Willapa River
Dissolved Oxygen
Total Maximum Daily Load

Water Quality Improvement Report
and
Implementation Plan

February 2006
Publication Number 06-10-017

Willapa River
Dissolved Oxygen
Total Maximum Daily Load

Water Quality Improvement Report
and
Implementation Plan

Washington State Department of Ecology
Water Quality Program

February 2006
Publication Number 06-10-017

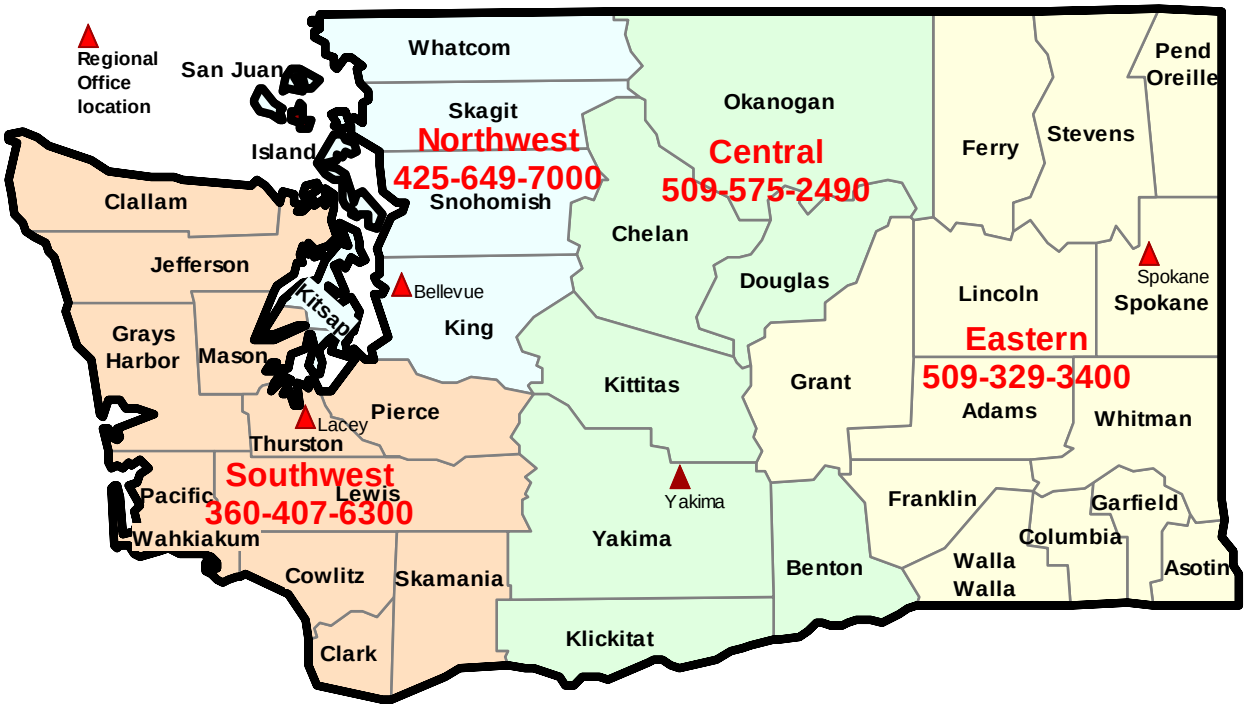
You can print or download this document from our Web site at:
http://www.ecy.wa.gov/biblio/0610017.html

For more information contact:

Department of Ecology
Water Quality Program
Southwest Regional Office
P.O. Box 47775
Olympia, WA 98504-7775

Telephone: 360-407-6270

Headquarters (Lacey) 360-407-6000



Persons with a hearing loss can call 711 for Washington Relay Service.
Persons with a speech disability can call 877-833-6341.

If you need this publication in an alternate format, please call the Water Quality Program at 360-407-6270. Persons with hearing loss can call 711 for Washington Relay Service. Persons with a speech disability can call 877-833-6341.

Table of Contents

List of Figures

List of Tables

Overview of Study and Cleanup Plan

Report Purpose

This report summarizes results of a dissolved oxygen total maximum daily load (TMDL) study in the Willapa River Watershed conducted by the Washington State Department of Ecology (Ecology), Pacific County Government, and private consultants. It also provides a detailed plan for limiting pollution discharges in the lower river to meet state water quality standards.

