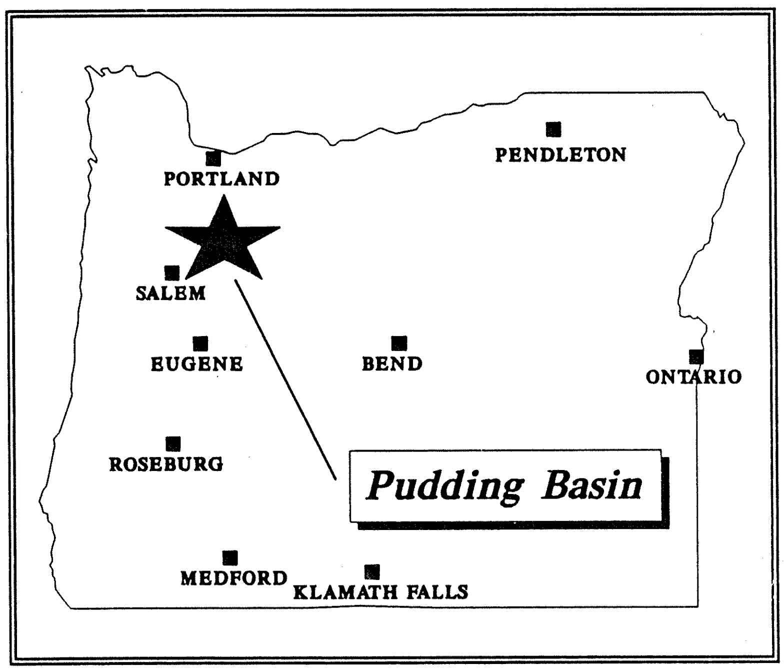
August 1993

Pudding River

Water Quality Report

Total Maximum Daily Load Program



State of Oregon

Department of Environmental Quality
Standards & Assessments Section
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Pudding River

Water Quality Report

Total Maximum Daily Load Program

This report describes the work that the Oregon Department of Environmental Quality (DEQ) has conducted to address water quality concerns in the Pudding River. The assessment is part of the Total Maximum Daily Load (TMDL) process within DEQ's Water Quality Program and reflects the State's water-quality-based approach to water quality problems.

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Oregon's Total Maximum Daily Load Program

OVERVIEW

BENEFICIAL USES

The quality of Oregon's streams, lakes, estuaries, and groundwaters is monitored by the Department of Environmental Quality (DEQ). The information collected by DEQ is used to determine whether water quality standards are being violated and, consequently, whether the **beneficial uses** of the waters are being threatened. The beneficial uses include fisheries, aquatic life, drinking water, recreation, shellfish, irrigation, hydroelectric power, and navigation. Specific State and Federal rules are used to determine if violations have occurred: these rules include the *Federal Clean Water Act of 1972*, Oregon's Revised Statutes (ORS), and Oregon's Administrative Rules (OAR Chapter 340).

WATER QUALITY LIMITED STREAMS AND TOTAL MAXIMUM DAILY LOADS

The term **water quality limited** is applied to streams and lakes where required treatment processes are being used but violations of water quality standards occur. With a few exceptions, such as in cases where violations are due to natural causes, the State must establish a **Total Maximum Daily Load**, or **TMDL** for any waterbody designated as water quality limited. A **TMDL** is the total amount of a pollutant (from all sources) that can enter a specific waterbody without violating the water quality standards.

WASTELOAD AND LOAD ALLOCATIONS

The total permissible pollutant load is allocated to point, nonpoint, background, and future sources of pollution. **Wasteload allocations** are portions of the total load that are allotted to point sources of pollution, such as sewage treatment plants or industries. The wasteload allocations are used to establish effluent limits in discharge permits. **Load allocations** are portions of the total load that are attributed to either natural background sources, such as soils, or from nonpoint sources, such as agricultural or forestry activities. Allocations can also be set aside in reserves for future uses.

TMDL PROCESS

The establishment of TMDLs is required by Section 303 of the Clean Water Act. The process of establishing a TMDL includes studying existing data, collecting additional data to answer specific questions, using mathematical models to predict the effects of changes in wasteloads, evaluating alternative strategies for implementation, and holding public hearings and allowing public comment on the TMDL.

PURPOSE OF THIS REPORT

This report provides information on one of the waterbodies in Oregon's TMDL Program. The report includes background information on the drainage basin, the pollution sources, and the applicable water quality standards; a summary of the monitoring data and the technical analyses; and a discussion of the current pollution control strategy.

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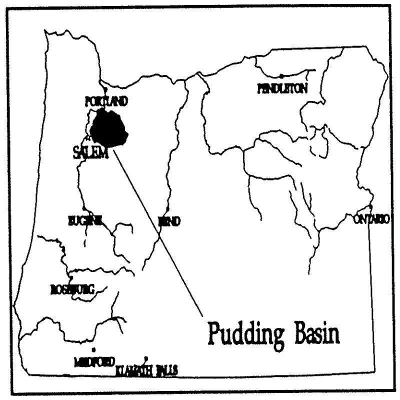
Pudding River

WQ CONCERNS AT A GLANCE:

Water Quality Limited? *Yes*
Segment Identifiers: *22K-PUDD*
Parameter of Concern: *Dissolved Oxygen*
Uses Affected: *Aquatic Life*
Known Sources: *Point Sources — POTWs**
Nonpoint Sources — Agriculture, Forestry



BACKGROUND INFORMATION

The Pudding River is located in northwestern Oregon in the Willamette Valley near Salem. The river originates in the low Waldo Hills and flows sluggishly in a northerly direction for 62 miles. It follows a meandering channel with little slope, flowing past the communities of Silverton, Mt. Angel, and Woodburn. Along the way, many tributaries, such as Butte, Bear, Abiqua, and Silver Creeks flow into the Pudding River. The Pudding empties into the Molalla River, which flows into the Willamette River near Wilsonville at river mile 36.

The Pudding River Basin covers 480 square miles and forms roughly the western half of Marion County. Agriculture is the predominant land use in the drainage basin; water from the Pudding River is used primarily for irrigation to maintain the basin's high agricultural productivity. The basin supports a warm-water game fishery and provides recreational opportunities for the residents of Marion County. Steelhead and spring chinook salmon use the Pudding as a migration route to reach tributary streams. Salmon are not known to spawn in the mainstem Pudding River; it is considered a ''non-salmonid-producing'' stream.

*Publicly-Owned Treatment Works

WATER QUALITY CONCERNS

The Pudding River watershed has been impacted by development since pioneers settled the Willamette Valley in the mid-19th century. Over the past few decades, there have been water quality concerns related to dissolved oxygen, bacteria, nutrients, and habitat degradation due to sedimentation. The Pudding is a naturally turbid stream, most likely due to its flat gradient and the types of soils in the watershed.

Segments of Concern

Segments within the Pudding drainage appear in Oregon's water quality standards as part of the Willamette Basin. Four segments in the Pudding drainage have been identified as water quality limited in Oregon's 1992 Statewide Water Quality Status Assessment Report:

Segment	Name	Boundaries
22K-PUDD	Pudding River	R.M. 0 – 30
22K-PUDD	Pudding River	R.M. 30 – 50
22K-PULI	Little Pudding River	R.M. 0 – 5
22K-ZOLL	Zollner Creek	R.M. 0 – 5

