Macroinvertebrate Community Structure in Wildcat Creek, Washington. Ecology Report		1987		Kendra, W.	Ecology
Engineers Investigation and Feasibility Report: Proposed Flood Control District		1997		Lewis County Public Service	
Environmental checklist and determination of significance and adoption of existing environmental document and spartina control water quality permit application to control spartina and management plan. Plant services division, Washington Department of Agriculture. Olympia, Washington.		1996	td 196 h47 w374	Dolstad, D. K. WADOA	mcm
Environmental monitoring program 1983. Washington public power supply system nuclear project no. 3. Washington Public Power Supply System.		1984	621.3125	Jeane, G. S., et al. WPPSS	library
Erosion of the Ebb-tidal deltas on the Washington Coast – A long-term trend (workshop report). US Geological Survey Open-File Report 97-471, p. 68-69		1997		Sherwood C.R.	Thurston County
Exploring Wetlands Stewardship		1996		Ecology	
Federal Insurance Administration. 1991. Hazard mitigation opportunities in the state of Washington, supplemental report of the interagency hazards mitigation team, FEMA-883-DR-WA. Federal Emergency Management Agency, Region X, Washington.		1991		FEMA	NWGIS
Final habitat Conservation Plan. South Puget and South Coast Planning Units Contain DNR lands in the Chehalis Basin. Washington State Department of Natural Resources		1997		WSDNR	Jean Caldwell
Freshwater Ambient Monitoring Report for Wateryear 1991		1993		Hopkins, B.	Ecology
Freshwater Ambient Monitoring Report for Wateryear 1991		1993		Hopkins, E.	Ecology
Freshwater ambient monitoring report for wateryear 1992. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Ambient Monitoring Section, publication no. 94-70. Olympia, Washington.		1994	94-70	Hopkins, B. WADOE	mcm
Geologic Map of Washington – Southwest Quadrant		1987		WA Dept. of Natural Resources	

Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
Geology & Ground Water Resources of West-Central Lewis County		1966		Dept of Conservation/ Division of water resources	
Ground Water Flow and Solute Transport Modeling of the Lakes Areas, Thurston County, WA. UW Master of Science Thesis		1987		Pachernegg, Sheila M.	Thurston County
Ground Water Quality Assessment: Sheridan Dairy Lagoon, Adna, Washington – August 1992		1992		Erickson, D.	Ecology
Groundwater Drainage System – analysis of System Performance. In Proceedings of the tenth International Conference on Soil Mechanics and Foundation Engineering, Stockholm 15-19 June 1981. A.A. Balkema (Rotterdam), v.1, p. 453-456		1981		Mercurio, W.F.; Bain, G.L.	Thurston County
Hazard mitigation opportunities in the State of Washington, supplemental report of the Interagency Hazard Mitigation Team, FEMA-883-DR-WA. Federal Emergency Management Agency, Region X, Washington.		1991		FEMA	NWGIS
Hazard mitigation survey team report for the 1996-1997 Washington Winter Storms, FEMA DR-1152-WA, declared January 7, 1997, and FEMA DR-1159-WA, declared January 17, 1997, including an addendum report for FEMA DR-1172-WA, declared April 2, 1997. Hazard Survey Mitigation Team, Region X, Bothell, Washington.		1997		FEMA	NWGIS (Given to Greg 12/2 to return to her)
Honne, the Spirit of the Chehalis; the Indian interpretation of the Origin of the People and Animals		1925		Palmer, Katherine Evangeline Hilton Van Winkle	Timberland Regional Library
Hydrogeologic Characterization for Protection of the Wildcat Creek Aquifer		1994		City of McCleary	Ecology
Hydrology and Quality of Ground Water in Northern Thurston County, Washington		1994		Dion, N.P., G.L. Turney, M.A. Jones	USGS, Tacoma Office
Hydrology and Quality of Ground Water in Northern Thurston County, WA. US Geological Survey Water –Resources Investigations Report 92-4109 9revised), 230 p., 6 plates		1998		Drost, B.W.; Turney, G.L.; Dion, N.P.; Jones, M.A.	Thurston County
I-5 Toutle Park Road to Maytown, draft environmental impact statement, Washington.		1997		ACOE US Department of Transportation	NWGIS
Interactions of Landslide-Supplied Sediment with Channel Morphology in Forested Watersheds. UW Master of Science Thesis		1989		Perkins, Susan J.	Thurston County
Interagency flood hazard mitigation report, in response to the January 18, 1990, disaster declaration, FEMA-852-DR-WA, covering Benton, Grays Harbor, King, Lewis, Pierce, Thurston, and Wahkiakum Counties.		1990		FEMA	NWGIS

Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
Interagency Hazard Mitigation Team Report including progress report on early implementation strategies. State of Washington winter storms of 1995-1996, FEMA-DR-1079, declared January 3, 1996, and FEMA-DR-1100-WA, declared February 9, 1996. Federal Emergency Management Agency, Mitigation Division, Federal Regional Center, Region X, Bothell, Washington.		1996		FEMA	NWGIS (Given to Greg 12/2 to return to her)
Interim Washington State hazard mitigation strategies and policies document (draft). Washington State Military Department, Emergency Management Division, Camp Murray, Washington.		1998		WAMiltary Dept	unknown
ITT Rayonier class II inspection, segment no. 10-22-04. Washington State Department of Ecology, Environmental Investigations and Laboratory Services, Compliance Monitoring Section. Olympia, Washington.		1989	WA 574.5 EC7itt r 1989 c2	Reif, D. WADOE	library
Lake Carlisle Restoration Phase II: Water Quality Monitoring		1990		Moore, B.C.	Washington State University
Lake water quality assessment program. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Watershed Assessments Section, document 96-304, Olympia, Washington.		1993	96-304	Rector, J. WADOE	NWGIS
Letter dated April 24, 1993, to Colonel Cunningham, District Engineer, U. S. Army Corps of Engineers, Seattle District. Folmer Solggard, Chairman of Commissioners of Lewis County Flood Control District Number 2.		1993		Solggard, F. USACOE	NWGIS
Letter dated December 14, 1994, to Linda Smith, Planning Branch, U. S. Army Corps of Engineers, Seattle District. Kaaren Roe, Community Development Specialist of the Washington Department of Community Trade and Economic Development.		1994		Roe, K. CTED	NWGIS
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Long Road Diking District, Flood Control Project, fish and wildlife resources planning aid report for the U. S. Army Corps of Engineers, Seattle, District. U. S. Fish and Wildlife Service, Ecological Services, Olympia Field Office, Olympia, Washington.		1994		Dubbs, N. USFWS	NWGIS
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Memorandum dated August 6, 1990, to Darrel Anderson, Southwest Regional Office, Washington Department of Ecology. From Betsy Dickes, Washington Department of Ecology, Environmental Investigations and Laboratory Services, publication no. 90-e15. Olympia, Washington.		1990	90-e15	Dickes, B. WADOE	mcm
Memorandum dated December 21, 1995, to David Serdar, Washington Department of Ecology. From the Washington Department of Ecology, publication no. 96-e14. Port Orchard, Washington.		1995	96-e14	Knox, R. WADOE	mcm
Memorandum dated February 23, 1998, to Forest Brooks, U. S. Army Corp of Engineers, Washington.		1998		Lewis County. ACOE	PIE
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Nisqually River Management Plan		1987		Nisqually River Task Force	
Old Washington Well Tested. Oregon Department of Geology and Mineral Industries Ore-Bin, V. 21, No. 4		1959		Anonymous	Thurston County
Pesticide Residues in the East Chehalis Surficial Aquifer, Pesticides in Ground Water – Report No. 5		1994		Larson, A.	Ecology
Plan and profile of Chehalis River (map): Bunker to Pe Ell, and South Fork to mile seven, Washington. Surveyed in cooperation with the State of Washington, Department of Conservation and Development.		1940		Giles, G. C. and F. F. Lawrence. USGS	UW Library
Preliminary report on ground-water resources of the central Chehalis Valley, Washington. U.S. Geological Survey Open-File Report, 43p.		1947		Schlax, W.N., JR.	Thurston County
Project WET Curriculum & Activity Guide		1995		Montana State University	
Quality and Fate of Fish Hatchery Effluents During the Summer Low Flow Season		1989		Kendra, W.	Ecology

Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
Quality and Fate of Fish Hatchery Effluents During the Summer Low Flow Season		1989		Kendra, W.	Ecology
Quality of Salmonid Hatchery Effluents during a Summer Low-Flow Season Transactions of the American Fisheries Society		1991		Kendra, W.	Ecology
Quality of Salmonid Hatchery Effluents during a Summer Low-Flow Season Transactions of the American Fisheries Society.		1991		Kendra, W.	Ecology
Reaching Home		1994		Tom Jay & Brad Matsen	
Receiving Water and Sediment Sampling: American Crossarm and Conduit Pentachlorophenol Spill. Ecology Report		1987		Yake, W.	Ecology
Reclamation of Flood-plain Sand and Gravel Pits as off-channel Salmon Habitat. Washington Geology, v. 26, no.2/3, p. 21-28		1998		Norman, David K.	Thurston County
Rennie Island Discharge (1981-1982). Memo to George Houck.		1983		Clark, D.	Ecology
Results of monitoring copper sulfate application to Sylvia Lake. Washington Department of Ecology, publication no. 95-322. Olympia, Washington.		1995	95-322	Serder, D. WADOE	mcm
Results of Sampling for Copper in Drainages to Sylvia Lake. Memo to Loree Randall, SWRO.		1996		Serdar, D.	Ecology
Revised WA State Flood Damage Reduction Plan		1995		WA State Military Dept./ Emergency Management Division	
River and Watershed Conservation Directory		1996		River Network/ National park Service	
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Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
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Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
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Geologic Map of the Centralia Quadrangle, WA. Washington Division of Geology and Earth Resources Open File Report 87-11, 28 p., 1 plate, scale 1:100,000	Middle Chehalis (above)	1987		Schasse, Henry W., Compiler	Thurston County
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Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
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Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
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An assessment of water-related reports for Thurston County, Washington. Thurston Regional Planning Council, Olympia, Washington.	Middle Chehalis, Black River	1985		Morrison, S., et al. Thurston Regional Planning Council	NWGIS
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Thurston Regional Wetland and Stream Corridor Inventory-Phase II Northern Thurston County	Northern Thurston	1993		Morrison, S. Thurston Regional Planning Council	
Town of PeEll Water System Comprehensive Plan	PeEll	1998		Gibbs and Olsen	
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Inventory of Vegetative communities and Associated Wildlife of the Skookumchuck River Drainage	Skookumchuck	1979		Wash. Dept. of Game	
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Groundwater Program Database – Microsoft Access and ArcView GIS formats, Contains water quality and water level data and well locations for wells in Thurston County	Skookumchuck, Middle Chehalis (all), Black River	1998			
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Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
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Water Resources Monitoring Report, Water year 1994-1995	Skookumchuck, Middle Chehalis (all), Black River	1996		Thurston County Storm and Surface Water Program and Environmental Health Division	
Water Resources Monitoring Report, Water Year 1995-1996	Skookumchuck, Middle Chehalis (all), Black River	1997		Thurston County Storm and Surface Water Program and Environmental Health Division	
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Stillman Watershed Analysis	Stillman Creek	1994		Weyerhaeuser	Library or WDNR Geology Library
Map showing depth to bedrock of the Tacoma and part of the Centralia 30'X60' quadrangles	Tacoma to Centralia		Map mf 2265	Buchanan-Banks, J.M., Washington USGS miscellaneous field studies,	
Management Options for Groundwater Protection	Thurston County	1990		Morrison, S. Thurston County Advance Planning	
Thurston County Water Resources Profile	Thurston County	1996		Morrison, S. , Thurston County Advance Planning	
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Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
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Initial watershed assessment, water resource inventory area 23, Upper Chehalis River, draft, Open File Technical Report 95-03. Washington State Department of Ecology, Olympia, Washington.	Upper Chehalis (all)	1995		Wildrick, L., et al. WADOE	NWGIS
Letter dated November 16, 1994, to Folmer Solggard, Chairman of Commissioners of Lewis County Flood Control District #2. Robert B. Bert, Director, Department of Public Services, Lewis County.	Upper Chehalis (all)	1994		Berg, R. B. Lewis County	NWGIS
Letter dated November 21, 1995, to Linda Smith, Planning Branch, U. S. Army Corps of Engineers, Seattle District. Folmer Solggard, , Chairman of Commissioners of Lewis County Flood Control District Number 2.	Upper Chehalis (all)	1995		Solggard, F. Lewis County	NWGIS
Lewis County Interim Critical Areas Ordinance	Upper Chehalis (all)	1996		Lewis County	
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Sewage Drainage Basin Plan for Upper Chehalis Basin (Basin 23)	Upper Chehalis (all)	1975		R.W. Beck and Associates	Timberland Regional Library
Upper Chehalis River: Dry Season Total Maximum Daily Load Study	Upper Chehalis (all)	1994		Pickett, Paul J.	Timberland Regional Library
Upper Chehalis Watershed Analysis	Upper Chehalis (all)	1994		Weyerhaeuser	Library or WDNR Geology Library
Upper Chehalis watershed initial assessment (draft). Prepared in cooperation with the Washington State Department of Ecology, report no. 95-150, Water Resources Public Outreach, Olympia, Washington.	Upper Chehalis (all)	1995	95-105	Langlow Associates, Inc., Dames and Moore, Inc., and associated firms. WADOE	NWGIS
Comprehensive Flood Hazard Management Plan for Lewis County, Volume 1. Lewis County Department of Public Services Document 4107-004, Chehalis, Washington.	Upper Chehalis (whole basin)	1994a	4107-004	ENSR Consulting and Engineering. Lewis County	Marie mailed on 5/26/99

Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
Comprehensive Flood Hazard Management Plan for Lewis County, Volume 2: Appendices. Lewis County Department of Public Services Document 4107-004, Chehalis, Washington.	Upper Chehalis (whole basin)	1994b	4107-004	ENSR Consulting and Engineering. Lewis County	Marie mailed on 5/26/99
Evaluation of Total Maximum Daily Loads, Summery Report	Upper Chehalis (whole basin)	1994		Water Quality in Washington State	Thurston County
Nonpoint Source Pollution Control Strategy for the upper Chehalis River TMDL, DRAFT	Upper Chehalis (whole basin)	1996		Overview of Nonpoint Source Pollution Management in WA	Thurston County
Southwest Washington flood disaster economic adjustment strategy for the counties of Gig Harbor, Lewis, Cowlitz, Wahkiakum, and Clark, Vancouver, Washington.	Upper Chehalis (whole basin)	1996		EMHCO & Assoc	PIE
Strategy for Implementing the Upper Chehalis River TMDL	Upper Chehalis (whole basin)	1995			Thurston County
Upper Chehalis River basin Evaluation of Total Maximum Daily Loads, Summary Report	Upper Chehalis (whole basin)	1994		Department of Ecology	Thurston County
Upper Chehalis River Basin Well Water Testing Project	Upper Chehalis (whole basin)	1995		Thode, Robert John	Ecology
Upper Chehalis Watershed Initial Assessment (Summary Report).	Upper Chehalis (whole basin)	1995		WDOE, The Langlow Assoc., Dames & Moore, Inc.	Ecology
Watershed Assessment – WRIA 23	Upper Chehalis (whole basin)	1995		Ecology	
Watershed Assessment Primer	Upper Chehalis (whole basin)	1994		EPA	
Section 205 Initial reconnaissance report on Salzer creek in Lewis county, Washington.	Upper Chehalis Basin	1988		ACOE	NWGIS
Section 205 Initial reconnaissance report on China creek in Lewis county, Washington.	Upper Chehalis Basin (all)	1988		ACOE	NWGIS
Upper Chehalis River total maximum daily load study. Washington State Department of Ecology, Environmental Investigations and Laboratory Services Program, Watershed Assessments Section, document 94-126, Olympia, Washington.	Upper Chehalis River (all)	1994		Pickett, P. WADOE	NWGIS