The final TMDL study was conducted as a cooperative effort by Cosmopolitan Engineering, Tetra Tech (contractor to USEPA), Gray and Osborne, and. Ecology. Cosmopolitan was the principal contractor who finished the TMDL study and technical report. The technical basis for this cleanup plan is detailed in Cosmopolitan's report *Willapa River Watershed Dissolved Oxygen Total Maximum Daily Load Study* (Cosmopolitan, 2005). That report provides the technical support necessary for USEPA approval of the TMDLs addressed in this plan.

The 2005 TMDL report characterizes dissolved oxygen conditions in the lower river and recommends wasteload allocations (numerical limits) in order for facilities covered by wastewater discharge permits to meet dissolved oxygen standards. This document serves as the water quality Improvement Report and Implementation Plan because it includes the technical elements required for TMDL approval and it discusses a potentially successful approach for water quality protection. The Improvement Report and Implementation Plan are two project phases required for administrative completion of a TMDL project.

Pollution Concerns and Causes

The lower Willapa River includes the tidally-influenced portion of the Willapa River from Camp One Road (Willapa River Mile 17.5) downstream to the river's mouth in northeast Willapa Bay (Figure 1). Monitoring of the lower Willapa River since the early 1970s shows that dissolved oxygen (DO) fell below the state water quality standard of 6.0 mg/L on many occasions during late summer and early fall (July through September). As a result, several segments of the lower Willapa River are included on Washington's 1998 303(d) list of impaired waters for dissolved oxygen. Adequate levels of dissolved oxygen are necessary to protect the health of aquatic organisms and to maintain other beneficial uses of the river system.

The pollutants believed to most affect DO levels are carbonaceous biochemical oxygen demand (CBOD) and ammonia nitrogen. Point sources for these pollutants include the Raymond and South Bend municipal wastewater treatment plants (WWTPs) and three seafood processors: Coast Seafoods, South Bend Packers, and East Point Seafoods. Potential nonpoint sources include failing septic systems and urban, industrial, and agricultural runoff. However, nonpoint sources account for less than 1 percent of the allowable DO deficit. Therefore, this TMDL applies just to the point sources.

Water Quality Targets

State water quality standards pertinent to the estuarine conditions of this TMDL classify the lower Willapa River as Class A marine waters (as defined in WAC 173-201A-060 (2)). Applicable marine criteria require that DO shall exceed 6.0 mg/L. If natural conditions are found

to be near or below the criteria, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L by human-caused activities.

The natural background concentrations in the study area are below 6.0 mg/L during late summer. Therefore, the numeric water quality target for this TMDL is the DO deficits that will meet the applicable water quality criteria.

Effects of Existing Discharges to Willapa River

Leading up to this TMDL, the combined effects of wastewater loading to the receiving water during summertime conditions, exceeded the allowable DO deficit. However, industrial operation discharges are different now. One facility was contributing significantly to ammonia and BOD loading until they stopped operating in 2003.

During peak discharges from 1998 to 2003, all facilities collectively exceeded tolerable loading by 5% more than allowed. Recent wastewater analyses show that the facilities now collectively operate well within the maximum allowable DO deficit. Based on 2004 discharge data during peak critical operating conditions (assuming all facilities would be discharging peak pollution loads constantly and simultaneously) the facilities would only be utilizing 65% of the allowable pollution capacity. Therefore the environmental purpose of this TMDL is to protect rather than restore water quality. [However, the TMDL serves an additional administrative purpose: because the water body was "listed" several years ago as being impaired, this TMDL document forms the technical basis that the places of DO impairments can be removed from the 303-d list when the list is updated again.]

Loading Capacity

Water quality surveys were conducted in 1998 and 2001 to collect field data for modeling. A modeling system with hydrodynamic and water quality elements was used to determine the capacity of the river to assimilate pollution. Modeling found that natural conditions cause the river to fail DO standards during the critical season (Cosmopolitan, 2005). The TMDL challenge is to limit the facilities to the extra 0.2 mg./l DO deficit that the water quality standards allow in this setting. The loading capacity is 0.2 mg./L decrease in dissolved oxygen during the critical season.