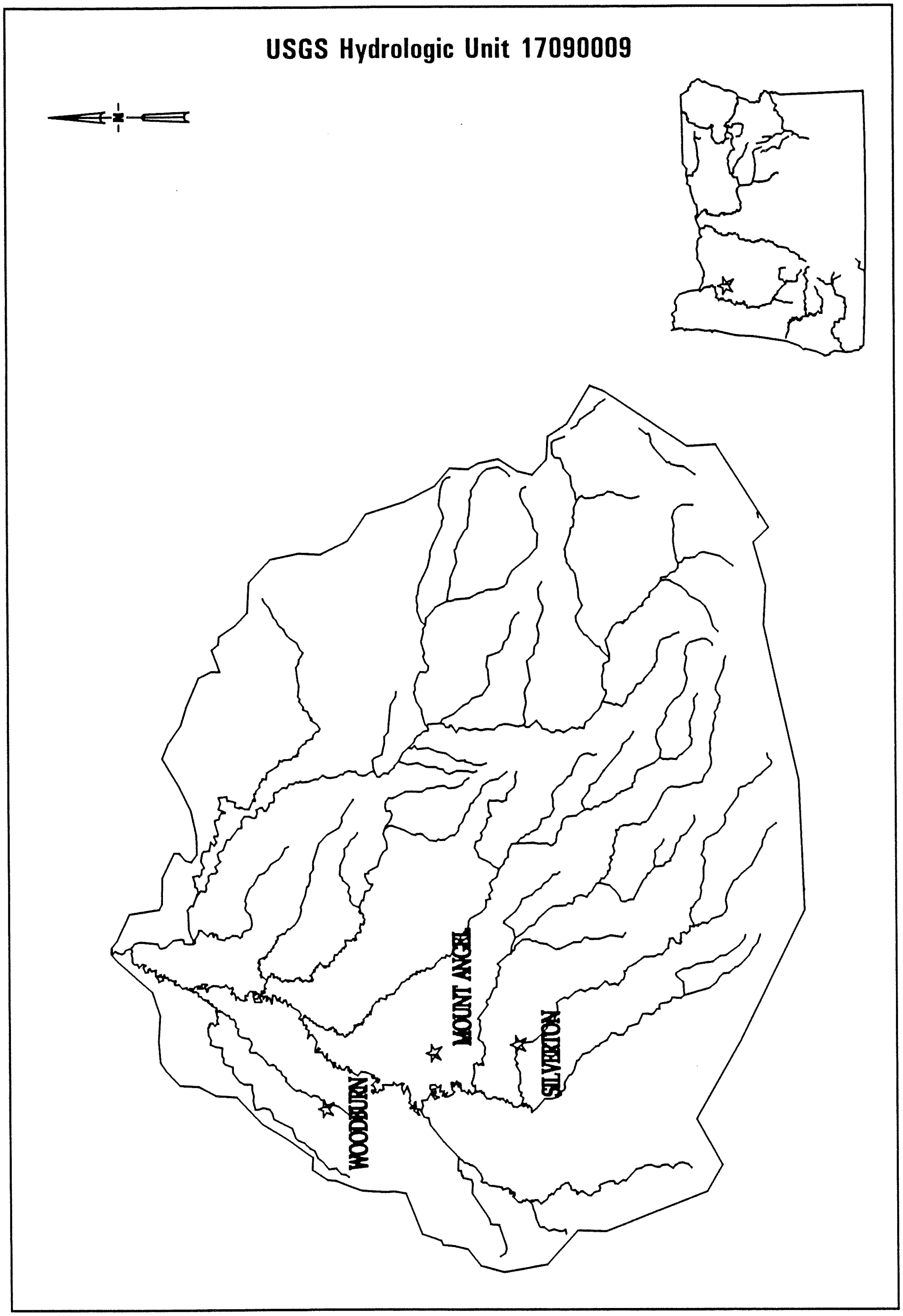


Figure 1. **Pudding River Drainage**

Beneficial Uses Affected

The designated beneficial uses of the Pudding River system are identified in Oregon's Administrative Rules (OAR). Uses include water supply, aquatic life, recreation, and aesthetics. As reported in the latest Statewide Water Quality Assessment (the 1992 305(b) Report), the beneficial use found to be most at risk in the Pudding system is aquatic life; it is listed as not supported for river miles 0 to 30 of the Pudding, 0 to 5 of the Little Pudding, and 0 to 5 of Zollner Creek. Water-contact recreation is also listed as not supported. Criteria used to evaluate use support are described in Appendix B.

Applicable Water Quality Standards

A number of water quality parameters, including dissolved oxygen and bacteria, have criteria values which have been adopted as regulatory standards for the Willamette Basin.

Dissolved oxygen is a critical parameter for the protection of aquatic life. The applicable dissolved oxygen criteria for the basin are:

- Salmonid Rearing: 90 percent of saturation.
- Warm-Water Fish (non-salmonid): 6.0 mg/L.

The lower mainstem Pudding River has been identified as a non-salmonid stream; therefore, the 6.0 mg/L criterion applies.

Bacterial water quality standards have been established for protection of water-contact recreation (e.g., swimming). Current standards for bacterial pollution are:

- Water-Contact Recreation:

  33/100 ml (Enterococci).
  200/100 ml (Fecal coliform).

Available Monitoring Data

The Pudding River has been monitored periodically since 1957, with the most extensive monitoring occurring between 1966 and 1975. An early key site was located near Canby; this site was sampled routinely from 1966 to 1975. In Water Year 1980, ambient monitoring was resumed at the Highway 99E Bridge. The purpose was to determine general water quality trends, compliance with the beneficial uses of the river, and any needs for more detailed study. In addition, this site near the mouth of the Pudding gives information on loading to the Willamette River.

Because of concerns related to low dissolved oxygen and high bacterial levels, the Department of Environmental Quality (DEQ) initiated more extensive data collection in 1989. Monitoring sites were located on all major tributaries and on the mainstem. Major point sources were also monitored during intensive sampling efforts. Results of the data collection efforts are presented in Appendix C.

Parameters of Concern

The Pudding River has been identified as water quality limited due to violations of the dissolved oxygen standard. Ambient water quality monitoring indicates that the river experiences periodic low levels of dissolved oxygen during the summer months. During the summer, point source discharges of pollutants have a major influence on water quality in the basin. A total maximum daily load (TMDL) has been prepared to address the dissolved oxygen problem. Fecal coliform levels also exceed standards in some segments. However, the Pudding has not currently been designated for TMDL development to address the bacteria concerns; the effectiveness of other regulatory mechanisms first needs to be evaluated.

POLLUTANT SOURCES

Water quality in the Pudding drainage is affected by both point and nonpoint source discharges. Point sources include several municipal wastewater treatment plants, as well as a food-processing facility. Major nonpoint sources include runoff from both agriculture and forestry activities.

Point Sources

Sewage treatment plants are located at Woodburn, Mt. Angel, Silverton, Molalla, Gervais, and Hubbard. An additional point source is the Agripac cannery. These sources hold National Pollutant Discharge Elimination System (NPDES) permits. Additional point sources land-irrigate their effluent. Mallorie's Dairy holds a no-discharge Water Pollution Control Facilities (WPCF) permit.

Nonpoint Sources

Nonpoint and background sources can also contribute to water quality problems. Runoff from agricultural land provides a significant load of biochemical oxygen demand, bacteria, ammonia, and organic nitrogen to the Pudding River and its tributaries. Forestry activites in the basin also contribute to nonpoint source loads.

ACTIONS TO DATE

Preliminary TMDLs for the Pudding River were established in 1988. Sources and the public were notified and provided a chance to comment. Based on additional data collection and mathematical modelling, wasteload allocations have been developed for the City of Woodburn and Agripac (see Appendix F).

POLLUTION CONTROL STRATEGY

In February 1993, point-source dischargers were notified of the proposed wasteload allocations and allowed to comment. A public hearing was held to allow for public comment. Final allocations will be issued as permit conditions for the sources, and will be implemented as such. (See Tables 1 and 2 below.) In some instances, compliance with conditions may require construction of new facilities or land application of effluent.

Although nonpoint sources, predominantly agricultural, contribute to the pollutant loads in the Pudding and its tributaries, point sources are believed to account for the majority of the controllable load. It is anticipated that water quality standards will be achieved by implementing the proposed wasteload allocations for point sources. Interagency agreements between DEQ and the Departments of Agriculture and Forestry will be used to promote Best Management Practices designed to reduce nonpoint sources of pollution in the basin and to eliminate impacts on beneficial uses.

APPENDICES

APPENDIX A — EXPANDED BACKGROUND INFORMATION

APPENDIX B — APPLICABLE WATER QUALITY STANDARDS

APPENDIX C — AVAILABLE MONITORING DATA

APPENDIX D — POLLUTANT SOURCE SUMMARY

APPENDIX E — TECHNICAL ANALYSIS AND TMDL DEVELOPMENT

APPENDIX F — PERMIT WASTELOAD ALLOCATIONS

Table 1. Wasteload Allocations (Effluent Limits) for Woodburn & Agripac

Parameter	Daily Maximum (mg/L)	Monthly Average (mg/L)	Minimum Daily Average (mg/L)
Carbonaceous Oxygen Demand ($CBOD_5$)	20	10	—
Total Suspended Solids	20	10	—
Dissolved Oxygen in Effluent	—	—	6.5
Ammonia Nitrogen (NH_3-N)	Based on Streamflow & Month (See Table 2)		

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Ammonia Nitrogen (NH_3-N)	Based on Streamflow & Month (See Table 2)		

Table 2. Wasteload and Load Allocations — Ammonia-Nitrogen and UBOD

Month	Pudding River Monthly Average Flow (cfs)	Ammonia-Nitrogen (mg/L)		Ultimate Biochemical Oxygen Demand (lb/d)
		Agripac	Woodburn	Nonpoint Sources and Background
June	>150	18	6.8	3,234
	100 – 150	15	5.7	2,156
	50 – 100	8.5	3.1	1,078
	<50	3.2	1.1	647
July and August	>100	10	3.2	2,156
	60 – 100	2.7	1.0	1,294
	30 – 60	1.5	0.50	647
	<60	0.30	0.10	323
September and October	>100	WLAs do not apply.		
	60 – 100	18	6.8	1,294
	30 – 60	9.0	3.3	647
	<30	4.0	1.6	323

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	30 – 60	9.0	3.3	647
	<30	4.0	1.6	323

APPENDIX A

EXPANDED BACKGROUND INFORMATION

General

The Pudding River is located in northwestern Oregon in the Willamette Valley near Salem. The topography of the area is generally level with gently rolling hills. The Pudding River is about 62 miles long with numerous tributaries, most notably the Silver, Abiqua, Bear, Little Pudding, and Butte Creeks. The Pudding River itself has 55 miles in typical flat valley drainage (sloping approximately 3 feet per mile) with mixed agricultural and urban land use. The upper 7 miles is more characteristic of foothill drainage with a steeper gradient (79 feet per mile). Overall, the Pudding is a low gradient, sluggish river.

The study area has a temperate marine climate, with cool, wet winters and warm, dry summers. About sixty percent of the annual precipitation occurs between November and February; about ten percent occurs between June and September. Average annual precipitation varies depending on elevation, from a low of 40 inches up to 130 inches. Winter temperatures usually stay above freezing but can drop as low as 10 degrees; summer temperatures normally range from 74 to 82 degrees, but can reach as high as 110.

The drainage area for the Pudding River is 480 square miles. Average monthly flows for the Pudding range from 63 cubic feet per second (cfs) (about 40 million gallons per day) in the summer to about 2,600 cfs in the winter. Streamflow responds to both rainfall and to snowmelt; the snowmelt maintains high flows into late spring. There is a marked decline in streamflow during the summer months, which impacts fisheries, recreation, irrigation, and assimilation of wastes from sewage treatment plants.