Document Name	Sub-Basin	Date	Reference Number	Prepared By	Document Location
Upper Chehalis River and Black River Total Maximum Daily Load Reports: Response to Comments	Upper Chehalis, Black River	1995			Timberland Regional Library
Turbidity sampling in the Wishkah River Basin, Final quality assurance project plan. Washington Department of Ecology, Environmental Investigations and Laboratory Services Program, Watershed Assessments Section.	Wishkah	1995		Sargeant, D. WADOE	mcm
Flood Plain Information; Chehalis, Wishkah, and Hoquiam River; Aberdeen, Hoquiam (and) Cosmopolis, Washington.	Wishkah, Hoquiam, Grays Harbor, Chehalis River (all)			U.S. Corps of Engineers for the Department of Ecology	Timberland Regional Library
1974 Wynoochee dam study: observations of 1974 Juvenile out-migration, and evaluation of 1973 fish passage success from adult returns. Supplemental progress report, power dam studies. Financed by U. S. Army Corps of Engineers contract no. DACW 67-73-C-0057. State of Washington Department of Fisheries, Management and Research Division.	Wynoochee	1975	WA 639.2 R3lwyn 1975 c3	Dunn, C. A. WA Dept. of Fisheries	library
Progress report no. 45, evaluation of downstream fish passage through multi-level outlet pipes at Wynoochee dam. Financed by U. S. Army Corps of Engineers, contract no. Dacw 67-76-C-006 and 67-73-C-0057. State of Washington Department of Fisheries.	Wynoochee	1978	WA 639.2 F532prr 45 1978	Dunn, C. USACOE	library
Wynoochee Dam and Lake. U. S. Army Corps of Engineers. Seattle, Washington.	Wynoochee	1983	D 103.2 W99	USACOE	Library
Wynoochee Dam. In Galster, R.W., chairman, Engineering geology in Washington. Washington Division of Geology and Earth Resources Bulletin 78, V.I, p. 317-322.	Wynoochee	1989		Eckerlin, Richard D.	Thurston County
Wynoochee Lake project flood control rule curve revision, Grays Harbor County, Washington, final environmental assessment. U. S. Army Corps of Engineers. Seattle, Washington.	Wynoochee	1993	wln 95-39025	USACOE	Library
Physical, Chemical, and Biological Characteristics of Weyco-Briscoe gravel Pit Ponds, (July 1989-June 1990), Wynoochee River, Grays Harbor WA – Annual report: Grays Harbor County Planning and Building Department	Wynoochee, Grays Harbor	1990		Grays Harbor College research; Samuelson, D.F.; Phipps, J.B.;	Thurston County
Fish Farm Discharge Study from 1980's - Includes facilities still in operation on Black River.	Black River	1980			

Black Lake Information

Original Survey 1854 documents – Dept. of Natural Resources					J. Roach
Persival Canyon Study – Shows over 30 erosion sites caused by Black Lake and that 85% of the water from Black Lake goes into Capital Lake		1989 ?		Thurston County	J. Roach
Study of Blake Lake Wetland – Shows Water flowing from the Wetland North into Black Lake				Kurt Christianson – Thurston County	J. Roach
Aerial Photos from Pipeline. 1936, 1965, 1993, 1997				DOT/DNR/J. Roach	J. Roach
Engineering drawings of pipeline 1963 – NW Pipeline Co. Salt Lake City and a letter from the pipeline that they did not weight the pipe on installation.				NW Pipeline Co.	J. Roach
Black River fish Kill Report **(in main document list)**					J. Roach
Black River Dry Season TMDL Study **(in main document list)**		1994		Pickett	J. Roach
Black Lake Annual Health Report				Thurston County	J. Roach
Dept. of Fish and Wildlife Services – Montesano – show all the different types of salmon runs that were/are on the Black River.					J. Roach

ATTACHMENT 2
CHEHALIS BASIN LEVEL 1 ASSESSMENT
TECHNICAL WORKSHOP SUMMARY

CHEHALIS BASIN LEVEL 1 ASSESSMENT TECHNICAL WORKSHOP SUMMARY

WORKSHOP OVERVIEW

The purpose of the workshop was to solicit ideas and agreement from professionals working in the Chehalis basin about the specific direction the Level 1 Watershed Assessment should take for assessing; Water Quantity, Water Quality, and Fish Habitat. A letter was sent to over 30 invited participants and 4 agencies, inviting them to attend or send a representative. The workshop was organized by specific topic, to allow the consultant team to address each topic separately with the appropriate professionals present. The turnout was excellent and the workshop went smoothly. There was ample discussion on some of the more important issues, and where the consultant team required input, there was easy agreement on the assessment approach. The following paragraphs summarize some of the key discussions and agreements reached in each of the topic areas.

WATER QUANTITY

The water quantity portion of the workshop was the most complex, since there are more tasks involved and more steps to each analysis that might be considered for Level 1 or Level 2 Assessment. One of the most important issues discussed was the most useful way to partition the basin. Fifty –four USGS stream flow gages have been in operation at various times in the two WRIA's. Many of these represent short periods of record and there are distinct subbasins that do not have any gages. There are 29 instream flow control points listed in WAC 173-522-020, eight of which do not correspond with the location of stream gage records. The consultant team recommended the basin be partitioned into 29 subbasins based on a combination of the stream gage network and instream flow control points. Most of the 29 subbasins have gaged flows for at least some portion of the basin, however a few subbasins are ungaged. (For example, the East fork and Middle fork Hoquiam do not have any stream gage records at their control points, nor in their basins, but clearly constitute subbasins.) Basin characteristics will be described for all 29 subbasins. Hydrologic statistics will only be summarized for those subbasins where there is both a legally established control point and an established stream gage station. This represents approximately 20 subbasins. A few tasks were identified that require more intensive effort than could reasonably be recommended for all subbasins at a Level 1 Assessment, yet were considered important for either prioritizing direction for Level 2, or evaluating the cost effectiveness of an approach. It was agreed that 5 subbasins will be selected for the establishment of "natural" streamflows and comparison to "instream" flows.

Agreement regarding appropriate ground water tasks for the Level 1 was obtained and included three items: 1) A description of the potential influence of basin geology on groundwater, 2) initial examination of usefulness and spatial coverage of the available well level data, and 3) identification of data gaps. For each of the 29 subbasins, the potential impacts, at a general level, of land use on the surface and ground water resources will be summarized.

The discussion on Water Rights and Water Use was very informative. Participants offered data sources that had not previously been identified and ideas on how to deal with these issues and especially how to handle exempt wells in the assessment. For example, census and parcel data were suggested for identification of exempt wells, since these data are available electronically. The approach to Level 1 presented by the consultant team was generally agreed upon by those present.

Workshop participants also agreed that two issues initially identified as possibly occurring in Level 1 were clearly more appropriate for the Level 2 Assessment. These were: 1) Conducting a monthly water balance for each subbasin, and 2) Estimating water use by exempt wells. The first will be addressed in Level 2 once estimates of natural flows and water use are available for each subbasin. It was also agreed that the exempt well issue should first be addressed as a pilot project in Level 2, and that a recommended approach for this pilot project should be developed as part of the Level 1.

WATER QUALITY

The Chehalis Basin is unique in having a moderately large number of surface water quality studies conducted in many of the subbasins. However, the majority of the information available pertains to the Upper Basin. There are five Ecology ambient monitoring stations for which a host of water quality parameters have been measured for five or more years. These are predominantly on the mainstem, or at the mouths of the more significant tributaries; only one of these is in the Lower Chehalis. Four Total Maximum Daily Loads (TMDLs) have been completed in the Upper Chehalis WRIA; one is in progress in the Lower Chehalis.

Groundwater data is primarily available through the Department of Health public water supply system database. However, Lewis and Thurston County also maintain a database of private well records. Of the parameters that might be most useful to this process, nitrate is the only parameter for which there is a consistent record in these databases. There are also a few groundwater studies that focus on specific known or suspected problem areas, such as landfills, wastewater application to the land surface, dairies, and other contaminated sites. Thus, the groundwater assessment will focus on nitrate and provide a summary of known problems.

In addition to the freshwater system, there is also a large volume of information available for the estuary. Ecology maintains four long term ambient monitoring sites in the estuary for which physical parameters have been recorded. There are also numerable reports available on sediment contaminants, bacteria, dredging impacts, shellfish, etc.

The workshop discussions for water quality approach focused primarily on the parameters that should be assessed, with some discussion on analysis approach and how to address estuary issues. A laundry list of possible parameters were mentioned during the workshop. These included; all of the nutrients, turbidity, suspended solids, temperature, dissolved oxygen, and even aquatic macroinvertebrates. There was no opportunity to prioritize this list during the workshop. The concern, of course, is that analysis of all of the data would not be overly useful to the Partnership for decision making, and would preclude more critical analyses that might be identified for the Level 2 Assessment. In discussions after the workshop, it was decided that the analysis approach should focus on those parameters that were most closely correlated with the intent of 2514 (water quantity and fish habitat). This approach was discussed and approved at a meeting with the TAC.