Wasteload Allocations Set By a 'TMDL EQUATION'

Multiple model runs were made to isolate and quantify the effects of $CBOD_5$ and NH_3-N from each point source. An equation was developed based on the solution to simultaneous equations derived from the model runs. Any combination of point source waste loads (in lbs/day) that satisfies the following TMDL equation meets the dissolved oxygen water quality standard:

+	$(0.207)\ CBOD5_{R}$	+	$(0.420)\ NH3\text{-}N_{R}$	
+	$(0.067)\ CBOD5_{SB}$	+	$(0.132)\ NH3\text{-}N_{SB}$	
+	$(0.031)\ CBOD5_{EP}$	+	$(0.178)\ NH3\text{-}N_{EP}$	
+	$(0.027)\ CBOD5_{SBP}$	+	$(0.155)\ NH3\text{-}N_{SBP}$	
	$(0.019)\ CBOD5_{CS}$	+	$(0.109)\ NH3\text{-}N_{CS}$	$\leq 199\ \mu g/L$

Where:

R	=	Raymond WWTP
SB	=	South Bend WWTP
EP	=	East Point Seafoods
SBP	=	South Bend Packers
CS	=	Coast Seafoods

The 'equation' is simply a calculation to figure the maximum amount of BOD and ammonia that each facility can discharge in order that the total discharges don't violate the water quality criteria. The equation provides the framework for setting both current and future WLAs for the affected facilities. The five facilities have since agreed to specific WLAs that are expressed in terms of equivalent oxygen demand (EOD) that combines the effects of both parameters on DO.

Implementation Plan

The wasteload allocations will be implemented through NPDES permits issued to the individual facilities. The facilities identify themselves collectively as the Willapa Resource Estuary Management Group (WERM). According to a WERM MOA (Appendix B), which Ecology agreed with, each facility NPDES permit will include the pertinent WLA facility limit as well as an aggregate limit that the facilities must meet collectively. As long as technology-based and aggregate limits are met, permit holders will be in compliance with the permits and no action will be taken on individual performance. If the aggregate limit is exceeded, enforcement would be taken on the facility or facilities that exceed their individual WLA.

The TMDL may include adaptive management to adjust the individual allocations over time. The MOA includes protocols and guiding principals to reallocate WLAs based on future needs, including management of a reserve allocation. A TMDL reserve allocation typically serves as a kind of savings account to hold back some of the available loading capacity so that future pollution from population growth can be accommodated with the reserve, instead of having to withdraw from wasteload allocations already committed to a certain facility. Any reallocations of WLAs recommended by the collective facilities are subject to approval by Ecology and would be implemented through revisions to NPDES permits. If a change to the 'TMDL Equation' is needed in order to establish different wasteload allocations (for example if a new facility needs to access a portion of the aggregate wasteload allocation), then the resulting TMDL modification must also be approved by EPA. Opportunity for public comment will be provided in the event of a proposed change to either the TMDL or NPDES permits.

Geographic Extent of Impaired Resources

The Willapa River drains a region of about 260 square miles. The study area covered about half of the basin - the lower portion of the upper river watershed. Figure 1 shows the entire watershed that has been the subject of several TMDL studies since 1998. This report addresses only the lower watershed affected by 303d listings for dissolved oxygen (DO) conditions. The lower river DO study and resulting cleanup plan covered by this report only affect the tidally influenced portion of Figure 1, which begins at the river mouth and ends at Camp One Road., - generally marked as river mile 14.5. A DO listing in the South Fork Willapa River is also covered in the scope of this report.

The Willapa River basin is largely rural with the exception of the cities of Raymond and South Bend. Principal industries in the cities are timber and seafood (mostly oysters). Agricultural land uses predominate in the river valley and silviculture is the main use throughout the rest of the basin. There are about four commercial dairy operations in the basin, and many smaller livestock operations for beef and young stock.

The lower Willapa River is a tidal estuary characterized by mixing of Willapa Bay marine waters with fresh water from the river and other tributaries. Tidal effects on river height can be observed just downstream of Camp One Road at River Mile (RM) 14.5, and saline marine water moves up through most of this area, depending on the flow.