Marion County's Comprehensive Plan designates the Pudding River as warm-water habitat. According to the Oregon Department of Fish and Wildlife, many species of fish use the Pudding River year round. These include largemouth bass, sunfish, bullhead catfish, carp, suckers, and sculpins. Seasonal salmonid runs include coho salmon (September to November), steelhead (December to May), chinook salmon (April to July), and cutthroat trout (January to May). The upstream tributaries and the upstream portions of the Pudding are more suited for spawning than the lower Pudding due to their steeper gradients and better oxygenation.

The entire length of the Pudding is zoned for Exclusive Farm Use (EFU) and its land-use designation is Primary Agriculture. The mild climate and wide variety of soils in the region support many different crops including grass seed, beans, corn, wheat, oats, barley, hay, hops, onions, berries, cherries, walnuts, and filberts. Agriculture and associated food-handling and processing plants are major employers in the area. The Nature Conservancy has identified natural areas at the Pudding River Marshland (wildlife/bottom land) and at the confluence of the Pudding River and Silver Creek (wildlife habitat). Recreation areas are located west of Silverton (the Pudding River Picnic Area) and west of Mt. Angel (the Evergreen Golf Club).

The economy of Marion County is largely dependent on farming and forestry. Land use in the county is predominantly agriculture and forests (47 and 43 percent, respectively), with 4 percent urban, 2 percent grazing, and 3 percent parks and conservation. With respect to nonpoint sources, agriculture is the predominant land use impacting the water quality in the Pudding Basin, particularly on the smaller tributaries. Municipal sewage treatment plants and several industries are significant point sources.

Water Quality Concerns

Development has occurred in the Pudding Basin since pioneers settled the Willamette Valley in the mid-19th century. The Pudding is a naturally turbid stream, most likely due to its flat gradient and the types of soils in the watershed. Over the past few decades, there have been water quality concerns with respect to dissovled oxygen, bacteria and nutrients. Habitat degradation due to sedimentation is an additional concern. The Pudding has been designated as water quality limited due to low dissolved oxygen levels and high levels of bacteria.

APPENDIX B

APPLICABLE WATER QUALITY STANDARDS

The Pudding River has been designated as water quality limited. The parameters of concern are dissolved oxygen and bacteria. Within the State of Oregon, water quality standards are published pursuant to Oregon Revised Statute (ORS) 468.020. Authority to adopt rules, regulations, and standards as are necessary and feasible to protect the environment and health of the citizens of the State is vested with the Environmental Quality Commission. Through the adoption of water quality standards, Oregon has defined the beneficial uses to be protected in each of its drainage basins and the criteria necessary to protect those uses.

Segments of Concern

Segments within the Pudding drainage are included in Oregon's water quality standards as part of the Willamette Basin. Within the Pudding, four segments have been identified as water quality limited in Oregon's Statewide Water Quality Status Assessment Report [1992 305(b) Report]. These segments are:

Segment	Name	Boundaries
22K-PUDD	Pudding River	R.M. 0 – 30
22K-PUDD	Pudding River	R.M. 30 – 50
22K-PULI	Little Pudding River	R.M. 0 – 5
22K-ZOLL	Zollner Creek	R.M. 0 – 5

Ambient water quality monitoring data have shown that the Pudding River as well as portions of several tributaries are water quality limited due to periodic low levels of dissolved oxygen and high levels of bacteria.

Beneficial Uses Affected

Oregon Administrative Rule (OAR) Chapter 340, Division 41, Rule 442, lists the beneficial uses for which water quality will be protected in the Pudding Basin. These are identified in Table B-1. This list of beneficial uses was established by the Oregon Water Resources Commission pursuant to direction given in Oregon Revised Statute (ORS) 536.300. As charged by ORS 468.020, the Oregon Environmental Quality Commission adopted rules and standards that were necessary to protect those recognized beneficial uses. In practice, water quality rules and standards have been set at levels to protect the most sensitive of the uses: aquatic life and human health.

Assessment activities have determined that aquatic life and water-contact recreation are not fully supported in the segments of the Pudding River listed under *"Segments of Concern"*. Aesthetics are listed as partially supported due to elevated levels of nutrients; however, no excessive algal growth has been noticed. Criteria by which supportiveness was evaluated are described in Table B-2.

Applicable Water Quality Standards

A number of water quality parameters have criteria values which have been adopted as regulatory standards for the Pudding Basin. Included are temperature, turbidity (also referred to as total suspended solids or TSS), pH (a measure of acidity), dissolved oxygen, fecal coliform bacteria, and dissolved chemical substances. The primary parameter of concern for the Pudding River is dissolved oxygen. Other parameters of concern are bacteria and nutrients.

Dissolved Oxygen: The Oregon Department of Fish and Wildlife has identified the lower mainstem of the Pudding River as providing passage for warm-water game fish but **not** providing for salmonid production. The Oregon Water Quality Standard for dissolved oxygen

Table B-1. Beneficial Uses to be Protected in the Willamette Basin

BENEFICIAL USES	
Public Domestic Water Supply[1]	Resident Fish & Aquatic Life
Private Domestic Water Supply[1]	Anadromous Fish Passage
Industrial Water Supply	Salmonid Fish Rearing
Irrigation	Salmonid Fish Spawning
Livestock Watering	Fishing
Boating	Wildlife & Hunting
Water-Contact Recreation	Commercial Navigation & Transportation
Aesthetic Quality	Hydroelectric Power

[1]With adequate pretreatment (filtration and disinfection) and natural quality to meet drinking water standards.

Source:

Oregon Administrative Rules, Ch. 340, Division 41 — DEQ Table 6, Willamette Basin.

Table B-2. Beneficial Use Support Criteria

FISHERIES AND AQUATIC LIFE	
Partially Supported	10% exceedence of basin DO mg/L or DO % Saturation standard.
	10% exceedence of basin pH standard.
Not Supported	25% exceedence of Oregon Administrative Rule (OAR) basin standard for DO mg/L or DO % Saturation.
	25% exceedence of the basin OAR pH standard.
WATER CONTACT	
Partially Supported	10% exceedence of Enterococcus upper-range standard.
Not Supported	25% exceedence of Enterococcus upper-range standard.
AESTHETICS	
Partially Supported	10% exceedence of 15 μg/L chlorophyll <u>a</u>.
	25% exceedence of 0.1 mg/L total phosphorus.
Not Supported	25% exceedence of pH standard for basin.

Source:

Oregon's 1992 Water Quality Status Assessment Report (305(b)) Report; pp. B3—6.

in the Pudding River states that: "The dissolved oxygen concentration shall not be less than 6.0 mg/L" [OAR 340-41-445(2)(a)(E)(ii)]. The standard represents the minimum value that the stream should not fall below at any time so that the beneficial uses of aquatic life, fisheries, and salmonid migration will be protected. Because the standard is stated as an absolute value, the total maximum daily load (TMDL) is calculated to attain 6.0 mg/L as a minimum. To account for the fact that dissolved oxygen will vary with the time of day due to the effects of sunlight, measured dissolved oxygen concentrations are reported as daily *averages* so that data are comparable from day to day. To maintain a *minimum* value of 6.0 mg/L, the *average* value will have to be higher to allow for daily variation and still achieve the standard. Diurnal measurements collected in the critical oxygen-sag area of the Pudding (above Agripac) were used to estimate a daily variation of 0.5 mg/L in the dissolved oxygen measurements. To allow for a variation of 0.5 mg/L above or below the measured value, a daily average of 6.5 mg/L must be maintained to achieve a minimum value of 6.0 mg/L.

Bacteria: OAR 340-41-445(2)(e)(A) provides a freshwater limit of "... a log mean of 200 fecal coliform per 100 milliliters based on a minimum of five samples in a 30-day period with no more than ten percent of the samples in that period exceeding 400 per 100 ml."

Nutrients: The basin standard limits pH to the range of 6.5 to 8.5 [OAR 340-41-445(2)(d)(B)]. DEQ's action level for chlorophyll a is 15 µg/L. The State also uses EPA's criteria of 0.1 mg/L for total phosphorus.

APPENDIX C

AVAILABLE MONITORING DATA

Robert Baumgartner, Water Quality, DEQ

The Pudding River has been monitored periodically since 1957, with the most extensive monitoring occurring between 1966 and 1975. An early key site was located near Canby; this site was sampled routinely from 1966 to 1975. In Water Year 1980, ambient monitoring was resumed at the Highway 99E Bridge. The purpose was to determine general water quality trends, compliance with the beneficial uses of the river, and any needs for more detailed study. In addition, this site near the mouth of the Pudding gives information on loading to the Willamette.

Four DEQ monitoring stations are located on the Pudding River for routinely collecting instream water quality data. Ambient data are stored in a computerized database called STORET. The ambient monitoring stations located in the Pudding River are identified in Table C-1. Several intensive water quality surveys were conducted during the summer of 1989. The data were compared to the regulatory standards to determine if violations had occurred. In addition, ambient and intensive data were used in mathematical models to predict water quality impacts during varying conditions, such as changing flow or temperature.

Intensive Surveys

Dissolved Oxygen: Monitoring results are summarized in Table C-2 for several parameters for the summer season of 1989. Summer is the season of primary concern due to the low-flow conditions in the Pudding River during that time. Table C-2 lists the median values (values which fall in the middle of the data set) and the regulatory standard for each parameter.