Another issue that arose during the workshop was how the estuary should be handled in the Level 1 Assessment. The Chehalis Basin is unique among WRIA's because the WRIA boundary was drawn to include the estuary. As with the selection of parameters described in the previous paragraph, the choices made at this stage will directly impact the funds available for tasks that will be prioritized for Level 2. If we select to do an assessment of the estuary data, we are by default selecting not to carry on tasks that will be identified later. Due to these concerns the consultant team recommended that the estuary assessment by quite limited, and that the need for more detailed assessment should be left to Level 2 when this need can be weighed against other priorities. This too was discussed at the TAC meeting. TAC members agreed with this recommendation and further refined our approach to recommend that the soon to be released fecal coliform bacteria TMDL be the emphasis of this portion of the assessment. Level 1 Assessment should provide a brief narrative discussion of the water quality in the estuary, noting problems including the TMDL for fecal coliform (scheduled to be completed by January), and qualitative estimates of the impacts of the mainstem on the estuary quality.

FISH HABITAT

The Chehalis Basin is in the enviable position of being "data rich" in terms of fish habitat information. There is excellent data base information collected as part of fisheries management (for example spawning surveys, or hatchery outplant records). For most of the Upper Chehalis WRIA, and for much of the Lower Chehalis WRIA upstream of the Wynoochee River, results of an extensive habitat survey, including summary reports and maps, are available. The most important data gap is information to assess instream flow needs. Although instream flows have been set for certain points in the basin, these were based on hydrologic statistics and not fish needs. Another deficiency is information on channel habitat features (e.g. pool, riffle, glide areas). Although this can to some extent be indirectly estimated with the large woody debris and from land use history. Last, the survey information has focused on salmonid species managed for sport or commercial fisheries (for example, coho, steelhead, chinook, cutthroat trout). Much less information is available on distribution of Bull Trout. Given the recent "threatened" listing of Bull trout under the Endangered Species Act (ESA), this may be a critical data gap.

Some of the additional options discussed for completing the Level 1 Assessment included; selecting a pilot project sub-basin and analyzing existing Instream Flow Incremental Methodology (IFIM) studies and instream flows, and completing a "limiting factors analysis" (LFA) for one of the sub-basins prioritized by the 2496 TAG. There was agreement by the fish habitat group that the Level 1 Assessment should consist of a general summary of fish habitat as it is already documented in the many reports and maps available. The group also agreed that the main focus of the effort should be integrating with the findings from the water quantity and water quality assessments and relating the information to land use. None of the optional assessment steps were considered to be important for completion at this time. However, it was also acknowledged that instream flow needs (as determined by fish) will be an important component of future efforts and that the Level 1 assessment must provide direction and priorities to meet this need.

Using the feedback from the workshop the consulting team developed a detailed approach for completing the Level 1 Assessment. The TAC recommended that this approach would best be shown through development of an annotated Table of Contents for the Level 1 Assessment. This is contained in the following pages.

ATTACHMENT 3
COMMENTS ON DRAFT LEVEL 1 ASSESSMENT

To: Joy Michaud

From: Lee Hansmann, Deputy Director of Community Development

CC: Sara Martin

Date: 4/19/01

Re: Level I Assessment comments

The following are comments on the Draft Level I Assessment Report, Technical Summary, Subbasin Assessment, and Data Gaps/Recommendations sections of the Envirovision report based on input from CBP/TAC members. Many of these comments may also apply to the Technical Appendices, not reviewed by TAC.

The pages referenced below coincide with the September 2000 version of the Draft Level I Assessment.

Section 1: Introduction

- Page 1-2: First paragraph: The sentence "Results and ideas from the workshop were used ..." is awkward. A possible rewrite is: "Results and ideas from the workshop were used to formulate a specific watershed assessment approach, which approved by the CBP. (Is this what was meant?)
- Page 1-3: 5th line from bottom "River" should be "rivers"

Section 2: Technical Summary

- Page 2-1: The Chehalis Basin does have several distinct geologic regions, with their own unique geologic history. This section would be clearer if it discussed geology in this context. For instance, the headwaters of the Chehalis arise out of the Willapa Hills, which are made up primarily of marine volcanic and sedimentary rocks and have no significant glacial history. Other regions might include the Black River/Scatter Creek/Skookumchuck glacial valleys, and the Olympic Peninsula drainages. It would also be useful to discuss the broad geologic history of the basin, in terms of the tectonic, glacial, and fluvial processes that have shaped the watershed and river valleys. For instance, much of the basin is underlain by old ocean floor material that was dragged up with the Olympic Mountains. The hills and valleys were carved into these slabs of oceanic rock by erosion, resulting in our low rounded hills and ravines. At the end of the ice ages meltwater from the Puget Sound glaciers flowed down the Black River and Lower Chehalis, forming a river that was about the size of today's Columbia River. After the ice ages ended, sea levels rose by several hundred feet and flooded the mouth of the Chehalis. This created Grays Harbor, and caused the river valleys to fill in with sediment. A process-oriented narrative can be used to explain many of the characteristics of our rivers and aquifers.

- Page 2-1 (Paragraph 4): The last sentence of this paragraph could be misread to imply that groundwater and surface water in the Chehalis Basin are not connected. Older wells in the basin are often drilled into valley-floor alluvium, where groundwater is definitely connected to river flows. Newer wells are usually close to 100-feet deep, and are often set in confined bedrock. In the valley floors these bedrock formations lie well below the river bed and are probably not connected to surface flows. However, wells drilled into bedrock on the ridges and hillslopes may very well be tapping groundwater units that are eventually intercepted by rivers and streams. This is especially true in the steeper streams and river headwaters, where valleys are downcutting through slabs of sedimentary and volcanic bedrock

- Page 2-3: Define "greatly" as in "... greatly exceeds the gaged mean monthly flows ..." Is there a numerical measurement (about a 1000 cfs?) that can be used rather than the subjective "greatly"?

- Page 2-5: Why was the flow at Montesano chosen? Tidal influence goes up to the Satsop River. If Montesano is correct, the Wynooche is west of Montesano and would still be within tidal influence. Would it be better to exclude the flow from the Wynooche, as then there would not be tidal influence? Also, the Wynooche flow has been affected by construction of the dam, and the changes in dam management? Traditionally, the USGS has used the formula of taking the flow measurement at Ground Mound, adding the flow from the Satsop River, and multiplying by 1.5 to estimate the flow in the reach just east of Montesano. How would what you obtain doing that compare to what is in the report? If we are really trying to get at stream flow versus water allocations, what makes the best sense to do in the lower Chehalis? How important is it to determine natural flows, with flow data that includes unknown (because they haven't been measured) takings?

- Page 2-6: Table 2.2-1. Print “Exceedance” correctly.
- Page 2-7 (Analysis of Natural Climatic Variability): In addition to identifying adherence to regional patterns, this section should also provide some insight into how representative our period of record is. Relative to long-term trends, is our period of record unusually wet or dry? Is it representative of what we can expect in the future?
- Page 2-7 (Analysis of Natural Flows): This section should include a clear definition of what you mean by “natural” flows. It seems to me you are referring to unregulated flows, in which you have subtracted out the effects of diversions and storage facilities. This is not really a “natural” flow, since it does not reflect the massive changes in natural hydrology due to timber cutting, land clearing, and development. Developing a true natural flow estimate is probably beyond the scope of this work, but you should be precise in defining what you are working with.
- Page 2-7: Energy Northwest can provide data from Elma for 1940-1977 (obtained from the National Weather Service), and for the Satsop site from 1977-present. The conclusion would probably be the same, but it would give an interim point in the basin. **Comment for future reference only.**
- Page 2-10: Table 2.3-1 (and whatever text is appropriate). As indicated in the Appendix, the report does not correctly identify the water allocation for the Satsop site. Energy Northwest (formerly Washington Public Power Supply System), currently holds a water authorization for 9.5 cfs for power generation using a combustion turbine. The Grays Harbor Public Development Authority has a water right for 20 cfs, which was transferred from the City of Aberdeen. The 80 cfs referred to in the appendix is no longer current (and hasn’t been since 1996). It’s also not clear if the water authorization for the raw water well is included. That was 1007 gpm until 1996, when it was reduced to 300 gpm. This is DOH water system source well, ID #18777V. (The well has never pumped more than 300 gpm, which brings into question use of rights and authorizations - is the intent to try and determine natural flows throughout the basin, or is the intent to determine if there is enough water in all areas of the basin, or is it both?) At any rate the table and associated text probably needs to be revised. Page 2-11 & 2-12: The Office of Financial Management has developed population projections for local counties and cities that carry into at least the year 2015. No need to redo your analysis, but you could use the OFM projections as a check on your population estimates in Table 2.3-2.