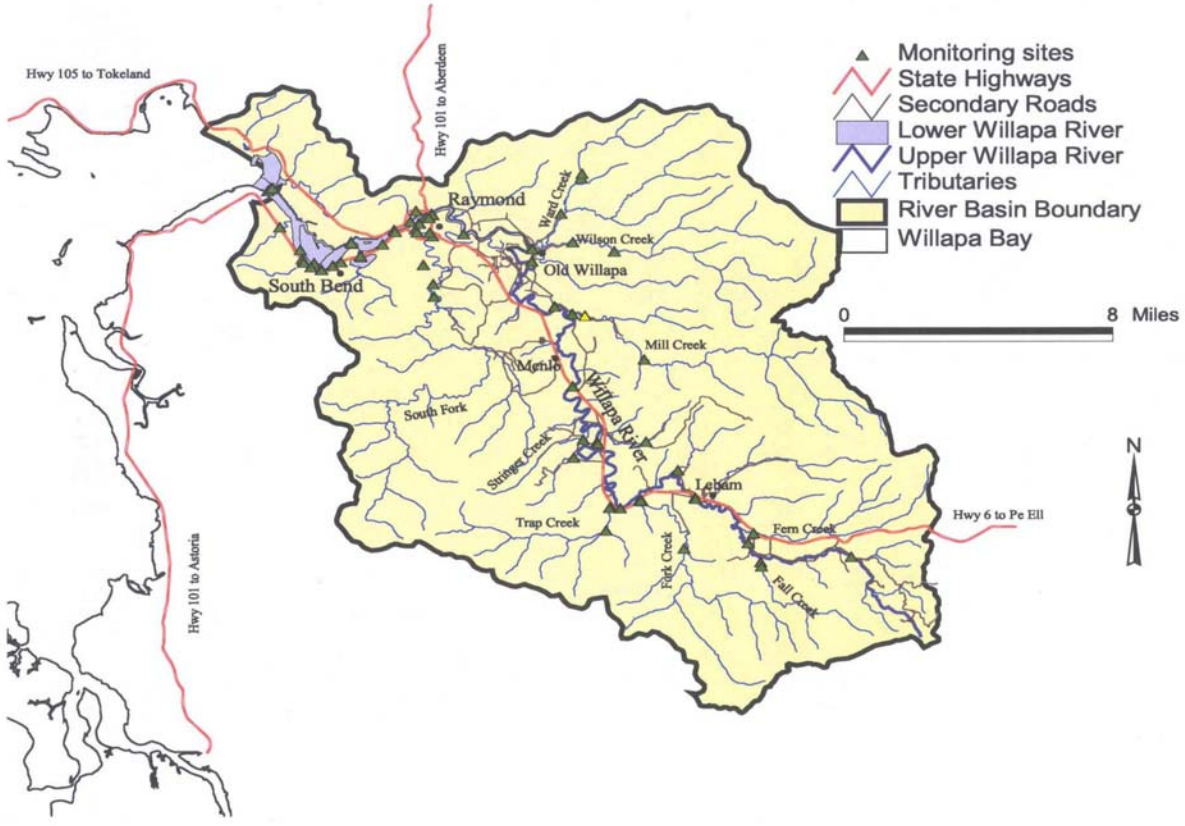


Figure 1. Willapa River TMDL Study Area

Based on salinity data from the Willapa River, the marine DO criterion applies year-round at all sites in the Willapa River downstream from Willapa Road. The fresh water DO criterion applies at all times at Camp One Road and upstream. Department of Ecology personnel have collected marine ambient monitoring data at Station WPA001 (near the Port of Willapa Harbor docks in Raymond since 1973). Out of 299 measurements over 25 years, DO was observed at or below the standard of 6.0 mg/L on 25 occasions, all during the months of June through September. During the September 1998 TMDL survey, DO levels below the marine standards were found at all stations on the lower Willapa River from Ellis Slough to South Bend, including the South Fork at the Highway 101 Bridge. Table 1 identifies the segments in the lower Willapa River that are being addressed by this report and implementation plan.

Table 1: 2004 303(d) Listings for Dissolved Oxygen in the lower Willapa River Watershed

January 2006

Name	Township, Range, Section & River Mile	2004 Identification Number
Willapa River at Johnson Slough	14N, 9W, 17 RM 0.4	9511
Willapa River below South Bend	14N, 9W, 28 RM 3.0	14882
Willapa River near Raymond Port	14N, 9W, 24 RM 6.4	10352
Willapa River at 101 Bridge	14N, 8W, 19 RM 7.7	14952
Willapa River near Ellis Slough	14N, 9W, 24 RM 9.5	43026
Willapa River at Willapa Rd.	14N, 8W, 28 RM 13.7	14961
Willapa River, South Fork	14N, 8W, 19 RM 7.1	14916
Total		7

Applicable Water Quality Criteria

The TMDL is designed to address impairments of characteristic uses caused by DO deficits. The characteristic uses designated for protection in Willapa River basin streams are as follows (from Chapter 173-201A WAC):

Characteristic uses shall include, but not be limited to, the following:

i. Water supply (domestic, industrial, agricultural).

ii. Stock watering.

iii. Fish and shellfish:
   - Salmonid migration, rearing, spawning, and harvesting.
   - Other fish migration, rearing, spawning, and harvesting.
   - Clam and mussel rearing, spawning, and harvesting.
   - Crayfish rearing, spawning, and harvesting.

iv. Wildlife habitat.

v. Recreation (primary contact recreation, sport fishing, boating, and aesthetic enjoyment).

vi. Commerce and navigation."