Diurnal (24-hour cycle) monitoring for dissolved oxygen was conducted for three-day periods during the summer and fall of 1989 using automated monitoring devices left in the stream for the full sampling period. The data provided by the monitors were used to develop equations which allowed data from samples collected at any time of the day to be converted to a *minimum* value for that day. Because of the natural variation in some parameters throughout the course of a day, this conversion allowed data to be more accurately compared to data from other days. On August 15, 1989, the estimated minimum dissolved oxygen value for the area between river mile 23.5 and river mile 17.2 was 5.3 mg/L. Both the observed minimum value and the estimated daily-average value were 5.9 mg/L, which is below the standard.

As can be seen in Table C-2, the standard for dissolved oxygen was violated in the Pudding River. The dissolved oxygen violations observed in 1987 were more frequent and severe than those observed during summer surveys in 1989. Minimum observed values fell to near 5.0 mg/L in the 1987 surveys. Observed violations occurred below the Agripac and Woodburn Sewage Treatment Plant (STP) discharges.

The low dissolved oxygen measurements in the Pudding River usually occurred in the early morning hours. These low readings might be explained in part by daily fluctuations in algal growth and respiration levels, since algal activity and consumption of oxygen is greatest in the morning. It does not appear, however, that the growth of algae in the Pudding River is excessive or usually results in nuisance conditions. Nuisance growth may be prevented by the relatively high levels of suspended solids and turbidity in the Pudding River which limit the amount of light available for growth of algae, or it may be prevented by other natural conditions.

Nitrogenous oxygen demand is the primary factor leading to the observed violations of the oxygen standard in the Pudding River. Organic nitrogen

Table C-1. Ambient Monitoring Stations in the Pudding River

Site Location	River Mile	STORET #
Highway 213	R.M. 49.9	402213
Mt. Angel / Brooks	R.M. 40.7	402560
Highway 211	R.M. 22.9	402317
Highway 99E	R.M. 8.1	402594

Table C-2. Water Quality Summary for the Pudding River Summer 1989

Parameter	Applicable WQ Standard or Criteria	Hwy 99E (R.M. 8.1)	Hwy 211 (R.M. 22.9)	Mt. Angel / Brooks (R.M. 40.7)	Hwy 213 (R.M. 49.9)
Dissolved Oxygen a.m.	6.0	6.5	5.5	6.6	4.7
Dissolved Oxygen p.m.	6.0	8.1	8.4	8.5	8.0
BOD_5	*	1.0	0.8	1.2	1.8
Total Phosphorus	0.1	0.23	0.43	0.09	0.065
Turbidity	**	4.0	6.0	3.5	–
Total Susp. Solids	*	110	90	61	–
Fecal Coliform	200	93	80	195	240
Ammonia (NH_3)	***	0.05	0.07	0.03	0.06
Nitrite-Nitrate Nitrogen (NO_2-NO_3)	*	1.40	1.40	0.55	0.44

- Values are reported as medians.
- BOD_5 represents the five-day biochemical oxygen demand.

LEGEND:

* No applicable standard.

** Standard allows an increase of up to 10% above background.

*** Standard is dependent on pH, temperature, and toxicity; turbidity may impact ambient dissolved oxygen levels.

Units:

- Turbidity as JTU.
- Fecal coliform bacteria as MPN (most probable number of colonies per 100 milliliter).
- All others as mg/L (milligrams per liter).

and ammonia enter the stream from both point source discharges and nonpoint source runoff. Nitrogenous demands result from the conversion (or nitrification) of organic nitrogen to ammonia (nitrogen plus three hydrogens, NH_3) to nitrite (nitrogen plus two oxygens, NO_2^-) to nitrate (nitrogen plus three oxygens, NO_3^-). The oxygen that becomes associated with the nitrogen is no longer available to fish as dissolved oxygen.

Data collected at the monitoring station at Highway 211, below the Woodburn Sewage Treatment Plant discharge, showed an increase in ammonia and nitrate and a decrease in oxygen, indicating the effect of the STP effluent on the stream. Other low oxygen levels in the upper section of the river, along with relatively high concentrations of BOD, indicate a significant impact from nonpoint sources.

Observed Loads: Point source loads to the Pudding River, as observed during the intensive sampling trip in August 1989, are shown in Table C-3. The observed loads resulted in daily average dissolved oxygen values of 5.9 mg/L during the intensive survey. Flows were above 30 cubic feet per second (cfs) and instream temperatures approached 23 degrees. Observed temperatures in the Pudding have exceeded 27 degrees during July and August in previous years. Minimum streamflows (7Q10) are estimated at 15 cfs. Observed minimum flows during 1989 were less than 20 cfs at Highway 211; minimum dissolved oxygen during 1989 was 5.1 mg/L.

Fecal Coliform Bacteria: The presence of fecal coliform bacteria is commonly used as an indicator of pathogen contamination in surface waters. Elevated levels of fecal coliform bacteria have been observed in the Pudding River. The violations of the standard for fecal coliform bacteria appear to be related to nonpoint sources, particularly in the upper basin (see Table C-2, Highway 213).

Stream Processes — General Information

The dissolved oxygen concentration in a stream results from a balance of processes which consume oxygen and processes which restore oxygen. Fish and other desirable aquatic organisms require a high level of dissolved oxygen to survive. Dissolved oxygen is restored mostly from the atmosphere (reaeration) and from photosynthesis. It is depleted mostly by the activity of bacteria which break down organic matter (particularly by the decay of algae) and by chemical processes such as the conversion of ammonia to nitrate (nitrification).

Pollutant loads are typically described in terms of their biochemical oxygen demand (BOD) or their chemical oxygen demand (COD). The BOD test determines the amount of oxygen required by bacteria to decompose the load of organic matter in a sample of water. The COD test measures the amount of oxygen required to convert both biologically-available and non-biologically-available organic matter to carbon dioxide and water. The BOD test is generally more representative of actual instream conditions. Results can be obtained much more quickly with the COD test, however, which makes it valuable in certain situations such as a waste spill.

Table C-3. Observed Loads to the Pudding River (August 1989)

Source	Flow (cfs)	Observed During Intensive Sampling		
		UCBOD	TSS	Ammonia
Agripac	2.17	130	100	17
Woodburn	2.54	205	200	18
Source	**Flow (cfs)**	**Typical Loads — Estimated**		
		UCBOD	**TSS**	**Ammonia**
Agripac	1.91	300	100	25
Woodburn	2.54	270	200	68

If the pullutant load on a waterbody is light, the replenishment of oxygen can make up for the loss. This is referred to as assimilation. If the load is heavy, oxygen may be depleted to a point where fish cannot survive and aerobic organisms are destroyed. A stream's ability to assimilate waste is largely determined by its concentration of dissolved oxygen. As oxygen is depleted, anaerobic organisms, which can live without oxygen, will take the place of the aerobic organisms, resulting in odors and nuisance conditions. The oxygen-depleted water may travel a considerable distance before natural purification processes can restore the oxygen levels.

Temperature will also influence the dissolved oxygen concentration in a stream. The maximum possible concentration of dissolved oxygen in water (referred to as the saturation level) is largely determined by the water temperature. A stream's ability to process oxygen-demanding loads (its assimilative capacity) is greater at lower temperatures because dissolved oxygen saturation is greater at lower temperatures. This allows an extra reserve during colder weather. Conversely, when temperatures are higher, the stream has a reduced capacity to process wastes.

For example, cold water at 15°C (59°F) can hold up to 10.1 mg/L of dissolved oxygen. After meeting the minimum of 6.0 mg/L required by water quality standards, the stream would have a reserve assimilative capacity of 4.1 mg/L. In contrast, warm water at 24°C (75°F) can hold only 8.4 mg/L of dissolved oxygen, allowing a reserve capacity of only 2.4 mg/L above the minimum standard of 6.0 mg/L. This reduction in assimilative capacity at warmer temperatures and low flows limits the amount of waste which can be tolerated and may prohibit discharge.

Because of the effects of seasonal differences in temperature and streamflow on a stream's assimilative capacity, wasteload limits will be set by month for varying flow and temperature conditions as necessary to meet water quality standards. The summer limits will typically be the most restrictive, with greater discharge allowed during the winter when flows are high and temperatures are low.

APPENDIX D

POLLUTANT SOURCE SUMMARY

Robert Baumgartner, Water Quality, DEQ

Water quality in the Pudding drainage is affected by both point and nonpoint source discharges. Point sources include several municipal wastewater treatment plants, as well as industrial sites including food-processing facilities. Major nonpoint sources include runoff from both agricultural and forestry activities.

Point Sources

The main point sources of pollution in the Pudding River Basin are listed in Table D-1. They include municipal, industrial, and agricultural sources. The point sources which discharge directly to the Pudding River are required to have National Pollutant Discharge Elimination System (NPDES) permits. Within the Pudding Basin, current NPDES permits are issued to the Silverton, Woodburn, Molalla, Mt. Angel, Gervais, and Hubbard sewage treatment plants, and the Agripac cannery. Additional point sources are required to land-irrigate their effluent or may be discharging without a permit. Mallorie's Dairy holds a no-discharge Water Pollution Control Facilities (WPCF) permit.

Municipal Sources: *WOODBURN* — The major point-source discharge to the Pudding River is the City of Woodburn's sewage treatment plant (STP). Dilution of the effluent is provided by the river. The amount of dilution will vary as river flow changes throughout the year but must stay within permit limits.

Permit limits for Woodburn have not been stringent enough to provide for adequate dilution of effluent. Woodburn has been allowed by permit to discharge 3.1 million gallons per day (mgd) or 4.8 cubic feet per second (cfs) during the summer. A seven-day-average low flow of approximately 50 cfs occurs every other year in the Pudding River near Aurora. Based on that flow and Woodburn's discharge volume, a dilution ratio of 10.4 can be calculated. According to the guidelines of the Oregon Water Quality Standards [OAR 340-41-375(1)(c)], a dilution ratio of 15 is required. The existing dilution ratio of 10.4 during critical summer low flows is thus not adequate; under those conditions, the discharge would exceed dilution requirements by fifty percent. New TMDL-based permit limits require reduced oxygen-demanding loads from Woodburn to ensure adequate dilution ratios during low flows and to prevent oxygen sags.