- Table 2.3-3 lists the sum of the per-capita demands for WRIAs 22 and 23 as the TOTAL per-capita demand for the watershed. What you really want here is some kind of weighted average of the 22 and 23 values – the sum of per capita demands does not have any meaning.

- It should be noted in this section that irrigated agriculture is not only in decline – it is being replaced by residential uses. The water rights for residential use are often obtained by transferring agriculture water rights. **Concern clarified during TAC meeting discussion.**

- It would be useful to include here a rough estimate of what proportion of residents in the basin are on exempt wells. Exempt wells are by far the most common source of water for rural residents. **Concern clarified during TAC meeting discussion.**

- Page 2-12: Middle of the page. They talk about "not insubstantial." (The phase is awkward.) That needs to be defined, and put into context. For example, 70 cfs is what percent of an Ecology base flow for the time in question; 17 cfs is what percent of base flow? As above, be objective, not subjective. The accuracy of flow measurements needs to be talked about somewhere. For example, for the Satsop site area, USGS had determined that the accuracy of the proposed gauge would be such, that a difference in 2 cfs could not be measured. In other areas it may be more, or less, depending on the physical characteristics of the river at the gauge station. In that context 17 cfs may or may not be "not insubstantial".

- Page 2-13: 2nd paragraph. Is the report talking about the Chehalis basin, or several basins.

- Page 2-13: Methods. Just a note to let someone know that as part of the Satsop site development, lots of environmental studies were done, including Chehalis River water quality, as well as fish studies. This information is all public and can be made available. There is also data that has been collected to support the Chehalis Generating Station (proposed natural gas fired combustion turbine in Chehalis), and it may be possible to obtain that data - URS in Seattle is the environmental consultant for Chehalis Generating Project. **Comment for future reference only.**

- Page 2-13 : In paragraph 2 it states that the last 3 years of each decade were used to equalize data sets. Was any analysis done of how well these 3 years represented the entire decade? It seems to me that by arbitrarily picking the last 3 years of each decade you could end up comparing a very wet series of years in one decade to a drought period in another decade. **Concern clarified during TAC meeting discussion.**

- Beginning on page 2-14: The different water quality criteria classes are often very confusing to lay people. It needs to be stated very clearly that the Classes are defined based on beneficial uses, and do not reflect actual water quality. When you say that Class A means excellent waters, it implies that all Class A waters have excellent water quality, when you really mean that Class A waters have very high standards (that they may or may not be meeting).

  This section focuses only on conventional pollutants, primarily because these are what DOE has monitored. This does not mean that there might be other kinds of water quality problems. Pesticides are widely used throughout the basin for agricultural, commercial, and residential purposes. Some qualitative discussion of possible impacts would be appropriate (possible referring to the results of some of the recent Puget Sound studies by the USGS). We also have several Superfund sites in the basin, where volatile organics have migrated into nearby aquifers like the Fords Prairie aquifer (one of the largest water bearing units in the upper basin). Urban drainages in Chehalis, Centralia, Aberdeen, and other cities contribute a variety of metals, organic pollutants, and hydrocarbons. For all of these there is probably not enough data for detailed analysis, but these should be identified as important data gaps.

- Page 2-14: Is it the “Chehalis Reach” or the “Centralia Reach” (as on p. 2-16)? Is there a map in the document (one of the appendices that can be referenced in the text) to show where everything is, like common names of areas, one for where all the sub-basins are, and another for mile posts? Is there a map of the river and/or basin to show where the different Class waters are?

- Page 2-15: Is there a map (or maps) for where the impaired segments are?

- Page 2-16: “Chehalis Reach” or “Centralia Reach”?

- Beginning on page 2-16: The figures that describe River Miles need to include a point a reference. Such as River Mile 10 is _______. This was very confusing for TAC members to understand the chart and the data.

- Page 2-17: 1st full paragraph. Clarify the next to last sentence, "As previously described, the slow-flowing Centralia Reach represents a natural condition that is at largely responsible for the temperature and DO problems."

- Page 2-17: last paragraph. Which river, the Black?

- Page 2-18: top of page. What other segments have FC exceedances?

- Page 2-18: 1st full paragraph. Fecal coliform sources are located downstream of RM 101 (Doty) to what river mile?

- Page 2-20: 1st sentence is awkward. Not certain what that paragraph is trying to say. When reviewing the data, it doesn't look like the TSS's are fairly close (and what is fairly close - statistically insignificant?).

- Page 2-20: The authors should clarify what they mean by the following sentence: "the pollutant load for all three parameters did increase with downstream distance in the dry season, indicating that this difference may represent a baseline condition." To what difference are they referring, and how would it be used to identify a baseline condition? What is meant by baseline?

  In much of this section the authors discuss trends. Were any statistical tests used to test the significance of observed trends?

- Page 2-21: Ist paragraph - What is "by sing"? Probably a typo.

- Page 2-21: Discharge monitoring reports could be used to determine what the actual loading was, and compare to projected loading based on NPDES permit authorizations. Is there a reason for the steady TSS loading increase at the upper station?

- Page 2-22: middle of the paragraph. Nooksack is spelled incorrectly.

- Beginning on page 2-23: This section should provide a more detailed discussion of land use patterns in the basin, and a tie-in to what kinds of pollutants would be expected from these land uses (this may be in the Appendix. There is data from other basins that could shed light on expected pollutant loadings from agriculture, timber, rural residential, and urban land uses. Again, there should at least be some qualitative discussion of other pollutants like pesticides, heavy metals, and toxic organics.

- Page 2-24: TSS loads are strongly tied to temperature and dissolved oxygen problems, and are therefore equally critical with respect to fish habitat.

Section 3: Selected Subbasin Assessment

- Page 3-1: Report should include a map delineating subbasins and identifing name and number for all 30 subbasins.

- Page 3-2: Include map of subbasins with the document.

- Page 3-4: 1st full paragraph: What is a minor diversion? How can the flow records without adjustment be considered "natural flow" when the diversions could total up to 6.6 cfs (21.3% of the base/instream flow for September). Even with some return (say 75% for the best case), the consumptive use would be 1.65 cfs or 5% of the base/instream for September. These amounts withdrawn could be considered significant.

- Page 3-4: On tables, state that 50% exceedance means average flow as measured by USGS.

- Page 3-4 (and throughout the document): For the Ecology flow, use the word "base" rather than shortening to instream, or just continue using base/instream. Somewhere in the document explain that these flows come from WAC 173-522-020, what they mean, and how they were derived, as they are idealized desired flows at any given location, and true natural flows could be less than what Ecology desires.

- Pages 3-4, 3-8, and 3-9: As an alternative to averaging the base/instream flow (which oversimplifies the data) and using the 50% and 90% exceedance, you could use the number of days each month that the flow as measured by the USGS was below the base/instream flow as specified by Ecology. (For power plant operations this is what we have to do, so we have a better idea of when, and how long, we would have to cease operations or provide sufficient storage to carry operations past the low flow period.)

- Page 3-5: Correct Table 3.2-2 with the data you have (and explain on page 3-6), so that 3.84 cfs becomes 2.5 cfs. The CD provided to Grays Harbor County contained incorrect information. It would be helpful to reader to show this chart in a pie chart format.

- Page 3-6: It would be good to stay either in cfs or gpm throughout the document.

- Page 3-6: The location of your title for "Residential Water Use" should be placed after the third paragraph, and a new heading entitled "Public water system" should start the section. That is because public water systems can serve more than residential customers - your text indicates that this is the case for Pe Ell. Where the public water system provides commercial or industrial water, do not repeat the information.

- Page 3-7: What is important about the first full paragraph?

- Page 3-7: Leave out the speculation under Commercial and Industrial Water Use. Show this as a data gap instead.

- Page 3-7: 2^{nd} paragraph under Irrigation: The last sentence has awkward phrasing.

- Page 3-7 and 3-8: Rewrite the last paragraph on page 3-7, to explain why using the Aberdeen data is important. If Centralia is not indicative of what could be expected, then don't mention it at all, and exclude it from your figure.

- Page 3-10: First and second paragraphs: For this subbasin in particular, is it fair to say that the measured USGS flow is the natural flow, when you know there are diversions, and the diversions could be a significant number? If you knew what the actual consumptive use was to match the flow record, then you could provide percentages.

- Page 3-11: Define LWD with the first use of the abbreviation (1^{st} full paragraph).

- Page 3-11: What percent of bank protection/riprap was observed? (All your other numbers are in percent.)

- Sections 3.3, 3.4, 3.5, and 3.6 (Many of the comments on Pages 3-2 through 3-11 apply to the other sub-basin sections; therefore, no need to repeat. A better way is needed to get out how much of a problem over-allocation may be in comparison to the base / instream flow in each of the sub-basins.)

- Page 3-21: State that you have a "calculated" natural flow, as you don't really know what the natural flow is.

- Page 3-25 (and wherever in the document you talk about power): The nonconsumptive power use is for hydropower. All other power uses (thermal power plants such as coal, nuclear, natural gas) have consumptive water use.

- Page 3-27: If you haven't already done so, check with WSU Cooperative Extension to obtain Grays Harbor County data on irrigation and crops. Further investigation regarding changes in crops might be a next step or data gap.

- Page 3-30: As Vance and Newman creeks are not in this sub-basin, you need to separate the data if you can. If you can't separate out their data, explain up-front that they are included only because the data can't be separated, and that they were included in the USFWS / WDFW data base that way.

- Page 3-31 (and throughout Section 3.5): Change subheadings to reflect Section 3.5 (you use 3.3).

- Page 3-31: The average rainfall for the Satsop site is closer to 70 inches per year (1940-1999 records). Therefore the 59 inches seems low. Where did that number come from?

- Page 3-32: How does your calculated flow compare to the USGS formula of using flow recorded at Grand Mound and Satsop and multiplying by 1.5? There was a temporary gage put in downstream of the Satsop River (where the nuclear plants were supposed to discharge) for a one year period in the 1980's. That data could be used as a comparison to any calculated flow.

- Page 3-35: Washington Public Power did have an authorization for 1007 gpm for water withdrawal. However, that was for industrial as well as domestic (in fact 1000 gpm was for construction and 7 gpm was for potable). The authorization was modified in 1996 to 300 gpm for construction, restoration, domestic, and fire protection services. It is not used for any residential purposes. The actual maximum withdrawal, even with the 1007 gpm authorization, was 300 gpm.

- Page 3-36: Do you know what Briggs Nursery's pattern of use is. The water is used within greenhouses, with a gravel floor. Would this affect the return rate?
- Page 3-39: There was water quality and aquatic (including fish) data collected on this stretch of the river to support the nuclear plants. The data is available through Energy Northwest. Fuller and Purgatory creeks would also be within this sub-basin but are not mentioned here. Why is it important to compare inorganic nitrogen levels in this sub-basin (or any sub-basin) with the data from Puget Sound?
- Page 3-40: Most of the railroad grade has been abandoned, and therefore, is being allowed to slide.
- Page 3-40: Fourth full paragraph: Most of the information is not needed here, as the sub-basin as you defined it, ends at the Satsop River.
- Page 3-41: Humptulips is not a town and is not incorporated. It is a community in Grays Harbor County.
- Clarify water claims and water rights.
- Define or better describe 50% exceedance and 90 % exceedance.
- Include tables used by Joy during 10-26-00 meeting in the report.

Section 4: Data Gaps/Recommendations

- Section 4.2, Geology and Hydrology: The groundwater/surface water study should include assessment of well records and other geologic information to identify key water bearing units and their relationships with specific rivers and streams. Water balance analysis and preliminary groundwater flow modeling should then be used to begin quantifying surface water/groundwater interactions for each watershed and hydrogeologic unit. For larger-scale aquifers and priority watersheds a detailed hydrogeologic modeling effort will be needed.

  Under Hydrology you recommend continued natural flow investigation. You should include here a recommendation for the best way to approach ungaged watersheds (Modeling? Additional gages?).

You recommend investigation of land use changes. You should identify why this is needed – are you looking at the influence of land use changes on hydrology? Will this eventually be used in land use decisions? I think this is a good idea, but we should expect to find that land use throughout the basin has been radically altered from historic conditions, and massive hydrologic changes have occurred. Given our relatively low population and water use, these land-use related impacts are probably much more substantial than the impacts of simple consumptive water use.

- Page 4-1: There is geological and hydrological information on the Chehalis Basin that is contained in the Final Safety Analysis Report for the nuclear plants. This is available through Energy Northwest or the Grays Harbor Public Development Authority.
- Page 4-2: To determine natural flow, more than information on dam regulation is required.
- Page 4-2: Make the last bullet under Hydrology a very low priority (and it is not really related to hydrology).
- Page 4-2: 4.3.1: Punctuation error.
- Page 4-3: Not only should you map water rights, but you should also find out when withdrawals actually started and how much. This is really important in sub-basins where withdrawals are a substantial portion of the flow.
- Page 4-3: Rank all sub-basins for further study based upon how many days the base/instream flow is not met, first just from a "natural flow" standpoint, and then from a "base/instream plus allocation" standpoint.
- Page 4-3: Match up rights with sub-basins before doing refinements and investigations. Do the highest ranking sub-basins first.
- Page 4-3: Start with historical photos of the area to determine actual irrigation, then do communication. Photos would help determine if there has been a change in land use.
- Page 4-3: Why do we need to do additional mapping of water rights for sub-basins with larger allocations (just do priority sub-basins).

- Section 4.4 Water Quality: Some member of the group are having trouble seeing where our water quality effort is going. The study efforts described don't really seem related to potential management decisions that the CBP will be making, and it does not establish a clear tie-in to the existing Upper Chehalis TMDLs for Non Point Source Pollution and Temperature. The recommendations should be more of a sequence of actions, rather than a simple list of things we'd like to know.

- It seems that the CBP needs a much stronger tie-in between pollutant yields/loads and impairments. In other words, we need to use the pollutant yield to identify major sources of non point source pollution, and use this information to prioritize improvement actions. Level 2 recommendations might include the following (which include some of yours):

  - Monitor water quality in rivers where data are not adequate (South Shore of GH, Wynooche, Wishkah, etc.).
  - Identify priority basins subbasins based on level of impairment
  - Develop pollutant yield estimates for priority subbasins using Level 2 hydrologic data
  - Identify and rank sources of pollution in priority subbasins (what kinds of land use or activities are causing the most degradation?). Use this information to prioritize improvement actions.
  - Establish long-term water quality monitoring stations to represent baseline conditions. These should include stations on major rivers to identify long-term basin-wide improvements, and stations on smaller representative watersheds to identify impacts of typical BMPs.

- With respect to the IN yield, don't get too hung up on this. Our watershed is so different from anything in the Puget Sound.

- Revisit the limited set of water quality parameters . Realizing that the CBP/TAC decided to focus on these conventional pollutants, but it seems we should take at least a preliminary look at toxics, pesticides, and other things to make sure we are not missing a real problem. Some kind of biologic monitoring program might help here (Benthic Macroinvertebrates?). There is a lot of local interest in volunteer monitoring of this type, so there could be a good tie in with public outreach efforts.

- Page 4-4: There is some data on Grays Harbor. Might check with Grays Harbor College to see if they know what has been collected.

- Page 4-4: Why update monitoring on Wynooche and Wishkah rivers and not others?

- Page 4-5: Could increase levels of inorganic nitrogen be a result of fertilization techniques, soil types?

- Page 4-6: How did you reach your recommendation for the specific rivers mentioned?

General comments on Sections 4:

Many reviewers felt the Data Gaps / Recommendations Section needed to include a strategic discussion relating where the CBP is now in Level 1 to where the CBP needs to be at the end of Level 2 to begin Phase 3 planning. This would help provide context to the recommendations for Level 2. This discussion could begin with a summary of what kinds of decisions we will be making in Phase 3 related to water quantity, quality, and fish habitat. Then identify what kinds of data are needed for these decisions. A rough example is as follows:

In Phase 3 the CBP will develop a watershed-wide plan to improve water quantity, water quality, and fish habitat in the Chehalis Basin. The CBP will make important decisions on issues such as:

- *Management of groundwater withdrawals in areas where groundwater/surface water interactions are important and surface water flows are over-allocated.*
- *Identification of water sources to meet projected population growth in the basin, based on comparison of water availability to existing allocations.*
- *Augmentation of flows in rivers where instream flows targets are not being met.*
- *Targeting areas for water quality improvement through Best Management Practices, based on estimated loadings and identified impairments.*
- *Etc.*

To make these decisions, the CBP will need to understand:

- *The interaction of groundwater and surface water flows in each watershed*
- *The degree to which surface water flows are over or under allocated in each watershed*

- *Existing and projected water used, based on population growth and changes in land use*
- *The extent to which water rights are actually being used, especially in areas where agriculture is declining (which is pretty much everywhere here).*
- *The degree to which water quality is impaired in each watershed*
- *Sources and magnitude of pollutant loading in each watershed*
- *Etc.*

Level 1 identified existing data, and performed preliminary analyses to begin understanding how well the data met our needs. In Level 2 we need to refine both the data and the analyses, to provide a more rigorous and defensible understanding of water quantity, water quality, and fish habitat in the Chehalis basin. A discussion like this could serve as the introduction to Section 4, and would lead easily into existing discussions on each subject area.

Recommendations are sometimes a bit soft – you use words like “may” and “could”. This section is really the key work product of Level 1, and the scope of work for Level 2 should literally jump out of the recommendations. If Envirovision thinks something needs to be done, say it outright and leave off the qualifiers.

General Comments

- Envirovision’s map presented during the meeting October 12, 2000 contained a big mistake or needs clarification. Salzer Creek drains a small basin roughly northeast of Chehalis and southeast of Centralia. It hooks up with the Chehalis River near the fairgrounds. Coal Creek ties in with Salzer before its confluence with the mainstem and is considered part of the Salzer drainage. On the map Coal Creek was just a little blue squiggle that did not connect to anything. It stopped before reaching Salzer Creek. There was a subbasin division running through this gap, so maybe Coal Creek is in the next subbasin south of Salzer.

- The report did not include maps referenced in the report. It would be nice to examine the maps while reviewing the report.

- Each Appendix included a separate Reference Section at the end of each respective Section. The report also contained a section on references.

Consolidated the references into one section. Some TAC members would like a bibliography for the basin.

- The report needs a list of acronyms.
- The glossary could use some additions as suggested by Joy.
- Consistently reference Chehalis Basin or Chehalis basin.
- Define or describe Chehalis basin and Chehalis River Basin.
- Change reference to WDOE to Ecology. WDOE may imply to some the Department of Energy.
- Develop a four-page “fact sheet” for public outreach.

THE INITIAL ASSESSMENT OF THE CHEHALIS BASIN WATERSHED

BY
JOY P. MICHAUD

OVERVIEW

The 1998 Washington State legislative session established the Watershed Management Act (ESHB 2514) to address diminishing water availability and quality, and the loss of critical habitat for fish and wildlife in the state. The Act was designed to encourage collaboration among local citizens and governments, tribes, and state agencies to develop watershed management plans. These plans would focus on solving water-related issues, such as satisfying water supply needs for people, maintaining stream flows at a level to fully support fish use, and improving water quality. The Chehalis Basin was one of the first to begin this watershed planning process.

In December 2000, the first step in the planning process was accomplished. A team of scientists, lead by Envirovision Corporation, and supported by Technical and Citizen committees from the Basin, completed the Initial Watershed Assessment for the Chehalis Basin. The outcome of this effort is a report that is a tremendous source of information and analysis. However, it is 4 inches thick and over 350 pages long; a bit more than most people have time to read. This article provides a summary of the process that was used in developing this initial assessment and results of the assessment. The Initial Watershed Assessment report also has a Technical Summary chapter that provides a more detailed overview of results. Lee Hansmann, at Grays Harbor County, is the coordinator for the watershed planning process. She can be contacted to obtain a copy of this summary (360) 249-4222.

The first task for the project was to assemble available information on the Basin and begin creation of a permanent library and a master list of documents. Next, the consulting team conducted an all day workshop with technical experts, local agencies, and citizens to discuss issues and concerns pertaining to the Basin. The outcome of the workshop was development of a technical approach for conducting the Initial Watershed Assessment. This approach was approved by the Chehalis Basin Partnership (CBP); a group of representatives from local and State agencies and citizens formed to oversee development of the Watershed Plan. As a consequence, from the very beginning of the process, information and opinions were collected from throughout the basin to provide direction for the assessment process.

BASIN DESCRIPTION

The Chehalis Basin covers 2,520 square miles, and is second in size only to the Columbia Basin in the State of Washington. It is bound on the west by the Pacific Ocean, on the east by the Deschutes River Basin, on the north by the Olympic Mountains, and on the south by the Willapa Hills and Cowlitz River. Given the size of the basin, it was more useful to divide it into smaller pieces for assessment. Therefore, the Basin was divided into 30 subbasins according to major tributaries. Most of the data accumulated during the study (precipitation, size, land use, water flows, water rights, etc.) is reported for each subbasin. In addition, 5 of the 30 subbasins were selected for more detailed analysis. These 5 subbasins were chosen to represent the diversity of natural and manmade conditions in the Chehalis Basin. Together, they represent a wide range in basin size, land use, climate, water use, and geology. A summary of key characteristics for the 5 subbasins is provided in Table 1.

Table 1. Key Characteristics of the 5 subbasins chosen for detailed analysis.

Subbasin	Size (mi^2)	Geography	Annual Precip. (in)	Runoff (cfs per mi^2)	Geology	Land Use % Forestry/ % Agriculture
Chehalis Headwaters	116	Mid-elevation Willapa Hills	89	5	basalt-upper, alluvium-lower	96/3.1
Newaukum	156	Cascade foothills	52	3-5	volcanic-upper; glacial outwash-lower	80.5/17.3
Cloquallum Creek	70.3	Low elevation	68	4	glacial till-headwaters; glacial & alluvial-lower	90.9/3.3
Lower Mainstem Chehalis	94	Valley floor	59	3-4	alluvial valley floor; side slopes sedimentary rock	78.9/4.9
Humptulips	244.3	Olympic Mountains, coastal	127	10	volcanic-headwaters, alluvial & glacial drift-lower	96.2/1.4

The Chehalis Basin has several distinct geologic regions with unique geologic history. Thus, bedrock of volcanic and sedimentary origin are represented as well as glacial deposits and alluvial material. Much of the Basin possesses glacial deposits from at least four different glaciations. The complex geologic history dictates to a large degree the distribution, quantity, and movement of groundwater, adequacy of wells, connections between groundwater and surface water, and many other factors.

There is also a wide variation in precipitation levels throughout the Chehalis Basin. As shown in Table 1, precipitation in the 5 subbasins ranged from 52 inches per year in the Newaukum subbasin (near Chehalis) to more than twice that in the Humptulips subbasin. The amount of precipitation, along with soils and geology, influences how much of this water soaks into the land and how much leaves as surface water runoff. The estimated range in surface water runoff from the 5 subbasins was from 3 cubic feet per second/square mile (cfs/mi^2) along the low lying valley bottom areas, to 10 cfs/mi^2 in the upper watersheds draining the Olympic Mountains.

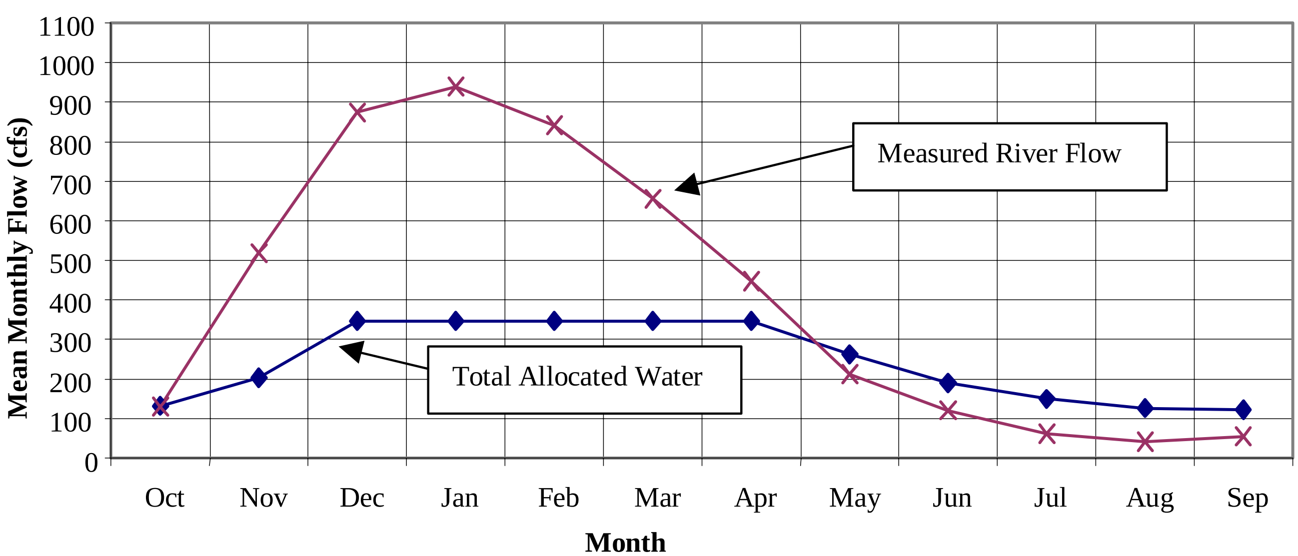
Another important factor contributing to surface water runoff is human development, which can cause huge changes in hydrology. Ditching, draining, diverting, damning, soil disturbance and loss, and increases in hard surfaces such as pavement and buildings, are a few of the activities that contribute to changing hydrology. These activities have occurred throughout the Chehalis Basin. In the Upper Basin (upstream of Montesano) these activities have been proliferated by urban development and agricultural activities, while in the Lower Basin (Grays Harbor area) forestry activity is probably the greater culprit.

WATER AVAILABILITY

Assessing the amount of water available in a river is like balancing a checkbook. First, it is necessary to know your beginning account balance. Then you must subtract the amount of money designated for checks that have not cleared, subtract for future savings, and then subtract the minimum balance that must be maintained in the account. The money remaining is what is available to spend or use. In this example, in terms of water availability, the beginning account balance can be represented by measured river flows. Uncleared checks can be represented by the amount of water allocated for human use via water rights and other permits. Future savings would be the amount of water that needs to be set aside to allow for future population growth. The minimum balance can be represented by the term "instream flow". Instream flows are set and regulated by the State and are a representation of the amount of water needed to support fish in all life stages. After allocated water, future needs, and instream flows are subtracted from measured flows, the amount remaining is what can be withdrawn from the system for other uses. All of this information was gathered, compared, and analyzed in the Initial Watershed Assessment.

Once all of the necessary information was gathered a graph depicting the water availability for the river was drawn. Figure 1 below portrays this information for the Upper Chehalis River as measured near the town of Porter. Monthly average river flows are shown in the figure by the red line with the crosses. The blue line with the diamonds shows the amount of water that has been allocated through water rights plus what has been set aside to protect fish habitat (i.e. instream flow). When the red line is greater than the blue line, there is water to spare. When the reverse is true, it indicates that water has been over-allocated. This graph demonstrates that the combination of instream flow and water allocation for human use exceeds the average monthly flows for the river from May through September. Unfortunately, this problem exists in much of the Chehalis Basin. This is why the issue of watershed planning and assessments is so important. The State Department of Ecology can not continue to approve new water rights when the river is already over-allocated.

Figure 1. Chehalis River at Porter Regulated Mean Monthly Flows



Luckily, this over-allocation is to some extent a "paper problem". Obviously the river does not run dry from May through September each year. This is because the amount allocated for human use does not reflect the true amount being used. For example, there may be a water right for as much as 100 units of water, but the water right holder may only be using 1 unit of water. In the Chehalis as well as throughout the state, the amount allocated is not an accurate reflection of what is actually being used or needed. Preliminary estimates of actual water use were made for the Initial Watershed Assessment, more extensive estimates should be a priority for future work.

WATER QUALITY

One of the preliminary steps of the water quality assessment was to get agreement from the CBP and others on which water quality parameters and locations would be the focus of the work. The parameters eventually agreed upon were selected because they are most closely linked to the objectives of watershed planning. They are either directly related to fish habitat and flow problems (dissolved oxygen and temperature), or are good indicators of water pollution (total phosphorus and total suspended solids), or important in the Basin since they are tied to a commercial industry (fecal coliform bacteria). This is not meant to imply that other pollutants, such as heavy metals or pesticides, are not a concern. These pollutants may be prioritized for analysis at a later date.

The selected parameters were assessed a number of ways. Monitoring results were compared to State water quality standards. Comparisons were also made between sites or locations, and over time, to look for obvious trends in the data. A pollutant load and yield analysis was also performed to enhance comparisons between watersheds.

Every two years the EPA provides a "List of Impaired Waterbodies" in the nation. This is referred to as the "303(d) list" because that is the subsection of the Clean Water Act that requires this listing. The most frequently used method for assessing whether a water body (a stream or stream segment) is impaired, is by comparison to water quality standards. Therefore, EPA's 303(d) list provides one method for summarizing the Basin condition in terms of water quality standards. Within the Chehalis Basin there are 25 segments of streams or rivers that are on the 303(d) list. These are listed due to violations of temperature, and/or dissolved oxygen concentrations, and/or fecal coliform bacteria. Of the 25 listings, 19 were due to elevated fecal coliform levels, 11 were due to low summer dissolved oxygen concentrations, and 9 were due to elevated summer temperatures. The majority of the listings are in the Upper Basin. The combination of generally higher temperatures and lower oxygen concentrations experienced in the Chehalis during late summer represents a critical set of conditions for fish.

Although it is informative to know whether water quality standards are being met, it is also interesting to know whether water quality has changed since monitoring began in the 1970's. Long-term trends were assessed for temperature, dissolved oxygen, and fecal coliform bacteria. On a seasonal average basis, no significant trends were noted in the mainstem of the Chehalis River, for these parameters. This tells us these problems do not appear to be either improving or deteriorating.

The pollutant loading analysis indicated that nonpoint sources of pollution were probably the most significant. (Nonpoint pollution sources are those not associated with a direct discharge such as from a wastewater treatment plant or industrial facility. The pollutant yield analysis indicated that suspended solids yields were notably higher than in subbasins with higher runoff and precipitation. However, the same trend was not apparent for other parameters.

CONDITIONS OF FISH STOCKS AND FISH HABITAT

A total of two spring chinook stocks, seven fall chinook stocks, two chum stocks, seven coho stocks, two summer steelhead stocks, eight winter steelhead stocks, one bull trout/Dolly Varden stock and two coastal cutthroat stocks have been identified in the Chehalis Watershed. No pink salmon or sockeye salmon stocks have been identified in the area. Of the thirty-one stocks identified, twenty are classified as “healthy”, four as “depressed”, and seven as “unknown”.

While the condition of habitat varies widely between subbasins, some basin-wide patterns are clear. As a result of past and present land use practices, stream channels in the Chehalis Basin show a consistent pattern of riparian vegetation removal, shade reduction, and reduction in streambank stability leading to bank erosion and elevated levels of instream sediments. Available information indicates that instream woody debris levels are either non-existent or much lower than historic levels. While information about loss of side channel and wetlands habitats is more anecdotal, patterns of timber harvest and agricultural practices have left stream channels in a more simplified state than in pre-settlement periods. This has contributed to streambank instability, lower shading, and poor instream habitat. Although summer water temperatures in the basin may naturally be somewhat high due to relatively low elevations of many of the streams, riparian vegetation removal, lowered shading levels, and degradation of streambanks have most likely contributed to an increase in the magnitude and range of this problem. In a few subbasins, habitat conditions may be in partial recovery from past damages. This is most likely on forested lands managed under federal or state forest practices where protection of riparian corridors has become the rule during the last few decades.

CONCLUSION

In the next few years, difficult decisions will need to be made about how water is allocated and used in the Chehalis Basin. As documented in the Assessment report, besides being very large, the Chehalis Basin is also naturally more diverse and complex than other basins. The 30 subbasins identified, have different background conditions of geology, precipitation and topography. They have experienced a different set of historical uses, and currently have different land use and water use patterns. This diversity means that priorities and needs will be different between the subbasins. The consultant team has recommended that future assessment work be done on a subbasin scale to enhance its use for decision-making and eventual development of a Chehalis Basin Watershed Plan.

The *Chehalis Basin Level 1 Assessment* is a preliminary step in the planning process set up through the Watershed Management Act. It is a great first step in collecting and assessing information on the Basin, and reflects a tremendous amount of work by the consulting team, the citizens and scientists on the advisory committees, and the Chehalis Basin Partnership. However, the work has just begun. Although there is never a bad time to become involved in this process, right now is a particularly good time as we move into the next phase of planning. Lee Hansmann at Grays Harbor County is spearheading this process. She can provide information on who your local representative is, and also how to become involved. Lee can be reached at 360-249-4222.