State water quality standards describe criteria for DO for the protection of characteristic uses. Streams in the Willapa River basin are designated as Class A. The criteria for Class A waters are as follows:

- **Water Quality Criteria**: Freshwater - dissolved oxygen shall exceed 8.0 mg/L. Marine water - dissolved oxygen shall exceed 6.0 mg/L. When natural conditions, such as upwelling occur, causing the dissolved oxygen to be depressed near or below 6.0 mg/L, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L by human-caused activities. (Note- The added 0.2 deficit can be allowed only during the critical period.)

- **General Considerations**: In brackish water of estuaries, where the fresh and marine water quality criteria differ within the same classification, the criteria shall be applied on the basis of vertically averaged salinity. The freshwater criteria shall be applied at any point where ninety-five percent of the vertically averaged daily maximum salinity values are less than one part per thousand. Marine water quality criteria shall apply at all other locations.

Seasonal Variation

Violations of DO standards occur only during the summer months. Therefore, the TMDL shall only apply during the months of June through September. DO data from Station WPA001 near the Port of Raymond are shown in Figure 2, along with the water quality criterion of 6.0 mg/L. This figure shows that the criterion has not been exceeded except during the period from July through September. Each diamond on the figure indicates a single sample result. Hence there are about 8 to 13 sample results for each month during the 10-year sampling period reflected in the table. In addition, the hydrodynamic and dissolved oxygen models were calibrated with data collected during that period (Cosmopolitan, 2005).

Dissolved oxygen concentration as low as 6.5 mg/L has been measured during October at Station WPA001. More analysis was done to determine if extension of wasteload allocations and permit limits through October would prevent DO levels dropping below the 6.0 mg/L Class A limit. Therefore, October critical conditions were evaluated and modeled separately from July through September critical conditions. However, based upon existing waste loads, the results demonstrated that there is no reasonable potential for violation of the DO criteria in October (Cosmopolitan, 2005).