HUBBARD — The City of Hubbard discharges to Mill Creek, a tributary to the Pudding River. Mill Creek enters the Pudding River below the area where water quality violations occur. Establishing TMDLs on the Pudding River should not affect Hubbard's NPDES permit. DEQ has little or no information describing the impact of this discharge on water quality; an intensive mixing-zone survey designed to evaluate permit conditions for the Hubbard STP needs to be conducted.

MOLALLA — The City of Molalla discharges to Bear Creek, a tributary to the Pudding River. DEQ has little or no information on the impact of this discharge on Bear Creek. The City has two options in its discharge permit: discharge to Bear Creek or use the effluent for irrigation water (land apply). Molalla currently land applies its effluent during the critical summer months. There does not appear to be a reason to discontinue land application, and as long as application continues, no wasteload allocation is required for Molalla.

MT. ANGEL — The City of Mt. Angel discharges to a small creek which is a tributary to the Pudding River. The City has elected to discontinue discharging during the summer low-

Table D-1. Point Sources in the Pudding River Basin

Facility	Permitted Discharge Quantity (Summer)	Location (River Mile)	Type of Waste
MUNICIPAL			
Silverton STP	1.0 mgd	Silver Creek to Pudding River	Domestic Sewage
Hubbard STP	0.34 mgd	Mill Creek to Pudding River	Domestic Sewage
Molalla STP	0.79 mgd	Bear Creek to Pudding River at R.M. 10	Domestic Sewage
Woodburn STP	3.1 mgd	Pudding River at R.M. 27	Domestic Sewage
Gervais STP	No Summer Discharge Allowed	Pudding River at R.M. 30.5	Domestic Sewage
Mt. Angel STP	No Summer Discharge Allowed	Pudding River at R.M. 34	Domestic Sewage
INDUSTRIAL			
Agripac, Inc.	2.0 mgd	Pudding River at R.M. 27	Fruit/Vegetable Waste
Avison Lumber	No Discharge	Bear Creek to Pudding River at R.M. 16	Log-Yard Runoff
Mt. Angel Meat	No Discharge	Zollner Creek	Processing Waste
AGRICULTURAL			
Mallorie's Dairy	WPCF Permit; No Discharge Allowed	Pudding River and Silver Creek	Manure, Milk-Processing Waste

flow period. The streamflows under which Mt. Angel may discharge and the accompaning efffluent limits are defined in the City's discharge permit.

SILVERTON — The City of Silverton discharges to Silver Creek, a major tributary to the Pudding River. These loads do not appear to influence the dissolved oxygen violations observed below Woodburn. Observed dissolved oxygen values are above the 6.0 mg/L standard identified for the lower river, but have fallen below the 90 percent saturation level required for salmonid waters. The STP is currently operating under a Stipulated and Final Order which identifies discharge limits.

GERVAIS — The City of Gervais is not allowed to discharge during the summer. No wasteload allocation will be given.

Industrial Sources: *AGRIPAC, INC.* — Agripac discharges processed cannery waste to the Pudding River. Agripac's discharge, in combination with the City of Woodburn's discharge, results in violations of water quality standards under current conditions. The TMDLs and wasteload allocations require reductions in the oxygen-demanding loads from Agripac.

MT. ANGEL MEAT — The stream closest to Mt. Angel Meat is Zollner Creek. No discharge from Mt. Angel Meat is allowed; no wasteload allocation will be given.

AVISON LUMBER — Avison Lumber holds a general log-pond permit which does not allow discharge. No wasteload allocation will be given.

Agricultural Sources: *MALLORIE'S DAIRY* —

Mallorie's Dairy has been observed to discharge a high-strength waste stream to the Pudding River. Although these discharges did not occur at the times when field samples were taken (in conjunction with critical low flows), analysis suggests that if a discharge of that type were to occur during a low-flow period, violations of water quality standards would result. Mallorie's Dairy does not have an NPDES permit; the dairy has a WPCF permit which does not allow discharge at any time. The dairy will not be given a wasteload allocation. Assurances must be made that discharges will not occur.

Nonpoint Sources

Interagency agreements between DEQ and the Departments of Agriculture and Forestry will be used to promote Best Management Practices designed to reduce nonpoint source pollution in the Pudding and its tributaries.

Nonpoint-source runoff from agricultural land provides a significant load of biochemical oxygen demand, bacteria, ammonia, and organic nitrogen to the Pudding River and its tributaries. These agricultural loads potentially contribute to water quality problems and impacts on beneficial uses in the tributaries and could contribute to violations of the dissolved oxygen standard in the mainstem of the Pudding River.

A reduction in the amount of nitrogen and other oxygen-demanding materials from nonpoint sources needs to occur not only in the Pudding but also in its tributaries. Loads coming from tributary streams such as Zollner Creek have as much impact as the minor STP discharges on water quality in the Pudding River. Dissolved oxygen violations have been observed in both Zollner Creek and the Little Pudding River although no major point sources are located on those streams.

Additional concerns have been raised by resource agencies and individuals regarding nonpoint sources in the Pudding Basin. The Oregon Department of Fish and Wildlife has stated that sediment in the river is degrading fish habitat. Agricultural interests are concerned with apparent toxicity in the Little Pudding River. Problems due to sediment, toxicity, nutrients, and bacteria should be addressed in the nonpoint source plans for the basin.

APPENDIX E

TECHNICAL ANALYSIS AND TMDL DEVELOPMENT

Robert Baumgartner, Water Quality, DEQ

Water Quality Modelling

QUAL2E, a steady-state, hydrodynamic model, was used to study the impact of wasteloads on instream water quality and the effects of varying streamflow and weather conditions. The model was used to predict daily average values of dissolved oxygen based on measured (observed) data. In addition to data from monthly monitoring, two detailed data sets were used for the modelling efforts. The data were collected during two intensive surveys which covered the area of the stream from just above the two major discharges to below the area of low dissolved oxygen (referred to as the dissolved oxygen sag). A third survey indicated that dissolved oxygen was not a concern when streamflow was high.

During the surveys, dissolved oxygen was measured along with several parameters which affect the level of oxygen in the stream: biochemical oxygen demand (BOD), nutrients, total suspended solids, ammonia and nitrate (used for determining the rate of nitrification), and temperature. These parameters were measured going downstream (longitudinally). Automated monitors which were left in place in the stream measured dissolved oxygen, temperature, and pH continually for three days and were used to determine the daily variability in dissolved oxygen. Knowing the variability in dissolved oxygen with respect to time made it possible to compute daily averages from the observed dissolved oxygen values. Since dissolved oxygen varies with the time of day, these corrections were necessary for accurate modelling.

Wasteloads and tributary loads were also monitored. Dye tests (time-of-travel tests) were used to estimate velocity as a function of flow. Knowing the velocity, it is possible to convert a change in concentration with distance to a change in concentration over time. In calculating flow-related TMDLs, concentration as a function of time is used to predict concentrations under varying flow conditions.

An initial laboratory measurement for the decay of organic matter (loss of BOD) was used as the starting point for calibrating the model. Decay rates and temperature coefficients were adjusted to fit the observed data for the loss of BOD and ammonia and for the increase in nitrates. The dissolved oxygen sag can be explained as an effect of the input of ammonia and BOD (which depletes oxygen) and reaeration (which replenishes oxygen). Reaeration is modelled as a function of stream velocity, depth, and turbulence using the O'Connor and Dobbins method (1958).

The first set of survey data was used to establish the initial conditions for the model (calibration). The second set of data was used to test whether the model could successfully predict dissolved oxygen under different background conditions (verification). Observed data for parameters such as upstream concentrations, flows, wasteloads, tributary loads, and weather conditions were entered into the model. The values which the model computed for dissolved oxygen were compared to the actual values of dissolved oxygen which were observed during the field survey. The values predicted by the model were found to reasonably match the observed values:

Once an acceptable model was established, the model was used to calculate wasteload and load allocations. There may be several sets of wasteload and load allocations that will achieve water quality standards for the Pudding River. The modelling approach allows alternative scenarios to be evaluated with respect to their impact on water quality. Different sets of values for streamflow, sunlight, temperature, turbulence, and boundary conditions (upstream loads and tributary loads) were entered into the model. The model calculated the level of dissolved oxygen which should be present under those conditions.

Initial modelling assumed an equitable distribution of wasteload allocations between the major sources (Agripac and Woodburn) and similar permit conditions for efficiency of waste removal. Alternative sets of wasteload allocations for varying flow conditions were entered into the model to determine the resulting levels of dissolved oxygen. Nonpoint source inputs were added to the model to test their effect on dissolved oxygen. The modelling process was repeated until the resulting dissolved oxygen concentrations met water quality standards and satisfied TMDL requirements. A margin of safety was added into the calculations to allow for inherent errors in measurements and modelling.