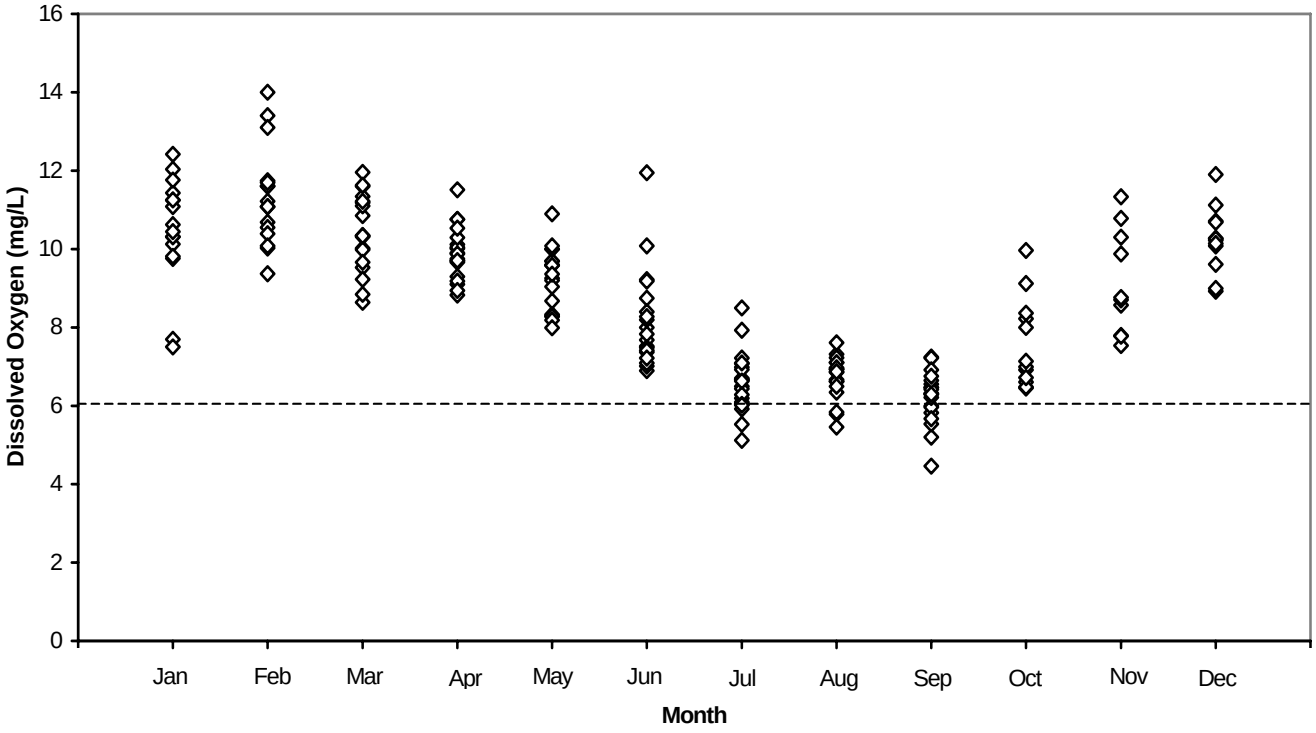


Figure 2. Dissolved Oxygen Data for Ecology Station WPA001 from 1990 through 2000

The TMDL Approach

The Clean Water Act mandates the Washington State Department of Ecology to develop total maximum daily load (TMDL) studies for water bodies that fail to meet water quality standards after technology-based water quality controls have been put into place. In 1997, Ecology signed a Memorandum of Agreement with the Environmental Protection Agency (EPA) assuring that TMDLs would be developed for all water bodies on the 1996 303(d) list. Ecology also agreed to develop submittal reports (Improvement Report) and detailed implementation plans (DIPs, renamed as Implementation Plans) for listed water bodies, obtain EPA approval, and to direct the implementation of these TMDLs.

Facility sampling during the critical dry-weather season in 2002 determined that the facilities were collectively discharging very close to the loading capacity of the river. (Gray and Osborne, 2003). The facilities proposed a wasteload allocation framework (the "TMDL Equation"-see Wasteload Allocations section below) to assure that their aggregate load will not cause the river to fail DO standards. The facilities further proposed that the WLAs be implemented through new NPDES permits that will administer both an individual facility limit as well as an aggregate limit that the facilities collectively must not exceed. The NPDES permits may also include more stringent technology-based (AKART) or mixing-zone based limits for $CBOD_5$ and ammonia for each facility, which supersedes the aggregate limit.

Ecology believes that the most important TMDL outcome is for the receiving water to meet standards and provide beneficial uses. Therefore, the most important measure of the NPDES permit effectiveness is the facilities collective performance to "ensure that DO in the receiving water drops no more than 0.2 mg/L below natural DO levels when natural levels are 6.2 mg/L or less".

To allow the facilities and community the maximum flexibility to work together to manage that outcome in ways that won't conflict with the TMDL, Ecology agreed to a flexible approach for enforcement of the facilities permits. The WERM Memorandum of Agreement (see Appendix B) that Ecology agrees with, defines how each facility NPDES permit will include the pertinent WLA limit as well as an aggregate limit that the facilities must collectively meet. Members of the WERM calculated and agreed to initial WLAs described in the Wasteload Allocations section (below). They will have the first opportunity to recommend modifying the WLAs, as necessary, when a new facility must be considered in reapportioning the aggregate wasteload among all affected facilities. As long as technology-based and aggregate limits are met, permit holders will be in compliance with the permits and no action will be taken on individual performance. If the aggregate limit is exceeded, enforcement would be taken on the facility or facilities that exceed their individual WLA.

Ecology plans to issue new NPDES permits during 2006 that will include the new limits. The facilities have agreed in their MOA to demonstrate permit performance using a coordinated monitoring program during the TMDL critical season. The city of Raymond volunteered to coordinate the monitoring by all facilities.