Parameter Estimation

Hydraulics Estimates: DEQ conducted several "dye studies" to determine the time of travel (TOT) for two sections of the lower portion of the Pudding River. Results varied in terms of accuracy. The dye tests demonstrate that measured velocities are very similar in the lower Pudding (between R.M. 27 and 15) for flows below 60 cfs. Hydraulic barriers, such as the numerous debris dams and the remnant concrete-sill dam (named Falls #1), act to impede velocity and flow during low-flow conditions. Velocity estimates varied both by the subsection for which the estimates were made, by multiple dye drops within the study reach, and by calculation of velocity between sub-reaches. For the set of points a to b to c, the velocity between b and c is calculated by:

$$\frac{[\text{RM (a to c) - RM (a to b)}]}{[\text{TOT (a to c) - TOT (a to b)}]} * \frac{\text{ft}}{\text{mi}} * \frac{\text{hours}}{\text{second}}$$

where TOT equals time of travel in hours. Average flow for a given reach (Q) was calculated as:

$$[\{Q_{upstream} + Q_{downstream}\}/2].$$

Flow estimates were derived from stage-discharge curves empirically developed for several locations on the Pudding River. The variation in flows in Table E-1 is primarily due to the different locations that were sampled during the dye tests.

The stage-discharge curves were developed using three to five representative flow and discharge measurements. For several of the stations, including key tributaries, an adequate number of measurements were not collected. Similarly, flows were not taken at all sampling sites during the dye studies. The hydraulic relationships are difficult to estimate with the available data.

Table E-1. Time-of-Travel Estimates for the Pudding River

Date	Location: River Mile	Flow (cfs)	Velocity (ft/s)	Comments
06/21/89	27 — 6.1	129 — 202		Unreliable
08/01/89	27 — 17.6			
09/26/89	17 — 8.1	22.5 — 49	0.17 — 0.24	Lower Section
10/03/89	27 — 17.5	62.5 — 65	0.28 — 0.46	Multiple Dye Drops

Power Functions: Power functions, developed by Leopold and Maddox, provide an empirical relationship between physical stream factors and streamflow. Several alternative power functions were calculated using different approaches. The resulting data were used in calibrating the model (see Table E-2).

Recognizing that streamflow is the product of cross-sectional area and velocity and that cross-sectional area is the product of width and depth, it can be shown that the sum of the exponents (n+m+f) is 1.0. Plotting the $\text{Log}_{\text{base } 10}$ of Q with the $\text{Log}_{\text{base } 10}$ of the physical stream factors of velocity, depth, and width provides the information for defining the equations. From the plots, the slope provides the power term (n,m,f), and the intercept at Q = 1 provides the remaining term (a,b,c). These relationships apply to free-flowing streams. Impounded reaches in rivers have exponents of m and f equal to zero. It is therefore appropriate to develop site-specific data. The availability of data for empirically developing the power functions is limited, however.

Using all of the available data, the power functions were estimated as:

$V = 0.028\ Q^{0.654}$ Using three dye tests below R.M. 27.

$D = 1.15\ Q^{0.293}$ Using stage-discharge curves near R.M. 27.

$W = 70\ Q^{0.053}$ Width observed at stage sites.

Considerations:

- The stage-discharge curves may not provide an accurate estimate of the depth relationship. The locations used for flow measurements were selected for high-velocity profiles and therefore occurred at free-flowing areas with constrictions, such as bridge crossings.
- The high-flow data for velocity are suspect at best. Very minor meter response was used as the "dye peak." It may not be appropriate to rely on this data to empirically determine the power functions.

The low-flow data appeared to provide a much different relationship than that observed during the high-flow dye study. The low-flow data provided a much flatter response with respect to velocity. The low-flow power functions (for flows less than or equal to 70 cfs) as estimated are:

$V = 0.089\ Q^{0.36}$ Low-flow period.

$D = 0.410\ Q^{0.59}$

$W = 0.750\ Q^{0.05}$

These low-flow power functions are appropriate for the Pudding River for flows at or below 70 cfs between R.M. 27 and 15. The single representative dye test below R.M. 15 resulted in slower velocities than estimated by the above power function. The velocity function was adjusted to predict the observed slower velocities in the lower river by changing the "a" term to 0.05, resulting in $V = 0.05\ Q^{0.36}$.

No dye tests were conducted above R.M. 27. The channel morphology and flow characteristics of the Pudding River do not change dramatically above where the dye tests were

Table E-2. Power-Function Values Used in Calibrating the Model

Equation	Typical Range for the Power Term
Velocity, $V = aQ^n$	0.5 (0.4 to 0.6)
Depth, $D = bQ^m$	0.4 (0.3 to 0.5)
Width, $W = cQ^f$	0.1 (0.0 to 0.2)

conducted. The primary differences are an increase in slope and the influence of several major tributaries which enter above R.M. 27.

Power functions were estimated using Manning's equation. Manning's equation was developed with the data available for the Pudding below R.M. 27. The equation was modified for the increase in slope (0.000405) above R.M. 27 as defined by contours on USGS quadrangle maps. The Manning's equation estimate should provide a representative estimate of the flow relationships. From this modified equation, the power functions defined were:

$V = 0.13\ Q^{0.38}$ Above R.M. 27.

$D = 0.40\ Q^{0.57}$

$W = 60.0\ Q^{0.05}$

Similarly, Manning's equation was used to estimate the power functions for Silver Creek, which receives loads from the Silverton STP. The slope of Silver Creek is 0.004781 ft/mi. The estimated power functions are:

$V = 0.49\ Q^{0.45}$ Silver Creek.

$D = 0.20\ Q^{0.45}$

$W = 12.0\ Q^{0.10}$

The estimates for Silver Creek are very rough and provide only a relative index of the flow relationships. The load from Silver Creek does not appear to greatly influence the substandard section of the Pudding River below R.M. 27. However, for calculating the TMDL, is it necessary to include all major point sources in the basin.

Flow Balance: The flow balance for the Pudding River was empirically developed using observed relationships between monitoring sites, available flow statistics (from USGS), and flows estimated using drainage basin area, stream miles, location in the drainage, and altitude at the reference site.

The site at Highway 211 was used as the initial reference site. Highway 211 is located in the water-quality-limited stream section where most of the water quality violations have been observed. This was also the site where flow was monitored most frequently by DEQ.

Flow at Highway 99 (Aurora) was estimated from the regression equation developed using observed flows at Aurora coincident and dependent on observed flows at Highway 211. Flows for the Pudding River near Mt. Angel and Silver Creek were estimated from historical records. For these regressions, it was assumed that the critical low flows (i.e., 7Q10) occurred coincidentally throughout the basin. From these statistics the estimates for Silver Creek, Butte Creek, and the Upper Pudding were made dependent on observed flows at Aurora (Highway 99).

Estimates for other streams (Butte Creek, Little Pudding River, Zollner Creek, Bear Creek, Abiqua Creek) were made using regressions developed using flows dependent on land area, stream length, location in the basin, and altitude of the reference location for known gauges. Flows for creeks without gauges were extrapolated from these regression equations. Flows for Butte Creek were modified for additional flow that would occur below the gauge site at Monitor.

Permitted point-source flows were calculated as the four-month average that occurred from July to October 1989, reported as monthly averages on the discharge monitoring reports. For Silver Creek, the predicted flow value includes the flow from the sewage treatment plant. All remaining flow estimates are additive. No attempts were made to adjust for irrigation withdrawals.

Input flows were balanced with observed and predicted flows at the three reference locations in the Pudding River. Flows not accounted for were then calculated and termed "overland flow." Overland flow varied from both positive to negative values. Minor flow modifications were proportioned out from the tributary stream estimates to prevent negative overland flow values. It is possible that these negative values are the result of irrigation. However, since the negative values occurred at higher flows, it seems likely they are a result of overestimating ungauged streamflows. This process allows us to identify specific inputs for desired streamflow statistics.

Sediment Oxygen Demand: Sediment oxygen demands (SOD) are a significant component of the oxygen balance in the Pudding River during summer low-flow conditions. The calibrated SOD rate was 0.25 grams/ft^2-day (0.112 grams/m^2-hr or 2.7 grams/m^2-day).

Table E-3 summarizes other model-derived SOD rates compared to measured rates as discussed in Terry and Morris (1986). Terry and Morris suggest that the indirect method (calibration) may provide a more realistic measurement of oxygen demand than measuring individual points of SOD *in situ*.

Similarly, Whittemore (1986) found a poor correlation (r^2 = 0.58) between field and laboratory measurements: *in situ* measurements were consistently higher at low levels of SOD; the reverse was observed at high levels of SOD. Such errors indicate the need for improved methods for estimating SOD. A summary of rates measured *in situ* by Whittemore (1986) is presented in Table E-4.

EPA suggests that *in situ* methods are more credible than laboratory methods at this time. Ranges for SOD reported in EPA (1985) are shown in Table E-5.

The model-calibration method for estimating SOD is subject to a reasonable range for SOD values. The SOD range estimated for the Pudding River appears to fall within the ranges observed for other streams.

Laboratory Tests for BOD Conversion: Determining which term, or component, of BOD is being referred to in reported BOD measurements can be confusing. The DEQ laboratory

Table E-3. Sediment Oxygen Demand Rates in Other Streams (Reference: Terry & Morris, 1986)

Stream Name	Calibrated Range (mean)	Measured Range (mean) g/m^2-day
Osage Creek	0.5 to 15 (5.9)	0.65 to 0.94 (0.7)
Illinois River	2.4 to 6 (3.8)	0.08 to 1.82 (0.8)
White River	0.7 to 11 (6.7)	1.20 to 6.00 (3.1)
Spring Creek	1.0 to 18 (8.6)	0.66 to 1.58 (0.9)
Muddy Fork	2.8 to 4 (3.3)	0.70 to 3.20 (1.8)

Table E-4. In Situ Rates of Sediment Oxygen Demand (Reference: Whittemore, 1986)

Stream Name	Measured Range (mean) g/m^2-day
Androscoggin River	0.2 to 1.18 (0.74)
Penobscott River	1.1 to 4.15 (3.04)
Presumscott River	1.5 to 6.4 (4.0)

Table E-5. Ranges of Sediment Oxygen Demand (Reference: EPA, 1985)

River Locations	Measured Range (g/m²-day)	Comments
Upper Wisconsin	30.022 to 0.91	Sullivan
Eastern U.S.	0.09 to 0.87	NCASI
Four Eastern Rivers below Paper Mills	2.0 to 33 and 0.9 to 14.1	Both ranges from NCASI; different measuring techniques
North Illinois	0.27 to 9.8	Butts and Evans
Eastern Michigan	0.10 to 5.3	Chiaro and Burke
New Jersey	1.1 to 12.8	Hunter, et al.
Sweden	0.3 to 1.4	Edburg and Hofsten
Spring Creek	1.7 to 6.0	McDonnell and Owens
England	1.5 to 9.8	Rolley and Owens
— Streams —	4.6 to 44	James

routinely monitors five-day BOD. Laboratory incubations were used to measure the conversion between $CBOD_5$*, BOD_5, UBOD, and UCBOD. From these relationships, it appears that BOD_5 provides a weak relationship to UCBOD. However, the typical values fall near the default of 66 percent of BOD_5 as UCBOD. Some data were collected for both BOD_5 and UBOD during the August 15 and October 25 (1989) surveys (Table E-6). No effort was made to separate out NBOD as calculated by concentration of ammonia.

Table E-6. BOD Measured During 1989 Monitoring Surveys

Parameter	Edge of Woodburn Mixing Zone	QA for Edge of Woodburn	Upstream of Agripac	Below Agripac
BOD_5	3.2 mg/L	3.0 mg/L	1.0 mg/L	2.0 mg/L
% of UBOD	36%	31%	27%	15%
% of UCBOD	88%	93%	66%	55%
% of $CBOD_{20}$	---	---	---	66%
$CBOD_5$	1.5 mg/L	1.3 mg/L	0.3 mg/L	1.2 mg/L
% of UCBOD	41%	40%	40%	33%
% of UBOD	17%	13%	13%	9%
$NBOD_5$	1.3 mg/L	1.4 mg/L	1.4 mg/L	0.5 mg/L
% of UNBOD	26%	29%	29%	8%
% of UBOD	17%	14%	14%	4%
% of BOD_{20}	---	---	---	5%
UCBOD	3.6 mg/L	3.2 mg/L	1.5 mg/L	3.6 mg/L
$NBOD_{20}$	5.7 mg/L	4.7 mg/L	1.3 mg/L	6.2 mg/L
UBOD	8.8 mg/L	---	3.6 mg/L	13 mg/L
$CBOD_{20}$	---	---	---	3.0 mg/L
BOD_{20}	---	---	---	9.3 mg/L

* BOD_{days} = biochemical oxygen demand, C = carbonaceous, U = ultimate, N = nitrogenous.

Application of Model

Pudding River TMDLs Refined Using QUAL2E: *Allocation Strategies* — Several alternative wasteload allocation strategies were considered during the modelling phase. Preliminary wasteload allocations relied on observed streamflows and temperatures during low-flow conditions and were therefore restricted to a limited number of observed flow and temperature regimes. To estimate TMDLs under other conditions, simulated temperatures for various flow conditions were used. The model was calibrated using data collected during intensive and ambient studies in August 1989.

Atmospheric data as measured near Salem were obtained from the NOAA National Climatological Data Center. Data from the date of sample collection and from the preceding two days were used as input to the model. The data in Table E-7 were used to develop allocations. Median values for barometric pressure were used; other data represents the 20th percentile of average monthly conditions for the last five years.

Observed instream temperatures in the Pudding River exceed 27°C (81°F) during summer low-flow conditions. The warm temperatures and low streamflow result in low assimilative capacity in the Pudding.

Summer is the critical period for allocations in the Pudding River. Allocations for the months of June and September are based on flows. A flow of 25 cfs at Highway 211 (the 14Q2) was used to calculate load allocations for the months of July and August. Although additional flow-based allocations may be developed, the assimilative capacity will not significantly increase even at higher flows.

Hydraulics — QUAL2E allows two methods for describing stream velocity, μ, as a function of streamflow, Q. The options are either Manning's equation or power functions. The power function option sets $\mu = aQ^b$, where a and b are empirically determined constants. Ambient dye tests were used to collect information for evaluating the empirical constants.

The dye tests suggest that for flows between 20 and 60 cfs, stream velocity near the point source discharges is similar (0.35 feet per second). Such a relationship would result in an equation where the "b" term is zero and the "a" term defines stream velocity independent of flow. The alternative model defines velocity as $0.35Q^0$.

The QUAL2E model input files have been modified to have constant stream velocity for the section of the Pudding below the point source discharges where the dye-test data indicated constant velocity below 60 cfs. The input files are only applicable for flows below 60 cfs.

Ammonia Decay — Ammonia decay is usually modelled as first-order decay. As described in U.S. EPA guidance manuals, ammonia decay is often modelled as having multiple steps for first-order decay. Multiple steps were used in the original model based on the observed in-stream decay rates. The observed and model-

Table E-7. Climate Data — Salem, Oregon

Month	Julian Day	Air Temp. (°F)	Wet Bulb Temp. (°F)	Barometric Pressure (mm Hg)	Wind Speed (mph)	Cloud Cover (Tenths)
June	168	64.0	50.6	29.83	6.5	5.0
July	198	66.8	51.7	28.85	7.1	3.2
August	229	67.8	52.7	29.81	6.5	3.6
September	260	62.7	49.3	29.81	5.5	3.8
Source: NOAA National Climatological Data Center.						

calibrated decay rates are higher below the point sources of total Kjeldahl nitrogen in the Pudding and appear to decrease downstream from the sources. The decay rates are modelled as a series of first-order decay rates.

The question of concern for calculating TMDLs is whether the decay rates are a function of concentration. Literature indicates that the decay rate of ammonia may be influenced by several factors, including physical factors and substrate concentrations. For example, shallow streams with large bottom-surface-to-volume ratios have been observed to have high decay rates. Decay rates dependent on substrate concentrations may be explained by a Michaelis-Menton type of kinetics. The growth of bacteria may be dependent on the amount of substrate (food). As the amount of substrate increases, the population growth of bacteria increases. The growth continues until the growth requirements of bacteria are saturated.

If the decay rates are dependent on substrate concentration, then as the TMDLs are implemented and substrate is reduced, the resulting decay rates would be expected to be lower than the previously observed decay rates. The dissolved oxygen depression, and therefore the assimilative capacity, is determined by the combined effects of the rate of demand and the rate of reaeration. Reduced decay rates would alter the assimilative capacity of the Pudding River and would therefore influence the loading capacity and subsequent TMDLs.

If we assume that the decay rate is dependent on substrate, it is necessary to predict the decay rate to determine the TMDLs. To estimate the decay rate as a function of concentration in a particular section of the Pudding, the observed decay rate, $[\ln\{NH_3\}_{t0} - \ln \{NH_3\}_{tt}]/\text{Time}$, was plotted against observed concentration. The plot resulted in a linear equation of $-0.085 + 13.85\{NH_3\}$. Although the ammonia concentration appears in both the axes of the plot, it did provide an indication of the change in decay rate due to initial concentration.

Iterations — Point source allocations were calculated by iteration using QUAL2E. For example, a minimum dissolved oxygen value was calculated for an assumed set of wasteload allocations and a given flow regime. Calculations were repeated using different data for wasteloads and flows until the resulting dissolved oxygen value of 6.5 mg/L was achieved. It is estimated that maintaining a daily *average* of 6.5 mg/L will assure that the daily *minimum* level of dissolved oxygen will remain above the standard.

Loads — In the model, current volumes of waste discharge were used for the major sources:

- Silverton — 1.19 cfs (0.8 mgd)
- Agripac — 2.16 cfs (1.4 mgd)
- Woodburn — 2.54 cfs (1.64 mgd)

The value used for Silverton was its current discharge rather than its permit load. The discharge for Mt. Angel was assumed to be zero to be consistent with its no-discharge permit.

Loads for Agripac and Woodburn were assumed to have equal quantities of TSS, UCBOD, NH_3, and organic nitrogen. TSS was included to form a basis for estimating organic nitrogen loads. For this analysis, it was assumed that the discharged TSS was in the form of cells represented as $C_5H_7O_2N$ (molecular weight of 113). Nitrogen is stoichiometrically 12.39 percent bacterial cells by weight. A discharge of 20 mg/L TSS would yield 2.48 mg/L organic nitrogen.

Nonpoint Sources — The preliminary modelling efforts assumed an overall reduction of 25 percent for ammonia, organic nitrogen, and CBOD from nonpoint sources. The reduction for Zollner Creek was assumed to be 65 percent. The nonpoint source reductions would increase the available supply of dissolved oxygen in the Pudding River above the major point sources and would reduce the amount of oxygen-demanding pollution entering the critical portion of the river. If nonpoint sources are controlled, the assimilative capacity available for the point sources would be increased. If nonpoint sources are ***not*** controlled, then the wasteload allocations for the point sources would need to be reduced.

Initial Modelling Results: *Preliminary Allocations Assuming Equal Effluent, 25 Percent Nonpoint Source Reduction* — Table E-8 presents

Table E-8. Alternative Wasteload Allocations Assuming Equal Effluent and 25 Percent Reduction in Nonpont Source Loads

Month	Flow (cfs) at Hwy 211	Pounds Per Day By Source					
		AGRIPAC			WOODBURN		
		UCBOD	NH_3	TSS	UCBOD	NH_3	TSS
June	280	175	115	230	205	135	275
	200	175	88	230	205	200	275
	50	115	6	115	135	7	135
July	<50	115	4	115	135	4.5	135
August	<50	115	4	115	135	4.5	135
September	25	175	58	230	200	68	270
	60	175	80	230	200	95	270
	100	175	110	230	200	130	270

alternative allocations for achieving the standard of 6.0 mg/L dissolved oxygen. No margin of safety is provided in these allocations, and no allocation is made for future growth and development. A 25 percent reduction in nonpoint source loads is assumed.

Review of the data suggests that very little benefit would occur by increasing the flow ranges during July and August. The 60Q2 estimated for the Pudding River at Highway 211 is approximately 50 cfs. The low-flow allocations result in effluent limits of 0.325 mg/L of ammonia at current discharge levels. Because this limit is not realistically achievable, it is most likely that the major sources would be required to use a "no-discharge" alternative to meet this allocation. The no-discharge period would be expected to extend for two months per year.

Discussion of Other Model Runs with Modified Conditions: *Low-Flow and Maximum Warm Temperature* — Applying the updated hydraulics estimates and the assumption that ammonia decay rates are dependent on ammonia concentration significantly increased the assimilative capacity available for wasteloads during summer low-flow conditions. The model was used to estimate wasteload allocations for differing flow conditions, such as the 30Q2 (monthly average low flow), the 7Q2 (weekly low flow), and the 7Q10 (critical low flow) periods. Conditions for an average July weather pattern and for a "warm" period were also evaluated.

The analysis suggests that during the summer low flows (≤ 30Q2) and warm temperatures (maximum thermal input, July), stream temperatures will approach 25°C (77°F) from below the STP discharges to Aurora. Observed temperatures in the Pudding River immediately above the STP have been observed at 24°C in the afternoon and 22°C in the morning. The temperatures observed at Aurora approach 23.5° to 24°C in the morning and 27°C in the afternoon. The predicted temperatures appear to be reasonable estimates of the critical conditions that may exist during extended warm weather and low-flow conditions.

The analysis also suggests that very little, if any, assimilative capacity will exist at the critical low-flow warm-weather temperatures. Alternatives to application of critical low-flow wasteload allocations could include a no-discharge period for July and August when flows are below 35 cfs and daily averaged stream temperatures are near 25°C.

Artificial Reaeration — Representatives of Agripac requested that DEQ review an alternative which relied on instream artificial reaeration of the Pudding River. The first assumption placed the artificial reaeration upstream of the discharges to provide greater assimilative capacity for the Pudding River. The aeration provided 150 lb/d of oxygen to attain near-saturation. No analysis was conducted to assure that supersaturation of gases other than oxygen would not occur. The second assumption placed an additional aerator of 150 lb/d of oxygen just below the Woodburn STP.

The analysis suggests that the effect of artificial reaeration would not be apparent for long distances below the point of application. Multiple appropriately-placed aerators could offset the oxygen demand placed on the stream. If placed effectively, greater wasteload allocations could be possible.

At this time, no wasteload allocations have been developed for any assumed level of artificial reaeration. A policy evaluation needs to be made to determine if reaeration would be a permissible approach for a point source wasteload allocation.

Nonpoint Source Load Allocations — Nonpoint sources are estimated as both tributary inflow and as overland flow. Analysis suggests that some relief in wasteload allocations may occur through effective nonpoint source controls.

Other Strategies — Because the oxygen-sag curves from Agripac and Woodburn overlap, the actions of one discharger could influence the alternatives available to the other. Although there may be other alternative strategies that would also be equitable, they would require extensive review.

Summary

Modelling efforts have focused on the area of low dissolved oxygen below the two major dischargers (Woodburn and Agripac) for the critical low-flow season extending from June through September. Based on the modelling, a TMDL has been developed which defines the wasteload allocations for point sources, the load allocations for nonpoint sources, and reserves. The analysis used for the final wasteload allocations assumed no significant modification to nonpoint source loads.

Time schedules and strategies for implementing the TMDLs have also been incorporated into the process. Monitoring will be continued to assure compliance and to verify the accuracy of the model. Because of the inherent uncertainties in any modelling effort, it is important that a reasonable margin of safety be included so that permit conditions will not need to be changed drastically in the future, resulting in costly design changes for waste-treatment facilities.

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APPENDIX F

PERMIT WASTELOAD ALLOCATIONS

Approach

The Department of Environmental Quality's 1992 Section 305(b) Report indicates that the Pudding River is water quality limited for dissolved oxygen and, therefore, is not able to fully support aquatic life. DEQ has proposed a total maximum daily load (TMDL) for the Pudding River. The TMDL is intended to limit introduction of oxygen-demanding pollutants into the Pudding River.

The TMDL includes proposed wasteload allocations (WLAs) for the both the City of Woodburn and Agripac, Inc., Plant #3 of Woodburn. These sources both discharge treated effluent into the Pudding River and have been found to be the two principal point sources that contribute to violations of the dissolved oxygen standard in the Pudding River. The wasteload allocations have focused on reduced flow-related loads of ammonia and oxygen-demanding material during the early summer (June) and little or no discharges of ammonia during critical low-flow periods (July and August). As stream temperature decreases in the fall (September), wasteload allocations are increased.

Wasteload Allocations

Agripac: The proposed **WLAs** for Agripac, Inc., Plant #3 are:

- For carbonaceous oxygen demand ($CBOD_5$): Daily maximum not to exceed 20 mg/L; monthly average not to exceed 10 mg/L.
- For total suspended solids (TSS): Daily maximum not to exceed 20 mg/L; monthly average not to exceed 10 mg/L.
- For effluent dissolved oxygen concentration: Daily average not to be less than 6.5 mg/L.
- For ammonia-nitrogen (NH_3-N) — see Table F-1.

Table F-1. Wasteload Allocations for Ammonia-Nitrogen for Agripac

June		
Pudding River Monthly Average Flow (cfs)	**Monthly Average Effluent Ammonia-N Concentration Not to be Exceeded mg/L**	**Daily Maximum Effluent Ammonia-N Concentration Not to be Exceeded mg/L**
>150	18	27
100 – 150	15	23
50 – 100	8.5	13
<50	3.2	4.8

(Continued on next page.)

Table F-1. Wasteload Allocations for Ammonia-Nitrogen for Agripac (Continued)

July and August		
Pudding River Monthly Average Flow (cfs)	Monthly Average Effluent Ammonia-N Concentration Not to be Exceeded mg/L	Daily Maximum Effluent Ammonia-N Concentration Not to be Exceeded mg/L
>100	10	15
60 – 100	2.7	4.1
30 – 60	1.5	2.3
<30	0.30	0.48
September and October		
Pudding River Monthly Average Flow (cfs)	Monthly Average Effluent Ammonia-N Concentration Not to be Exceeded mg/L	Daily Maximum Effluent Ammonia-N Concentration Not to be Exceeded mg/L
>100	WLAs do not apply.	
60 – 100	18	27
30 – 60	9.0	14
<30	4.0	6.0

Woodburn: The proposed **WLAs** for the City of Woodburn are:

- For carbonaceous oxygen demand ($CBOD_5$): Daily maximum not to exceed 20 mg/L; monthly average not to exceed 10 mg/L.
- For total suspended solids (TSS): Daily maximum not to exceed 20 mg/L; monthly average not to exceed 10 mg/L.
- For effluent dissolved oxygen concentration: Daily average not to be less than 6.5 mg/L.
- For ammonia-nitrogen (NH_3-N) (see Table F-2):

Table F-2. Wasteload Allocations for Ammonia-Nitrogen for Woodburn

June		
Pudding River Monthly Average Flow (cfs)	Monthly Average Effluent Ammonia-N Concentration Not to be Exceeded mg/L	Daily Maximum Effluent Ammonia-N Concentration Not to be Exceeded mg/L
>150	6.8	10.2
100 – 150	5.7	8.6
50 – 100	3.1	4.7
<50	1.1	1.7
(Continued on next page.)		

Table F-2. Wasteload Allocations for Ammonia-Nitrogen for Woodburn **(Continued)**

July and August		
Pudding River Monthly Average Flow (cfs)	**Monthly Average Effluent Ammonia-N Concentration Not to be Exceeded mg/L**	**Daily Maximum Effluent Ammonia-N Concentration Not to be Exceeded mg/L**
>100	3.2	4.8
60 – 100	1.0	1.5
30 – 60	0.50	0.75
<30	0.10	0.18

September and October		
Pudding River Monthly Average Flow (cfs)	**Monthly Average Effluent Ammonia-N Concentration Not to be Exceeded mg/L**	**Daily Maximum Effluent Ammonia-N Concentration Not to be Exceeded mg/L**
>100	WLAs do not apply.	
60 – 100	6.8	10.2
30 – 60	3.3	5.0
<30	1.6	2.4

Note:

Wasteload allocations (WLAs) displayed above represent oxygen-demanding mass load limits for specific flow scenarios in the Pudding River. These allocations will be fixed. The actual concentration and mass load limits may be represented differently in the waste discharge permit, however, depending on the specific wastewater control alternatives selected by the City or Agripac. For example, if either of the sources choose to irrigate a portion of their effluent, higher concentration limits may be permitted because effluent discharge flows would be less. Also, the WLAs were derived by distributing the loads based upon an equal percent removal of influent ultimate-oxygen-demand from both sources. The Department considered several other options, but believes this approach is as equitable as any of the alternatives. Load allocations for nonpoint sources are assumed to stay unchanged.