The WERM MOA also describes the process for modifying the individual facility WLAs. WERM will review possible changes in operations of facilities contributing to the aggregate limit (e.g., a current facility expands or a new business joins the community). WERM can modify the TMDL Equation to accommodate those facility changes as long as the total wasteload

doesn't increase beyond the current equation sum. Ecology doesn't plan to modify the TMDL or NPDES permits as long as the facilities that are part of the current TMDL Equation continue to meet the aggregate limit. However, if WERM proposes adding a different facility to the TMDL Equation, their MOA describes how the new facility could be considered. If the new facility is successful getting established as part of a new TMDL Equation, the new equation (with the current sum/aggregate limit) would serve as the starting point for a revised TMDL and new permit limits for each facility in the equation. Such changes to the TMDL or NPDES permit would be simple and straightforward since the TMDL equation will continue to serve as the operating limit for any changes. If revisions to the TMDL or NPDES are needed, Ecology will provide EPA a letter explaining the modified "TMDL Equation" to add as an errata or modification to the original TMDL and NPDES permit.

Overview of the Technical Analysis and Loading Capacity

The sensitivity of the water to DO deficit or the lower limits that will still allow the river to meet water quality standards is called the "loading capacity". The technical consulting team used the calibrated WASP 51t water quality model to determine the loading capacity in the affected lower Willapa River.

Waste loads were specified for point source loading from the two municipal wastewater treatment plants and three seafood processors, and for nonpoint source and background tributary loading. Tributary loading, including runoff from the lumber mills, was calculated from input flows (determined for the DYNHYD flow model inputs) and concentrations measured during surveys. Unmonitored tributaries were assigned concentrations from neighboring monitored tributaries. Point source loading for calibration and verification was calculated from measured flows and concentrations during the surveys.

For critical conditions modeling, point source loading was developed from critical design flows and contaminant concentrations. Gray and Osborne (2000) provided municipal flows and ammonia concentrations. Seafood processor flows and loading were determined from NPDES permit fact sheet information, the EPA development document for the seafood processing industry, and historical Discharge Monitoring Reports. Nonpoint source loading, including the lumber mills, was set at the highest seasonal concentrations for critical conditions, and the lowest seasonal concentrations for natural conditions.

A complete description of the loading capacity calculations, analytical framework, and calibration and verification of the modeling is presented in Cosmopolitan, 2005 (Appendix C).

NPDES permitted point source loads to the Willapa River Estuary include the city of Raymond and city of South Bend wastewater treatment plants, East Point Seafoods, South Bend Packers and Coast Seafoods. Dry weather flow and wasteload projections for each facility are presented in a draft report by Gray & Osborne titled *Willapa Estuary Dissolved Oxygen TMDL Alternatives Analysis* dated December 2003. The projected 2022 loadings of 5-day carbonaceous biochemical oxygen demand ($CBOD_5$) and ammonia nitrogen (NH3-N) are presented in Table 2.

Table 2. Year 2022 Dry Season Point Source Waste Loads to the Willapa River Estuary

Facility	*$CBOD_5$ (lbs/day)*	*NH_3-N (lbs/day)*
City of Raymond WWTP[(1)]	221	266
City of South Bend WWTP	85	81
East Point Seafoods	2,500	14
South Bend Packers	10	16
Coast Seafoods	500	28
[(1)] Includes flows from the Port of Willapa Harbor		WWTP means Wastewater Treatment Plant

The WASP51t model was run with the point source loads in Table 2. The nonpoint source loading was also included in the model run. Extensive sensitivity testing was performed. The critical model time and segment for dissolved oxygen deficit were found to be Day 20.751 of the model simulation, and Segment 25 (the confluence of the south fork and mainstem). The maximum DO deficit was 0.27 mg/L. The water quality standard allows a maximum deficit of 0.20 mg/L. Therefore, the final wasteload allocations represent a 26 percent reduction from the 2022 projected loadings in Table 2.

The TMDL model was run with the maximum measured loadings from each facility measured between 1998 and 2002. The model results indicated a DO deficit of 0.21 mg/L, which is just above the 0.20 limit. The loading and deficit during 1998-2002 included operation of a biopolymer manufacturing business, Vanson Halosource, Inc. Vanson processed crab shell into "Chitosan," producing a wastewater high in ammonia and CBOD. In 2003, when Vanson was not in operation, the DO deficit was reduced to 0.13 mg/L, which met the water quality standard. Chitosan production at the Vanson plant stopped in 2003 but they are still located at the Port of Willapa and expect to continue operating in some capacity for the foreseeable future.

Pollution Sources Needing Management

The pollutant believed to most affect DO levels is biochemical oxygen demand (BOD). BOD is categorized into two forms: carbonaceous BOD (CBOD) and nitrogenous BOD (NBOD). NBOD, measures the oxygen used by the oxidation of organic nitrogen to ammonia (mineralization) and ammonia to nitrate (nitrification). CBOD is a measurement of the amount of oxygen needed to oxidize the carbon in organic materials.

In the Willapa River basin, possible sources of BOD include both point and nonpoint sources. Table 3 lists the facilities that are sources of BOD and have NPDES permits from Ecology.

Table 3. NPDES-Permitted BOD Sources

Facility Name	*Type*
City of Raymond	Municipal Wastewater Treatment Plant
City of South Bend	Municipal Wastewater Treatment Plant
East Point Seafoods	Seafood Processor
Coast Seafoods	Seafood Processor
South Bend Packing	Seafood Processor
Weyerhaeuser Company	Lumber Mill (storm water)
Pacific Hardwoods (Raymond facility)	Lumber Mill (storm water)
Pacific Hardwoods (South Bend facility)	Lumber Mill (storm water)

The wastewater treatment plants (WWTPs) and the seafood processors have individual NPDES permits with BOD limitations. Both cities have secondary treatment with lagoon systems, and have been working over the years to correct infiltration/inflow problems. Raymond receives industrial wastewater from the Weyerhaeuser mill and, until recently, from the Biopolymer plant owned by Vanson on Port property near the docks. The Port provided pretreatment to Vanson prior to discharge to the city of Raymond sewer system.

The fish processors screen their wastewater and discharge directly to the Willapa River. Coast Seafoods processes oysters and uses a mixture of saline river water for shell washing and city water for processing. East Point seafood processes a variety of products, including fish, crab and shrimp, and uses city water for processing. South Bend Packers does mostly reprocessing of fish filets, and sometimes processes oysters.

An industrial NPDES stormwater general permit covers the lumber mills. The Weyerhaeuser mill has two oil-water separators and recently installed a biofiltration system. Otherwise the three mills provide no stormwater treatment. Historically there have been many more mills in the area, but economic conditions have led to a consolidation. There was woodchip loading operations at docks near the Port in the past, but barges have not been entering the Willapa River for many years.

Other possible sources of BOD typically found in nonpoint source pollution and also occurring in the Willapa basin include:

- On-site septic systems
- Urban stormwater run-off
- Livestock
- Natural background sources

Since most of the lower Willapa River is either tidal wetlands or behind levies, nonpoint sources are mostly assumed to reach the river through tributary creeks, sloughs, and drains. Nonpoint sources were estimated conservatively to contribute only an estimated 0.5 percent of the BOD load to the lower Willapa River during the critical dry weather conditions for dissolved oxygen. Impacts of those sources during the dry season are obviously extremely small but the study assigned them a numerical loading anyway, to be conservative. That assures that all of the available loading is not inaccurately assigned to the point source facilities. Also, identifying nonpoint as being presently inconsequential to this TMDL helps reinforce that preventive controls are important to maintain.

Compliance with the DO standard will be sustained primarily from application of wasteload allocations to the point sources.

Wasteload Allocations

NPDES permitted point source loads to the Willapa River Estuary include the city of Raymond and city of South Bend wastewater treatment plants, East Point Seafoods, South Bend Packers and Coast Seafoods. Dry weather flow and wasteload projections for each facility are presented in a draft report by Gray & Osborne titled *Willapa Estuary Dissolved Oxygen TMDL Alternatives Analysis* dated December 2003. The alternatives analysis reviewed many possible WLA options.

There are unlimited combinations of WLAs that would satisfy the TMDL model. Each discharge has a different impact on DO deficit at the critical segment at the mouth of the Willapa South Fork because of location (Cosmopolitan, 2005). For example, the Raymond wastewater treatment plant discharge has the greatest impact due to its proximity to the confluence, and Coast Seafoods has the least because it is the farthest away.

During critical conditions, the estuary is characterized by strong tidal mixing and relatively slow net flushing, due to the low river runoff. Waste materials discharged to the estuary are rapidly dispersed but slowly flushed from the system, which provides a significant buffer to short-duration peak discharges. Therefore, the WLAs will be implemented in NPDES permits as weekly average limits rather than daily limits.

The "TMDL Equation"

Multiple model runs were made to isolate and quantify the effects of $CBOD_5$ and NH3-N from each point source. A TMDL equation was developed based on the solution to simultaneous equations derived from the model runs (Cosmopolitan, 2005). Any combination of point source waste loads (in lbs/day) that satisfies the following TMDL equation (Figure 3) meets the dissolved oxygen water quality standard: