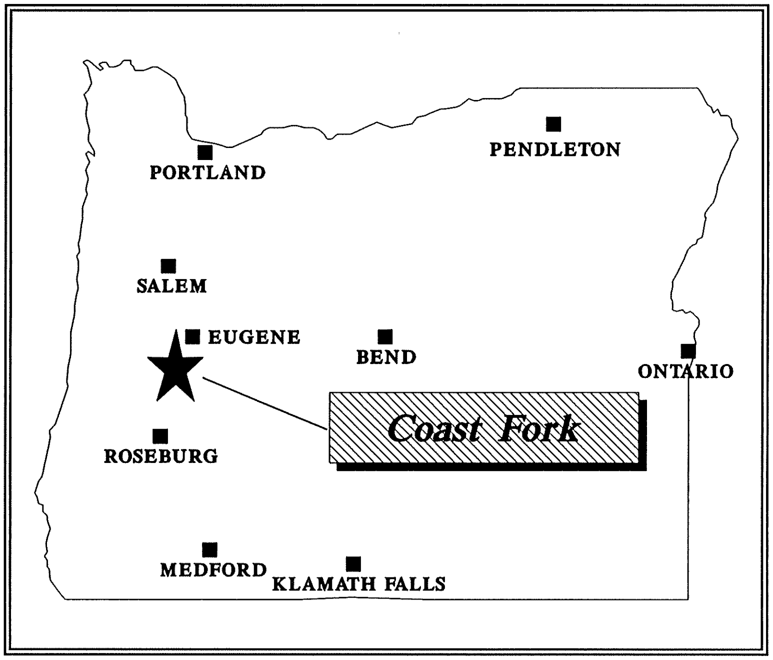
October 1995

Coast Fork

Water Quality Report

Total Maximum Daily Load Program



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Coast Fork

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 Coast Fork. 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 waterbodies 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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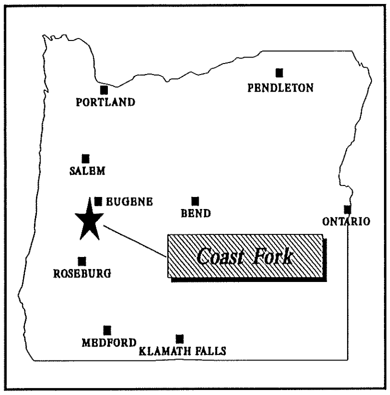
Coast Fork TMDL Development

WQ CONCERNS AT A GLANCE:

Water Quality Limited?	*Yes*
Segment Identifiers:	*11C-WICF*
Parameter of Concern:	*pH, DO Saturation, Nutrients, Periphyton Growth, Temperature, and Aquatic Life*
Uses Affected:	*Aquatic Life*
Known Sources:	*Cottage Grove STP**
Other Factors:	*Flow Regulated by Upstream Impoundments*



BACKGROUND INFORMATION

The Coast Fork of the Willamette River is located in the south western portion of the larger Willamette River basin. The Coast Fork drains 665 square miles of Lane County Oregon. Most of the basin is forested and in mountainous terrain. Both of the major streams in the basin, the Row River and Coast Fork, are regulated by reservoirs. The Row River enters the Coast Fork near the City of Cottage Grove. The Coast Fork River is 39 miles long and joins the Willamette River 187 miles upstream from the Columbia River. Below the confluence with the Row River, the Coast Fork runs thirty (30) miles through a valley with primarily agricultural land use. The City of Cottage Grove is the major permitted source of wastewater to the Coast Fork. The City of Cottage Grove discharges to the Coast Fork near the confluence with the Row River.

WATER QUALITY CONCERNS

The Coast Fork is relatively wide and shallow — supporting extensive growth of periphytic algal on the stream bed. The algal growth through photosynthesis and respiration has lead to violations of the State's water quality standards for dissolved oxygen saturation and pH. Nutrients discharged from the Cottage Grove Sewage Treatment Plant (STP) support the periphyton algal growth in the Coast Fork of the Willamette River.

Beneficial Uses Affected

The designated beneficial uses of the Coast Fork are identified in Oregon's Administrative Rules (OAR). Uses include water supply, aquatic life, recreation and aesthetics, salmonid rearing, and salmonid spawning.

The existing aquatic resources of the Coast Fork Willamette River are not well documented. Information on salmonid fish distribution is available from the Oregon Department of Fish and Wildlife (ODFW). The potential for anadromous salmonid production in the Coast Fork is uncertain. The ODFW may consider the Coast Fork for future production of winter steelhead. There are populations of mountain whitefish and cutthroat trout in the mainstem Coast Fork. Cutthroat trout reside in the river at least as low as Cresswell (RM 12.8) during summer low flow where further temperature increase may limit their distribution. Recreational fisheries exist for trout in the upper mainstem of the Coast Fork. The confluence of the Coast Fork and Row River provides a popu-

* Sewage Treatment Plant.

lar location for recreational angling. Native trout and whitefish are mainstem spawners. The ODFW believes that trout spawning may occur in the mainstem Coast Fork from January through April.

Applicable Water Quality Standards

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

Dissolved oxygen is a critical parameter for the protection of salmonid rearing and spawning. The applicable standards in the basin are:

- Salmonid Rearing: 90 percent of saturation;
- Salmonid Spawning: 95 percent of saturation; and
- Non Salmonid Producing: 6 mg/L.

The information from ODFW suggest that the Coast Fork as far down as Cressell (RM 12.8) is salmonid producing and the 90 percent saturation criteria would apply during summer low flow conditions.

The pH criteria establishes water quality conditions for protecting fish and aquatic life, including the sensitive salmonids. The pH standard in the Coast Fork is a minimum of 6.5 with a maximum of 8.5.

Available Monitoring Data

Monthly water quality monitoring data has been available at river mile 6.4 for 1979 through 1987, and at river mile 3.0 since 1987. More recent water quality data is available at a total of eight (8) locations in the Coast Fork and Row River since 1988. Stream discharge data is available below the reservoirs on the Coast Fork and Row River, and below the confluence of the Row River near Saginaw.

Limited data is available describing diurnal cycles, algal biomass, biomass accumulation, and periphyton community production and respiration.

Point Sources

The Cottage Grove STP is the only major point source that discharges to the Coast Fork during summer low flow conditions.

Nonpoint Sources

Nonpoint sources have not been extensively assessed. Concentrations of nutrient upstream of the major point source are high enough to support significant periphyton growth. However, point source discharge provides the dominate source of nutrients to the Coast Fork during the summer low flow period when standards violations have been observed. DEQ has elected to allocate background and nonpoint sources at current conditions. The TMDL includes a reserve allocations to cover uncertainty in analytical predictions on future growth and development.

TMDL History

The *Clean Water Act* (Public Law 92-500) established goals for water quality. The state of Oregon has established water quality standards for meeting the goals and requirements of the *Clean Water Act*. Section 303 of the *Clean Water Act* requires that waterbodies that fail to meet water quality after the implementation of technology based effluent limits be identified as water quality limited. For water quality limited streams, the adoption of a water quality based pollution control strategy and associated Total Maximum Daily Loads (TMDLs) provides the means for achieving the Standards.

In 1987, the Northwest Environmental Defense Center filed suit in US district Court for the failure of EPA and the State of Oregon to implement certain activities required by the *Clean Water Act*. Under a consent decree, the Department of Environmental Quality agreed to determine by August 1988 whether 16 waterbodies, including the Coast Fork, were water quality limited. The Coast Fork Willamette River was found to be water quality limited from the mouth to river mile 25 due to violations of the pH and dissolved oxygen standards.

Proposed Nutrient TMDL

A phased approach for implementing this TMDL will be used. The initial phase focuses on defining and implementing the point source waste load allocations. The point source provides the dominant source of nutrients to the Coast Fork. However, since NPS appear to provide nutrients and unidentified background and NPS result in relatively high nutrient concentrations upstream on the major point source, a NPS component is appropriate for this TMDL. The proposed LA and Reserve LAs will provide adequate allocation to address the NPS component. The initial phase for NPS will focus efforts of the Departments of Environmental Quality and Agriculture on tributaries with measured high phosphorus levels such as Gettings Creek and Camass Swale, and on verifying controls on confined animal feeding operations in the basin.

The pH and dissolved oxygen saturation criteria violations are the result of periphyton photosynthesis and respiration. Periphytic algal growth is influenced by many factors including stream flow, temperature, grazing by invertebrates, and nutrient supply. DEQ has defined regulatory control over a significant portion of the nutrient supply. The concentration of the macronutrients phosphorus and nitrogen supporting the algal growth are significantly influenced by point source discharge to the Coast Fork.

A nutrient control strategy focusing on phosphorus control has been developed to address the pH and DO saturation standards violations. A nutrient control program focusing on nitrogen was not believed to be effective at limiting the periphyton production. An alternative strategy that would limit both nitrogen and phosphorus would also be effective. Limiting both macronutrient would reduce uncertainty with the effectiveness of a nutrient control program compared to limiting a single nutrient. However, a program limiting both nutrients would limit options for achieving the TMDL and could increase the costs for compliance.

Several alternative wasteload allocation's (WLA's) strategies were reviewed. Table 1 provides a review of range of alternative nutrient TMDLs

Table 1. Alternative Nutrient TMDL Strategies Reviewed

WLA		LA	WLA Reserve	Comments
lbs/day	(μg/l)			
0.0	0.0	9.7	3.3	Reduced biomass throughout the river; achieve WQ standards. Both nitrogen and phosphorus reduced.
0.8	48	9.7	2.5	Below measurable increase in PO4; initially below community production levels.
1.0	60	9.7	2.3	Achieve standard in lower river; increased production near STP. Contains reasonable margin of safety in reserve WLA, NPS LA > WLA.
2.1	126	9.7	1.2	Achieve standard in lower river; greater extent of increased production below STP. Limited reserve to account for NPS and analytical uncertainty.
3.3	198	9.7	0.0	Initial levels at community respiration and cellular limitation in lower river. No reserve to cover potential NPS sources. The WLA approaches the loading capacity with no reasonable margin of safety for analytical uncertainty.
4.0	240	9.7	—	Average concentrations at community respiration limits; less certainty that nutrients will be reduced to cellular limitation in lower river. The WLA is at or greater than the loading capacity, no reasonable margin of safety.
8.0	480	9.7	—	Reduced extent and magnitude of ph violations; reduced algal biomass. Uncertainties with effects of grazing may allow significant reduction from current conditions.
Nitrogen TMDL		—	—	Would not be unilaterally effective.

Table 2. PO_4-P Wasteload Allocations

WLA STRATEGY FOR NUTRIENT CONTROL		
Load Parameters	LBS/D	µg/L
LC	13.0	16.0
LA Background	9.7	12.0
LA Reserve	2.3	2.8
WLA	1.0	60.0

reviewed. The table of nutrient WLA alternatives was simplified by assuming a total stream flow of 150 CFS. This stream flow includes the upstream flow from the Coast Fork, dilution from the Row River, and the STP discharge of 2 MGD. Upstream background concentrations were taken from mass balance calculations of both the Row and Coast Fork Rivers.

The effect of alternative WLAs on ambient nutrient concentrations was evaluated using both simple and probabilistic (monte-carlo) mass balance procedures and theoretical models available in the published literature. The influence of alternative WLAs and nutrient reductions on ambient pH were further assessed using a dynamic lagrandgian inorganic carbon balance. Existing ambient data and extensive literature review provided guidance and thresholds for comparing and contrasting alternative nutrient control strategies. Potential ammonia toxicity WLAs were evaluated using simple mass balance procedures. Ammonia WLAs were also evaluated using a Streeter-Phelps dissolved oxygen model to assure achievement of the dissolved oxygen standard.

It is not the intent of the TMDL to eliminate periphyton growth through nutrient control. The WLA strategy is anticipated to provide the greatest loading capacity having a reasonable probability of achieving water quality standards. The reserve load allocations (LAs) are intended to cover background and nonpoint source loads and the uncertainty in estimates of the impact of nutrient loads on periphyton production. The Department may re-assign part to the reserve LA to the WLA for Cottage Grove as the Department reviews alternatives for implementing the TMDL. The only WLA is assigned to the Cottage Grove STP. At design flows of 2 million gallons per day (mgd), a WLA of 1 lb/day is equivalent to 0.06 mg/L (60 µg/l) of dissolved ortho phosphate as phosphorus. The increase in ortho phosphorus would not be measurable below the confluence with the Row River (Table 2).

Proposed Ammonia TMDL

Ammonia WLAs were developed to make certain that selected alternatives did not result in ammonia toxicity standards violations or generate dissolved oxygen standard violations. The current dissolved oxygen standard violations are principally driven by algal respiration. Upstream of the Cottage Grove STP, the background oxygen levels fall to at or near the 90 percent saturation during diurnal minimums. Under these conditions, the background concentrations become the criteria and leave little room for any WLAs. The WLAs were calculated to assure no measurable decrease from background oxygen concentrations due to dilution with low oxygen effluent or oxygen demand. Adoption of the proposed 8.0 mg/L criteria will result in greater loading capacity (LC) and potentially greater WLAs (Table 3). The LAs establish background conditions. No efforts beyond the existing controls are needed to implement the ammonia TMDL.

The Coast Fork is not a priority watershed for nonpoint source pollution control efforts. The nonpoint source strategy for implementing the load allocation for the Coast Fork TMDLS includes four (4) principal components:

Table 3. NH_4-N Wasteload Allocation

COTTAGE GROVE AMMONIA WLAs (LBS/DAY)			
Criteria	LC	LA	WLA
90%	111	67	44
8 mg/L	297	67	230

- Work with the State Department of Agriculture (DOA) which is the designated management agency (DMA) for agriculture to inspect all CAFOs in the Coast Fork Willamette River and identify corrective actions needed.

- Work with DOA as resources allow to reduce phosphorus loading to Gettings Creek and Camass Swale, and any additional tributaries having high phosphorus concentrations.

- Continue ongoing efforts with the State Department of Forestry (DOF), the DMA for state and private forest lands to ensure the *Oregon Forest Practices Act* is implemented.

- Continue implementation of Memoranda of Agreement between DEQ and federal land management agencies to meet or exceed state forest practices requirements.

APPENDIX

APPENDIX A — EXPANDED BACKGROUND INFORMATION

APPENDIX A

EXPANDED BACKGROUND INFORMATION

BACKGROUND REPORT

Ambient Data

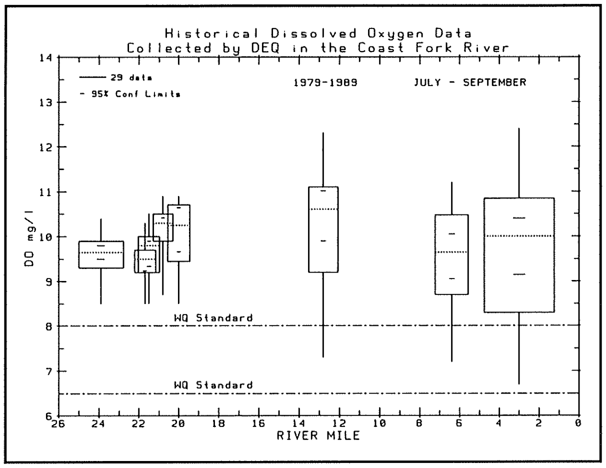
Water quality data for the Coast Fork is available in the USEPA STORET data base for several locations (Table A-1). Monthly monitoring data are available for river mile 6.4 from 1979 until October 1987, and at river mile 3.0 since then. More recent data are available at the remaining locations. Diurnal data are available from three surveys. The Row River site provides water quality conditions in a major tributary entering the Coast Fork Willamette. The Cottage Grove STP is located approximately 1 mile upstream from the confluence of the Row and Coast Fork at approximately river mile 21.6.

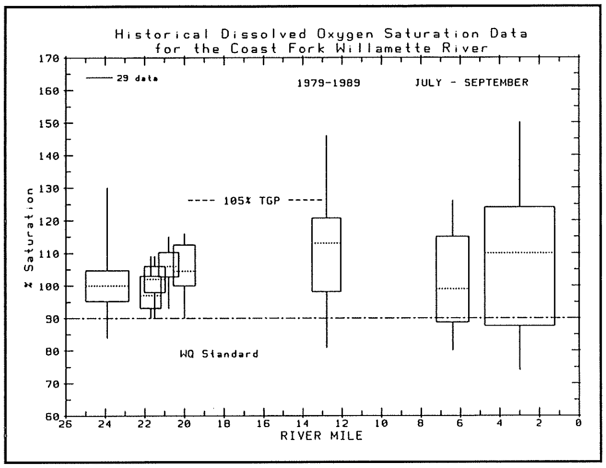
Historical discharge records are available from the United States Geological Survey (USGS) for several locations in the Coast Fork Basin. The two major streams, the Coast Fork and Row Rivers, have both been regulated by reservoirs since 1942 and 1949, respectively. The reported critical low flow, 7Q10, below the Row River at Saginaw prior to regulation was 22 cfs. After regulation, the reported 7Q10 measured near Goshen until 1982 was 129 cfs. Typical summer low flow is consistently near 150 cfs. Regulation by reservoirs has greatly increased summer minimum flows in the Coast Fork Willamette (Figures A-1 – A-8).

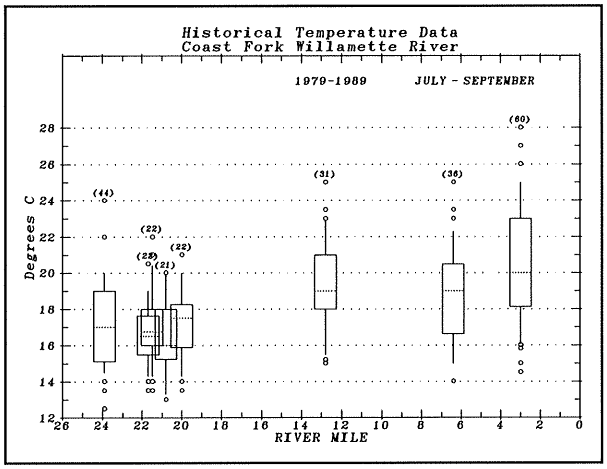
Seasonal flow and water quality data indicate that the summer low flow period from June through September is the critical period for pH and dissolved oxygen concerns. During the summer (low flow period of approximately June through September for the Coast Fork), dissolved oxygen occasionally falls below the state minimum standard of 90 percent saturation. Maximum oxygen saturation levels exceed 125 percent of saturation which, assuming only oxygen is supersaturated and standard barometric pressure, would be equivalent to the 105 percent Total Gas Pressure criteria for streams with 2 feet or less of depth. The average of measured DO concentrations are above the state proposed criteria of 8.0 mg/L for cold water fish system (ODEQ, 1993).

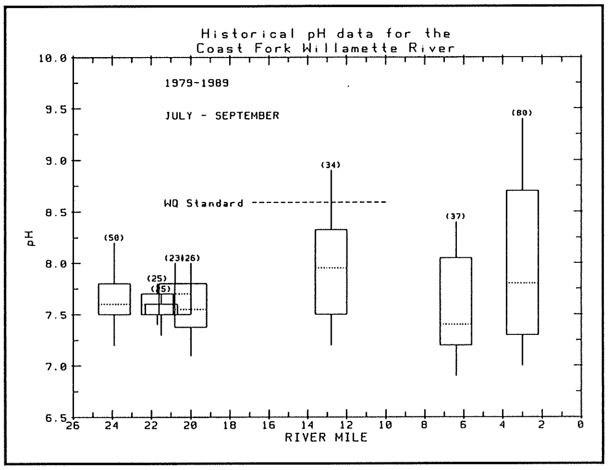
Table A-1. STORET Sites

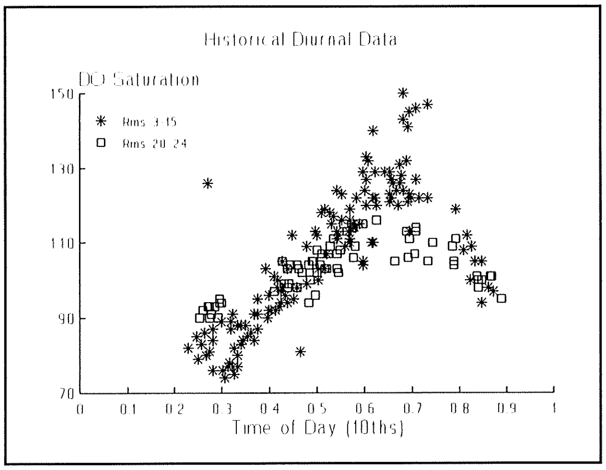
STORET STATIONS		
STORET No.	**River Mile**	**Name**
402955	3	William Parish
402047	6.4	Highway 58
402048	12.8	Cresswell
402049	20	Saginaw
402052	20.8	Row River
402956	21.5	Below STP
402050	21.7	Above STP
402051	23.9	Above City

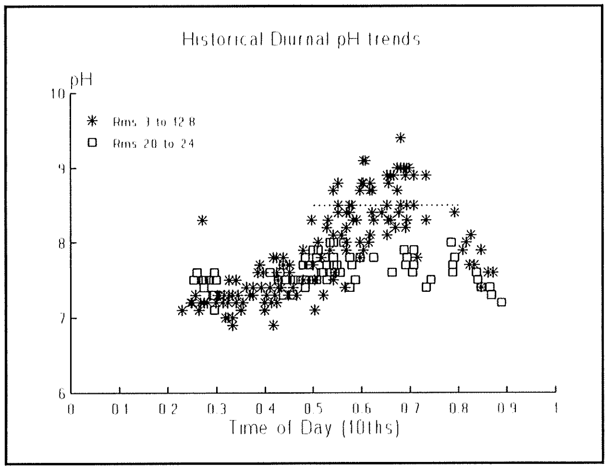




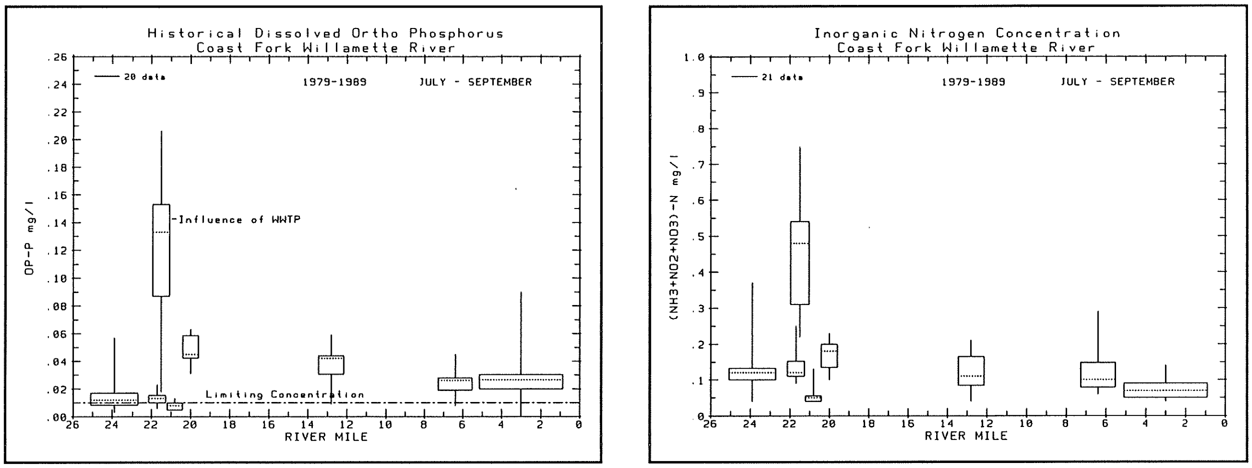








Figures A-1 – A-6. Historical Water Quality



Figures A-7 – A-8. Historical Water Quality

Observed pH measurements exceed the state maximum criteria of 8.5 at locations downstream of river mile 14, but remain within standard, typically below 8.0 above river mile 20. Most of the pH violations occur in the afternoon, and the lowest DO saturation levels occur early morning.

Relatively warmer stream temperatures occur below river mile 14 as compared to locations upstream of river mile 20 where average temperature remains below 17°C. Average temperatures approach 20°C, and maximums exceed 24°C, below river mile 14. The observed temperature pattern would make the lower Coast Fork River marginal habitat for cold water fish during summer low conditions.

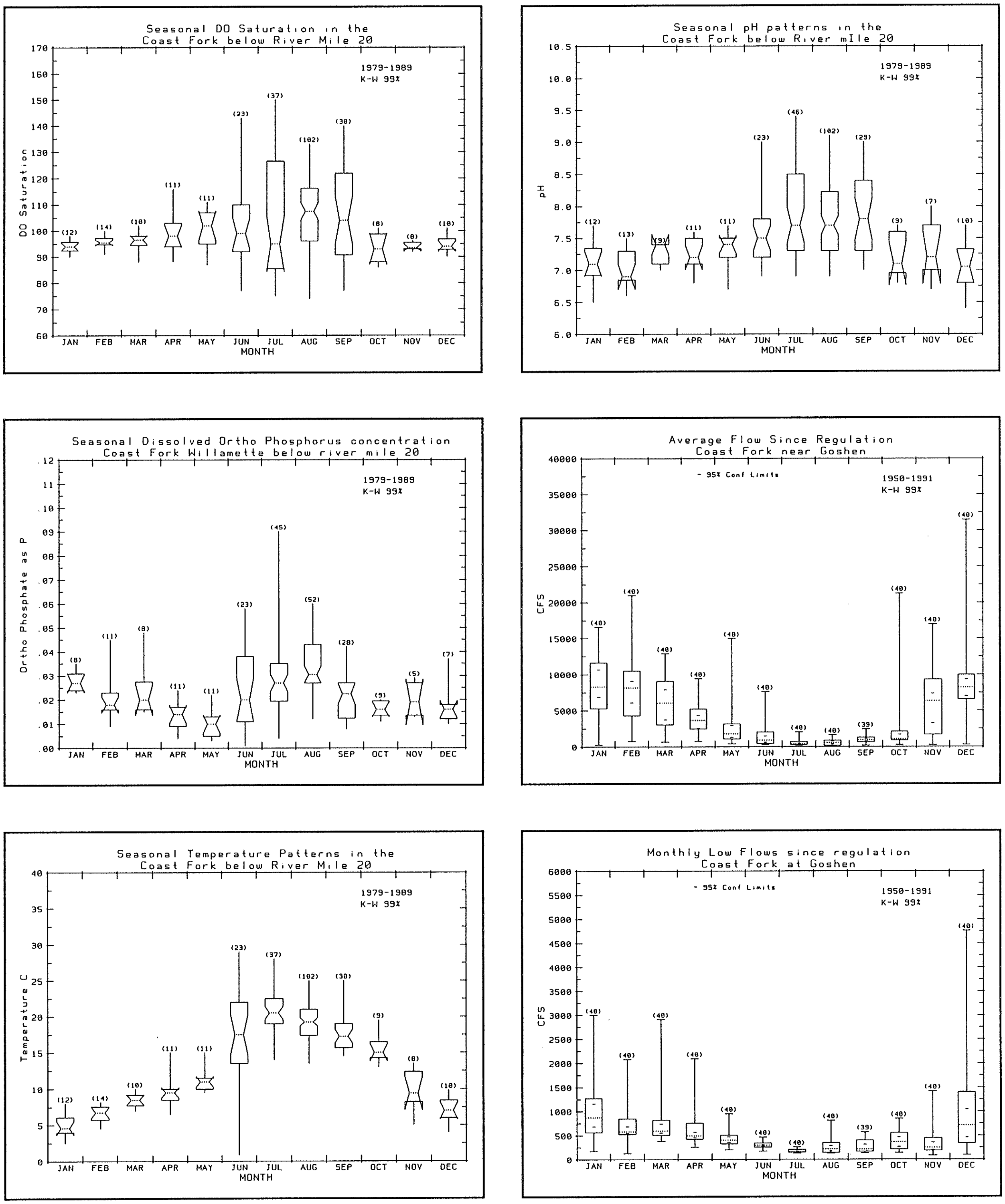
Figures A-9 – A-14 show that the low flow period from June through September appears to be coincide with the greater variation in dissolved oxygen saturation and pH and higher stream temperature. The greater variation in oxygen saturation and pH indicates greater influence of photosynthesis on water quality. Data collection efforts have focused on the June through September period and different monitoring intensity may influence the observed distribution. Based upon this monitoring data, the summer low flow period for the Coast Fork is roughly defined as June through September.

Both pH and dissolved oxygen data show similar patterns of diurnal change. A much greater range of diurnal variation occurs in the lower river sites, below river mile 14, as compared to upper river sites (Table A-2 and Figure A-15).

Photosynthesis from periphyton algae would produce oxygen and consume inorganic carbon during the day resulting in increased oxygen saturation and high pH values. Periphyton respiration at night would act to reduce oxygen and pH values. The DO and pH data show similar patterns of diurnal change and are correlated suggesting that the diurnal variation is influenced by photosynthetic activity of periphyton. The greater diurnal range in DO and pH observed in the lower sections of the river implies greater primary productivity than upstream sites. The violations of the oxygen saturation and pH standards appear to be the result of periphyton photosynthesis and respiration. Increased primary production may be supported by increased nutrients from the Cottage Grove Sewage Treatment Plant (CGSTP). The apparent diurnal variations may also be influenced by changes in hydraulic conditions and aeration rates, less shade, and diluted alkalinity as compared to sites upstream of the confluence with the Row River.

ALGAL GROWTH AND PRODUCTION MEASUREMENTS

Measurements of the algal growth and primary production were used to assess the influence that the existing levels of periphyton production may have on observed water quality.



Figures A-9 – A-14. **Seasonal Patterns for Oxygen, pH, Ortho-Phosphorus, Temperature, Daily Average Discharge, and Daily Minimum Discharge**

Table A-2. Diurnal Data

DIURNAL SUMMARIES BY RELATIVE LOCATION				
DO Average/ % Violation		**River Site**	**pH Average/ % Violation**	
a.m.	**p.m.**		**a.m.**	**p.m.**
85 / 15%	127	Lower	7.4	8.6 / 55%
93 / 6%	108	Upper	7.3	7.7

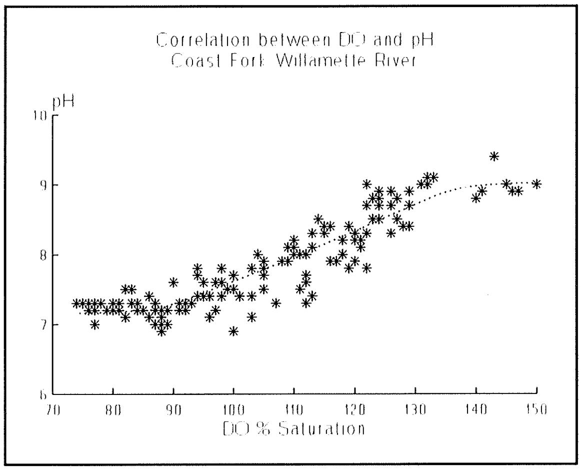


Figure A-15. pH vs. DO

Glass slides were used as in-situ artificial substrate for measuring the rate of periphyton accumulation on three occasions in the Coast Fork. Vandalism and losses from high flow events prevented obtaining complete data sets for two of the three sampling periods.

Multiple slides were placed in each location for a period of 28 days. At each location, slides were incubated at approximately 1 foot of depth and placed off of the bottom to limit grazing by macroinvertebrates. An additional series of slides were incubated at between 2 and 3 foot depths for all but the upper most station, where the stream depth was less than 2 feet.

Three control sites were selected: two upstream of the age Grove sewage treatment plant (CGSTP), one in the tributary Row River. Samples were collected below the CGSTP and above the confluence with the Row River and at five locations downstream from the confluence. Shade, measured as percent canopy closure, varied from 20–35 percent at the upstream controls, 40 percent below the STP, and varied between 0 and 10 percent at all other locations. Although stream depth generally increased, and velocity decreased in a downstream direction, the placement of in-situ samples was selected to minimize depth and velocity differences. (Figure A-16.)

Triplicate samples from the shallow slides, and single samples from the deeper slides were removed five times throughout the incubation periods and measured for ash free dry weight. Algal accumulation rates, due to initial colonization (a) and growth (k) were calculated by least squared regression of AFDW accrual to the equation $y = ae^{kt}$ for time up to 14 days (t). The calculated growth rate was converted to the more commonly reported units of doublings per day by division of by 0.693. After 14 days, the accumulation of biomass is significantly influ-

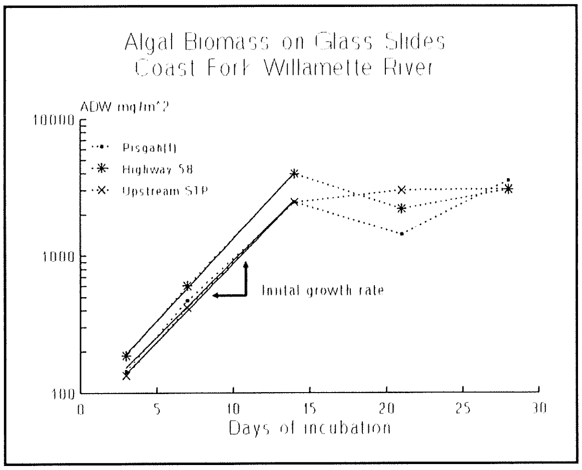


Figure A-16. Glass Slides

enced by sloughing and potentially invertebrate grazing on the slides.

Maximum biomass accrual was significantly less at the furthest upstream control than at all other locations ($p<0.0005$). No correlations were observed between maximum biomass and chemical or physical measurements taken from the various locations. The maximum biomass accrued was less on the deeper slides than the shallow slides ($p<0.005$).

Calculated growth rates varied between 0.33 doublings/day to 0.52 doublings/day. The calculated growth rates are similar to those reported for the McKenzie River (Oregon) of 0.3 doublings/day in experimental channels (Bothwell 1992). No correlations were observed between calculated growth rates or normalized growth rates $({}^{\text{Kobs.}}/_{\text{Kmax.}})$ and nutrient concentrations or other physical or chemical measurements.

The glass slides measure a thin film of periphyton accumulation. Results are consistent with the information reported by Bothwell (1992, 1988, 1985) that a single cell or thin layer of algae can be saturated by nutrients at very low concentrations of 1 to 3 µg/l of orthophosphorus. Concentrations of ortho-phosphorus measured site upstream of the CGSTP (10 µg/l) and in the Row River (7 µg/l) appeared to provide adequate levels to saturate growth requirements of a single cell or a thin layer of periphyton. Significantly greater concentrations of nutrient may be required to saturate the thicker mats of algae that occur in the river (Bothwell 1992, 1988).

Direct measures of algal biomass, production, and community respiration (CR) were made in the Coast Fork Willamette River as part of the larger Willamette River study and are reported by Gregory (1993).

Both chlorophyll a and biomass of periphyton increased downstream of CGSTP ($P<0.001$). Measures of biomass provide only an indirect approximation of the benthic metabolic production. Rates of benthic metabolism were measured by in-situ respirometer. Gross primary production (GPP) and community respiration (CR) (mg/m^2-day) increased below the CGSTP. The ratio of production rate divided by respiration rate was greater than one indicating a net input of oxygen. Measures of the primary production rates relative to biomass (GPP/BIOM.) or chlorophyll a provide a measure of the physiological state of the periphyton. Relative metabolic rates (GPP/BIOM.) increased below the CGSTP indicating that the periphyton assemblages are physiologically more active at the downstream location below the CGSTP (Table A-3).

Ambient data show that greater diel variation in DO occurs below the CGSTP indicating greater benthic metabolism. Continuous diurnal measures of dissolved oxygen in the Coast Fork Willamette River were used to estimate maximum daily benthic production. Production was calculated using methods described by Di Torro (1989) and Chapra and Di Torro (1992) for conditions where the estimated aeration coefficient (Ka) is near or less than 5/day. The estimates of production, using this method, are consistent with reported production for moderately enriched streams. These production calculations are sensitive to the estimated aeration rates and provide an indirect approximation of diurnal production (Table A-4).

Table A-3. Production Measures

PRODUCTION AND RESPIRATION IN THE COAST FORK — GREGORY (1993)				
RM	**GPP** $({}^{\text{mg O}_2}/_{\text{M}^2\text{-D}})$	**CR** $({}^{\text{mg O}_2}/_{\text{M}^2\text{-D}})$	**P/R Ratio**	**GPP/BIOM.** $({}^{\text{mg O}_2}/_{\text{AFDW-D}})$
28.5	718	635.6	4.4	23
25.7	1615	1153.2	1.7	185

Table A-4. Production

CONTINUOUS MONITORS — 08/28/87					
Location	DO mg/L	DO %Sat	pH	Ka / Day	Pa G/M^{2}D
Pisgah	11.8	136	9.2	1.6	3.8
	7.6	82	7.3		
Cresswell	11.9	134	9.1	5.3	4.7
	8.4	88	7.4		

NUTRIENT CONCENTRATIONS, PROPORTIONS, AND LIMITATION

Nutrient concentrations were monitored as part of the ambient sampling program and in conjunction with the periphyton accumulation surveys in the Coast Fork. The CGSTP is the primary source of dissolved ortho-phosphorus and a significant source of inorganic nitrogen in the Coast Fork Willamette River. Nutrient concentrations in the Coast Fork are then reduced due to dilution from the Row River, and further reduced downstream. Reduced concentrations and mass of dissolved ortho-phosphorus and nitrogen downstream of the confluence of the Row river appear to be due to nutrient uptake by the periphyton.

Molar ratios of inorganic nitrogen and ortho-phosphorus indicated nutrient balance or that phosphorus was in lowest proportion of algal needs upstream of the STP (27.6–24.6:1) and in the Row River (17). The molar ratio for sites influenced by the STP discharged indicated that nitrogen was in lowest proportion for algal growth requirements (6.2–7.5:1). The change in limiting proportion is due to the dominant influence of wastewater with a molar ratio on N:P in the effluent of 5.5:1 on ambient nutrient concentration.

Gregory (1993) measured the response of periphyton from the Coast Fork and mainstem Willamette Rivers to nitrogen and phosphorus additions under differing light intensities in closed recirculating chambers. Water used for the assays contained background concentrations of 25 μg/l inorganic nitrogen and 106 μg/l of phosphorus. Phosphorus concentrations in the reference waters was above reported limiting concentrations. Benthic algae were also taken from an enriched system. Periphyton can store excess phosphorus internally, consequentially the growth response of the periphyton removed from the Coast Fork to phosphorus supply may be influenced by growth supported by nutrients previously reserved.

Benthic algae exhibited increased production with increasing light intensities at all nutrient concentrations tested. No consistent response from algae assemblages from the Coast Fork were defined for incremental additions of phosphorus. Periphyton appeared to respond to incremental nitrogen additions above 500 μg/l. However, the lack of a response for additions of nitrogen below 300 μg/l may indicate that production rates are relatively stable at nitrogen concentration between 25 μg/l and 300 μg/l.

DISCUSSION AND LITERATURE REVIEW

Higher water temperatures occur downstream of the CGSTP as compared to upstream reference sites. With sufficient nutrient supply, periphyton would be expected to increase production in response to increased stream temperature. Maximum specific growth rates for nutrient replete conditions is predominately established by temperature (Bothwell 1988, 1992). Phinney and McIntyre (1965) showed that periphyton oxygen production increases in response to increased temperature. McIntyre (1966) observed that periphyton communities raised in slow-stream currents were more sensitive to changes in temperature that those communities associated with fast stream flow velocities for communities raised at temperatures below 13°C. The reverse was true at high (13–23) temperatures.

The CGSTP is a major source of both macronutrients, inorganic nitrogen, and phosphorus, and unmonitored micronutrient to the Coast Fork Willamette River. Observed inorganic nitrogen concentrations below the STP are on the order of 100 μg/l and greater. These concentrations exceed reported values for limiting cellular or community nutrient requirements.

Nitrogen limitation of periphyton has been reported by several studies — Grimm and Fisher (1986), Crumpton and Isenhart (1987). Marcus (1979) observed increased production related to nitrogen sources and noted that under high ammonium loading benthic algae can be expected to incorporate nitrogen almost exclusively from ammonium until the ammonia concentrations are reduced by uptake.

Ammonia in wastewater effluent increased algal production by 203 times in the Skunk River. Marcus M. D. (1979) also noted ammonia release increased periphyton production. Watson (1991, 1991-b) observed high levels of periphyton in Clark Fork at nitrogen levels of 20 μg/l – 30 μg/l. Dodds (1991) studying streams in western Montana noted positive correlations of the periphyton algae C. Glomerata with ammonia from secondary sewage.

In experimental troughs using periphyton communities and water from the McKenzie River (Oregon), relative specific growth rates of periphyton were saturated with less than an additional 10 μg/l dissolved inorganic nitrogen. Additions of 1.25 μg/l Nitrogen in Kraft Mill effluent almost doubled algal specific growth grates above background. Background nitrate was reported by Bothwell to be very low (~10 μg/l). Threshold levels would then be expected to be near 20 μg/l. The low threshold for saturation of cells may indicate why a lack of a dramatic response was noted by Gregory (1993) in nitrogen additions algal growth experiments .

The CGSTP is the predominant source of dissolved ortho-phosphorus in the Coast Fork of the Willamette River. Phosphorus concentrations upstream of the STP and in the major tributary Row River approach levels reported as limiting for a periphyton community in streams but exceed levels likely to limit cellular uptake. Below the CGST, the observed concentration of ortho-phosphorus exceed concentrations reported as saturation periphyton communities.

Phosphorus relationships to periphyton have received the greatest attention in the literature discussing periphyton nutrient limitation. Wong and Clark (1975) in one of the earlier studies noted a direct relationship was observed between the phosphorus content of ambient water and plant tissues with controlling levels near 60 μg/l. Manual-Fowler et al. (1983) concluded their studies supported Wong and Clark that 60 μg/l is sufficient concentration to promote maximum growth of Cladophera.

Horner et al. (1990) conducting research in laboratory streams observed increase in uptake by filamentous algae increased most dramatically as soluble reactive phosphorus (SRP) concentrations increased up to 15 μg/l, and uptake decreased beyond 25 μg/l SRP. The authors noted that this information corroborates that of Horner et al. (1983) who observed that SRP levels of 15–25 μg/l produced nuisance levels of algal biomass in laboratory channels. Seeley (1986) demonstrated rapid biomass accrual in artificial channels near 7 μg/l, to a maximum saturation near 15 μg/l. Stanley et al. (1990) found the response to enrichment was rapid when ambient P concentration was low (10 μg/l), but more moderate when P levels were higher (15–25 μg/l).

Bothwell (1985) notes that it is important to distinguish between influence of biomass and of specific growth rates on primary production. Steady state growth rates appear to saturate at very low levels of phosphorus. However, many workers have found that much higher levels of phosphorus (> 20 μg/l) are required to produce algal bloom problems in streams and rivers. Discrepancies may arise because of species differences, differing physical factors, the influence of algal mat thickness and community nutrient requirements, and the dynamics of nutrient spiraling.

Data reported by Bothwell (1992) on the Thompson River indicate that instream cellular phosphorus requirements are saturated at ambient phosphorus levels of near 3-4 μg/l. Additions of phosphorus as low as 1 μg/l can potentially cause dramatic increase in the productivity of rivers (Bothwell 1992). Although this data was collected at much cooler temperatures, near 10°C, than occur in the Coast Fork during the summer, it would appear that low phosphorus concentrations can saturate growth requirements for periphyton

Bothwell notes that the reported results may not be opposed to those of Horner et al. (1983) who reported limitation at 25 µg/l. Difference may be due to the facts that Horner was working with thicker algal mat densities, different species, and warmer temperatures. There appear to be differences between saturation growth rates and accrual rates, especially for the filamentous forms studied by Welch et al. (1989). Watson (1991) studied diatoms in artificial channels and noted that diatoms are likely to react different than filamentous forms (Cladophera). Lock (1979) noted that water movement increased P uptake except when the phosphorus demand of the mat was presumably satisfied at high phosphorus concentrations 105 µg/l.

Biggs (1990) studying diatom dominated streams found no difference between relative specific growth rates of diatoms above an STP (6–10 µg/l DRP and below an STP (150 µg/l DRP). However, higher concentrations of chlorophyll a accrued downstream as opposed to upstream on all eight ambient sampling stations. In natural streams with low concentrations of 1–3 µg/l phosphorus, increasing nutrients can increase accumulation rates by an order of magnitude and change species diversity (Perrin et al. 1987, Stockner and Shortreed 1978). These studies provide in-situ support for Bothwell's contention that individual cells may be saturated at low levels, but algal mat accumulations will react differently, with increased biomass accrual at higher nutrient levels.

Differences between cellular and mat saturation levels appear due in part to diffusion gradients. For a single cell, the diffusion gradient is established by cellular uptake rates. In a periphyton mat, the availability of nutrients to algal cells may be established by the diffusion of nutrients through the periphyton mat to the individual cells. Increased turbulence, often associated with increased velocity, can increase the availability of nutrients throughout the water collum to the benthic periphyton.

A focus on the macro-nutrients of phosphorus and nitrogen is an over simplification of the eutrophication effects of sewage in rivers. The introduction of organic nutrients, such as from sewage, can directly impact all type of periphyton. Steinman and McIntire (1990) observed that directly below a point source bacterial numbers including sewage "fungus" (sphaerotilus natans) increases but declined further downstream as organic matter is consumed. Protozoans populations increase which feed on the bacteria. Algal populations, especially those of Cladophera, increase as oxygen levels build up and inorganic nutrients are released from the remineralized organic matter. The introduction of organic waste usually results in an increase in heterotrophic (non-photosynthetic) biomass. Chapman and Simmons (1989) Traaen R.S. (1978) note that at high volume loadings of sewage effluent factors other than just phosphorus such as nitrogen, organic matter, and micro-nutrient change the water quality sufficiently to alter the original biota.

Effluent from sewage treatment plants increases biomass of photosynthetic algae in receiving streams and the effect is greatest at times of extended low flow. Wheuramm and Eichenberger (1975) demonstrated that benthic communities in experimental channels responded to sewage additions as low as 1:2000 vol/vol.) Temperatures observed during this study were near 10°C, cooler than often observed in the Coast Fork near 25C, and background phosphorus was usually low but as high as 10 µg/l OP, similar to background Coast Fork conditions. Benthic communities were quite sensitive to even small effluent loads. A volume of 0.5 percent effluent increased productivity by 4-fold. The production promoting effect of treated sewage may well explain the many observations in nature of "eutrophication" of rivers. Even small or unmeasurable increased in nutrients from sewage may lead to increased eutrophication of rivers.

Reduction of either nitrogen or phosphorus concentrations may influence periphyton growth and production in the Coast Fork of the Willamette River. Available information suggest that inorganic nitrogen is in lowest proportion of the macronutrients in the Coast Fork below the CGSTP. Upstream of the STP and in the major tributary Row River, nutrient ratios indicate nutrient balance or that phosphorus is in limiting proportion.

The nitrogen to phosphorus (N/P) ratio is often used to determine which nutrient is in limiting proportion for algal growth requirements. Bothwell (1992) reports that the response of periphyton to the addition of a single nutrient is frequently not the same as when two or more nutrients are added. Additions of nitrogen and phosphorus together may have greater effect than either added alone.

Krewer and Holm (1982) found that N/P ratios were important in understanding nutrient-periphyton relationships. Krewer and Holm found that good relationship between periphyton production and phosphorus were observed when N/P ratio indicates P limitation. Stockner and Reed (1978) reported N/P ratio less than 7 are nitrogen limited and at 10–20 indeterminate as to limiting proportions. Stockner and Reed (1978) further report that the N/P ratio will influence assemblages; changing may N/P ratio lead to change in species domination. Power (1991) noted an increase in the relative abundance of nitrogen fixing blue green algal such as *Nostoc* spp. in a nitrogen limited stream.

Fairchild et al. (1985) found that macronutrients may jointly limit overall growth and that the form of growth limitation differs by species within the periphyton community. The overall community response to nutrient change may be dependent upon a small number of species able to best respond to the limiting nutrient levels. Similarly, Rosemarin (1983) concluded that growth rates and saturation levels are different for different species of algae.

Because periphyton can respond to low levels of effluent, and low concentrations of nutrients are required to saturate cellular growth requirements, it is difficult to define effluent limits that will limit periphyton growth. However, areal biomass may be limited by phosphorus levels 2 to 3 orders of magnitude greater than required to limit cellular requirements. Reduction in nutrient concentration and effluent loads can reduce the extent downstream that periphyton growth is elevated. The distance below a source that periphyton are influenced by nutrient discharges depends on nutrient uptake rates and nutrient cycling within the periphyton community.

Nutrient cycling, or spiraling, refers to the coupled process of nutrients cycling between different forms and transportation downstream. Transfer of nutrients from the water column to the periphyton mat initiates the process of nutrient cycling. Nutrient cycling in streams involves release of soluble nutrients via cell lysis, leaching, or consumption-excretion by herbivorous. Nutrient cycling can influence the availability of nutrients to the periphyton community. Keup (1967) observed that phosphorus in a stream is attenuated out of flowing water mass, and that biota is the principle agent. After removal, phosphorus is stored in the biota and removed by bed load, or sheared periphyton resulting from high velocity and scour. Assimilation rates are rapid.

Sebetich et al. (1984) noted that relative removal of phosphorus increased with increased phosphorus concentration. Gregory (1978) noted that nutrient processing efficiency between streams will vary. Horner et al. (1990) observed that relative uptake rates increase with increasing velocity (up to 60 cm/s) and decreased with biomass.

Two mechanism of nutrient uptake were suggested by Mulholland et al. (1991-b); biologically controlled at low ortho-phosphorus concentrations that appeared to become saturated at concentration near 5 μg/l and a physical/chemical adsorption at high PO_4 that continued to increase with increasing concentration. Mulholland suggest that ambient removal rates will be overestimated from steady PO_4 releases from a source unless PO_4 concentrations are small. Currently observed removal rates in the Coast Fork below the CGSTP may be greater than removal rates encountered under reduced nutrient loads.

Although measurements of ambient levels may imply limitation by one or more nutrients, such information does not reveal tight nutrient cycling that can occur within periphyton-substratum complexes, Pringle C. M. (1978). Ambient nutrient levels alone are not a reliable indicator of the trophic status of periphyton populations which respond more to the total load upstream (Elwood et al. 1983). Total biomass developed over a stream reach may be related to the total mass of a limiting nutrient originating upstream than observed concentration (Welch et al. 1988). Elevated biomass will continue downstream until depletion of the nutrient occurs. Nutrient uptake could than allow periphyton to depress ambient levels to the extent that secondary nutrient limitation occurs.

When ambient nutrient supply decreases, recycling increases (Mulholland et al. 1991). The influence of lowered nutrient concentrations of periphyton may depend on the amount of invertebrate grazing and changes in recycling rates. In experimental channels, Mulholland observed the reduced nutrients did not reduce periphyton biomass without invertebrate grazing. Peterson et al. (1985) studying a phosphorus poor stream (1-μg/l) found additions of 10 μg/l increased periphyton growth for more than 10 kilometers downstream. In Peterson's (1985) study, there was also an increase in the biomass of invertebrates implying increased grazing.

There is no information describing the influence of grazing pressure on periphyton in the Coast Fork. The response of the periphyton community as nutrients are reduced below the currently excessive levels may be significantly dependent on grazing interactions.

Invertebrate grazing pressure can exert a controlling effect on periphyton assemblages. Several studies have shown that the taxonomic structure of periphyton communities can be altered by grazing (Powers 1990). Grazing may influence not only standing crop, but uptake and recycle rates and species distribution within the benthic algal mat. Algal biomass be controlled by grazing Jackoby (1987), Welch et al. (1988). Grazing generally resulted in lower periphyton biomass, a simplified algal community, lower rates of carbon production, and decreased nutrient recycling. Mulholland et al. (1991) observed that in heavily grazed streams nutrient cycling appeared constrained. Lamberti et al. (1987) observed that in experimental channels, grazing reduced periphyton biomass and chlorophyll, but increased the rate of primary production. De Angelis et al. (1990) observed that a grazing resulted lowered biomass as compared to an ungrazed system.

Gregory (1993) applied a stream ecosystem model developed by McIntire (1973) which evaluates the interactions of several variables including nutrients, grazing, and hydraulics on algae. The model provides a theoretical framework for evaluating ecological interactions, but cannot at the current stage of development or calibration be used as a predictive tool.

The importance of grazers on benthic communities is reflected in the work by Gregory (1993) in the Willamette River (Oregon) as a simulated 10-fold reduction of biomass by the presence of grazers up to nutrient concentrations of approximately 125 μg/l Nitrogen. Consumption by herbivores sharply reduced predicted benthic metabolic rates. At nitrogen concentrations greater than 125 μg/l, the predicted biomass and production was not as constrained by grazing. This theoretical exercise suggest that at moderately high nutrient concentrations grazing can constrain production. At higher trophic levels supported by high nutrient concentrations, such as observed below the CGSTP, biomass accumulation may overwhelm the effect of grazing and accumulate greater biomass and production.

DeNicola and McIntire (1991) observed that light and grazing effects could be related. At high irradiance in experimental streams, parts of the algae assemblages remained ungrazed. Sheltered substrate algae were more heavily grazed. Similar interactions are postulated for Oregon coastal streams because the dominate herbivore (Juga) snail distribution correspond to irradiance.

Differences in shade may influence the amount of periphyton biomass and production in the Coast Fork. Higher levels of shading have been observed at the upstream control sites (20–40%) as compared to sites in the lower river (0–10%).

Light may limit biomass accrual and influence the rate of invertebrate grazing (McIntyre, 1966; Hill and Harvey, 1992; Manual-Fauler et al. 1983; Lyford and Gregory, 1975). Wynne and Rhee (1988) conclude that the light regime not only alters the optimum N/P ratio, but has profound influence on phosphorus uptake rates and alkaline phosphatase activity of phosphorus limited cells. The light regime may influence species competition for limiting nutrients.

McIntyre D.C. (1973) suggests the relatively low biomass of periphyton observed in small western Oregon streams is the result of grazing activities, high silt loads during fall and winter months, and canopy shading (Light). Although modified by herbivores rates of primary productivity, and algal biomass accumulation generally increased with higher irradiance (Lamberti et al. 1989).

Stream flow in the Coast Fork near Cottage Grove is controlled by upstream impoundments on both the mainstem and major tributary Row River. Eutrophication is often greater below reservoirs because of flow regulations either limiting the frequency and intensity of spates which would remove periphyton biomass accumulations through physical shear, and often because of nutrient increase as well resulting from in lake processes.

Streamflow can have significant effect on periphyton by controlling biomass through shear, and by influencing nutrient supply through turbulent transfer (Dufford et al. 1988; Grimm and Fisher, 1986; Horner and Welch, 1981; and Welch, 1988). McIntyre (1973) indicates that high silt loads accompanying high flows help regulate periphyton in western Oregon streams. Periphyton communities respond relatively quickly following high flow events (Humphry and Stevenson, 1992; and Steinman and McIntire, 1990). The rate at which periphyton grow and accumulate after following a high flow event may be dependent upon nutrient supply. Controlled and more stable flows would increase the time available for periphyton communities to grow and develop because of the lack of episodic shear events.

EVALUATION OF ALTERNATIVE WLAs, NUTRIENT, PRIMARY PRODUCTION, AND pH

Several alternative WLA strategies have been evaluated. Although many factors, including invertebrate grazing, sunlight, temperature, streamflow, and nutrients combine to influence the growth of periphyton control, the Department does not have direct regulator control on all of these factors. The Department does have regulatory authority over a significant portion of the available nutrients, and to some degree over available flows. The TMDL therefore focuses on the ability to limit the impact of periphyton production on water quality standard violation through nutrient control.

A simple mass balance of the observed ambient and source flow and quality data provides a method for determining relative source inputs and downstream nutrient losses. Because of the low level of nutrients needed to saturate growth requirements for algae cells and even extensive mats formation, it may not be possible to define achievable WLAs to be below limiting levels. However, the distance below a source influenced by a waste discharge may provide a tool for establishing a nutrient TMDL to limit periphyton production.

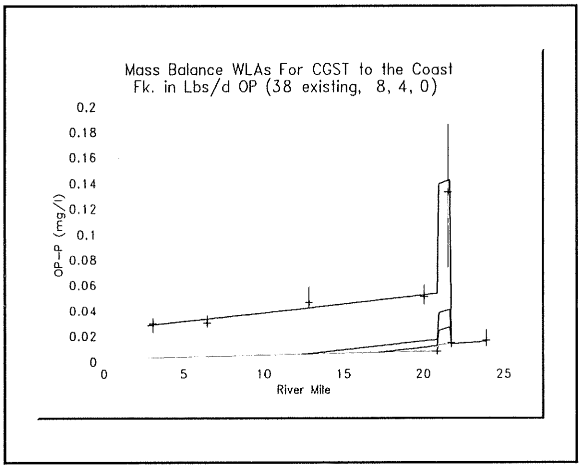


Figure A-17. Mass Balance PO_4

Violations of the pH standard are observed below river mile 13. It is uncertain if pH violations occur upstream of this location. River mile 13 provides a reference location where uptake should remove ambient nutrients to levels limiting periphyton production rates (Figure A-17).

Mass balance estimates of where nutrient concentrations under alternative WLA strategies was evaluated using data collected during the low flow surveys. Nutrient reduction was estimated as a zero order loss rate. Uptake is assumed to remain constant as long as the available nutrients exceed threshold levels for the periphyton community biomass. The esti-

Table A-5. Treshold Distance

RM WHERE REFERENCE PHOSPHORUS CONCENTRATION (mg/L) IS ACHIEVED UNDER DIFFERING MASS LOADS USING A SIMPLE MASS BALANCE.			
WLA	**0.010**	**0.005**	**0.0**
8.1	16.0	12.2	8.5
4.0	19.6	15.9	12.2
0.8	20.8	18.9	15.1

mate of nutrient concentrations under no WLA assumes that the loss rates observed upstream of the CGSTP would continue throughout the mainstem of the Coast Fork. This assumption may underestimate the nutrient uptake that would occur if periphyton biomass and uptake rates increase in the broader, more open portions of the river below the confluence with the Row River and below the CGSTP.

The distance below a source that elevated periphyton may occur is indicated by the distance required to achieve a phosphorus limited threshold. Removing phosphorus at the STP would result in a shift in the N/P ratio toward phosphorus limitation. A ambient concentration threshold of 0.0 mg/L provides an indication of phosphorus limitation; 0.005 mg/L is the Department's current lower reporting limit; and 0.010 mg/L provides a measure of community uptake limitation (Table A-5).

Assuming that uptake rates remain constant under a WLA of 8 lbs/day, it is apparent that increased response from periphyton can be expected for several miles below the CGSTP discharge. The assumption of similar uptake rates may be valid as long as nutrient concentrations are in excess of limiting concentration. Under a WLA of 0.80 lbs/day, the phosphorus concentration would be similar to estimates of background conditions about 1 mile below the confluence of the Row River. At current discharge levels of 1.5 cfs, a WLA of 0.80 lbs/day is equivalent to an effluent concentration of 100 μg/l (0.1 mg/L), which is much less than the existing mass loads.

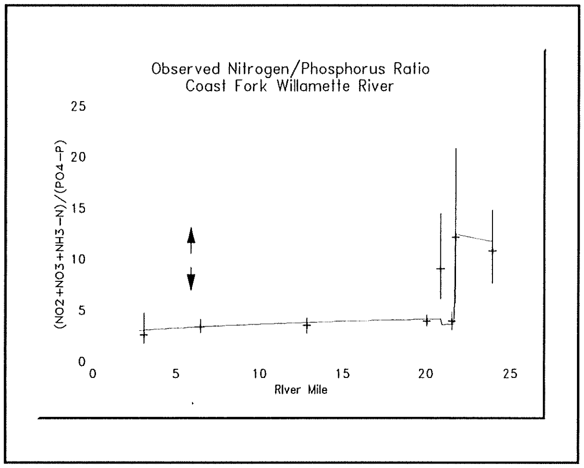


Figure A-18. N/P Ratio

The current nitrogen balance indicates that phosphorus acts as a limiting nutrient in the Row River, and is in limiting proportion in the Coast Fork upstream of the CGSTP. Concentrations upstream of the CGSTP are near or greater than concentrations cited in the literature that appear to limit periphyton biomass. Below the CGSTP (RM 21.5), the nutrient balance is dominated by the nutrient characteristics of the effluent. Nitrogen is in limiting proportions below the STP (Figure A-18).

Although nitrogen is in limiting proportions, the available nitrogen is above concentrations that have been documented as limiting periphyton biomass production. Estimates of background concentrations without an STP discharged assumed that nitrogen uptake would be similar to the levels that occur upstream of the STP. Without the STP discharge, the estimated background concentrations remained high enough to support periphyton growth throughout the mainstem Coast Fork. Estimated phosphorus concentrations and nutrient ratios indicated phosphorus limitation under background conditions (Figure A-19).

At current discharge volumes, the evaluated WLAs of 40, 24, and 8.1 lbs/day of inorganic nitrogen in Table A-6 are equivalent to effluent

Table A-6. Treshold Distance — Nitrogen

RM AT WHICH TARGET CRITERIA ARE ACHIEVED FOR VARIOUS NITROGEN WLAs			
WLA	**0.100**	**0.020**	**0.00**
40	15.7	4.7	—
24	18.2	7.2	4.4
8.1	20.7	9.7	7.0

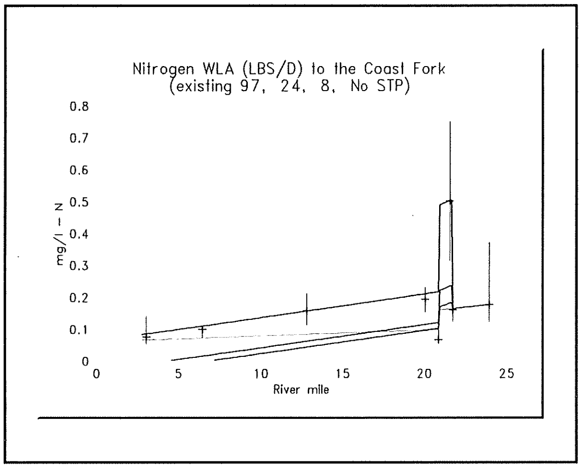


Figure A-19. Nitrogen Mass Balance

concentrations of 5, 3, and 1 mg/L, respectively. The simple mass balance estimates indicate greater distances are required to achieve nitrogen control thresholds as compared to similar thresholds presented in Table A-5 for phosphorus.

Because of the relatively high (100 μg/l) background inorganic nitrogen concentration and the nutrient ratios indicating phosphorus limitation upstream of the CGSTP and in the Row River, a periphyton control strategy based on unilaterally on nitrogen removal alone may not be as effective as a unilateral phosphorus control strategy. Nitrogen limitation would not likely occur until the benthic uptake removed background concentrations and WLAs to lower levels that were estimated for background conditions. Controlling both micronutrient nutrients would provide the greatest assurance of limiting the impact of periphyton production on water quality standards violations. Nitrogen limitation due to effluent limitation may result in an increase in nitrogen fixing algae which would add additional nitrogen to the system.

A simple mass balance does not provide information on the distribution and range of expected values. The expected range of ortho-phosphorus concentration can be estimated using monte-carlo methods. Figure A-20 illustrates the estimated distribution of ambient phosphorus concentration below the CGSTP under current mass loads (open boxes) and under phosphorus effluent limits of 4 pounds/day, and with no WLAs (superimposed lines).

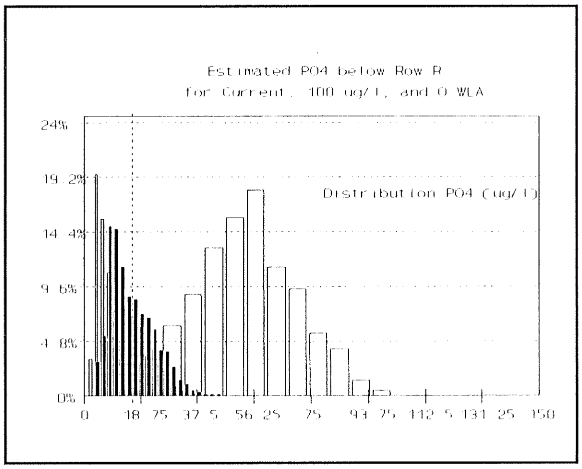


Figure A-20. Estimated PO_4

The variation in daily averaged summer low flow discharge was obtained from USGS gaging stations for the low flow period. Stream flow is typically near 150 cfs, with approximately 100 cfs from the Row and 50 cfs from the Coast, Fork Willamette River, but it is occasional much higher. As streamflow increases, the relative contribution from the Row River increases.

The distribution of ortho-phosphorus was determined from DEQ data collected during the low flow period. Variation in flow and effluent quality from the CGSTP was obtained from DEQ monitoring and from the wetlands feasibility study. For estimating distribution under alternative wasteload allocation, it was assumed that the standard error remained constant as effluent phosphorus decreased. The mass balance estimates do not account for periphyton uptake of phosphorus and thereby provide a measure of the total phosphorus available for algal uptake.

Wasteload allocations of 8 lbs/day result in estimated average concentrations near the upper range reported for limiting periphyton communities. Estimated instream concentrations below the Row River occasionally exceed in river concentration of 20 μg/l, levels reported in the literature that would limit periphyhton community production (Table A-7).

The Department's minimum reporting limit for ortho-phosphorus is 5 μg/l, with an accuracy (95% CI) of approximately +/- 1.5 μg/l. A WLA of 4 lbs/day would result in a measurable increase in instream phosphorus near 5 μg/l. The typical range of concentration below the discharge would be in the range where literature values indicate slight response due to community limitation by phosphorus.

A phosphorus WLA of 0.8 lbs/day, equivalent to an effluent limit of 100 μg/l, would be indistinguishable as field measures from the anticipated conditions with zero wasteload allocation. The range of anticipated ortho-phosphorus concentrations is likely greater than would limit individual cells, but would appear to be within the range that would limit development of areal biomass of periphyton. A WLA of 0.8 lbs/day increases the anticipated distribution or ortho-phosphorus by less than 1 μg/l above a no-discharge option.

Although an increase associated with a WLA of 0.8 lbs/day, ortho-phosphorus may be difficult to measure. There is reason to believe that the periphyton will respond to the discharge. Periphyton have been reported to dramatically increase areal biomass in response to low concentration, less than 1 μg/l of ortho-phosphorus (Bothwell, 1985) and to very dilute discharge of municipal effluent (Traaen, 1978). The discharge could greatly increase available nitrogen. Periphyton may respond differently to a supply of multiple nutrients than would be anticipated from evaluation of a single nutrient (Bothwell, 1992).

Table A-7. Distribution PO_4

MASS BALANCE ESTIMATES OF DISS. ORTHO PO_4-P (μg/l) IN THE COAST FORK BELOW THE ROW RIVER				
WLA	**85%**	**50%**	**15%**	**Mean**
Current	71	53	36	54
10.0 lbs	32	21.3	14	22.3
8.0 lbs	29.4	18.6	12.3	20.4
4.0 lbs	24.0	14.1	8.5	15.8
0.8 lbs	20.4	10.3	5.2	12.2
0.0 lbs	19.5	9.5	4.5	11.4

The estimates, of the distance downstream below the CGSTP required for nutrient uptake to reduce ambient concentrations to limiting levels, may be underestimated by the simple mass balance procedures due to nutrient cycling interactions. However, the observed uptake rates are consistent with uptake rates estimated through stoichiometry as suggested by Di Torro (1981) and expanded upon by Thomann and Mueller (1987). The distance downstream that a source of nutrients will support elevated periphyton is dependent on several factors. Welch et al. (1988) has formalized a hypothesis that relates a critical distance downstream of a source to production and uptake rates, nutrient supply, and a nutrient threshold.

Table A-8. Threshold Distance

RIVER MILE AT WHICH A 5 μg/l THRESHOLD IS REACHED				
Qcfs	WLA in Pounds per Day			
	16	8	4	0.8
125	3.5	11.1	15.0	18.0
150	4.8	11.7	15.1	17.9
200	6.5	12.4	15.3	17.7

Di Torro (1981) has developed an analytical formula that relates the observed range of diurnal dissolved oxygen (Δ_{DO}) and the aeration coefficient (K_a) to a measure of benthic production (P_a):

$$p_a = \frac{0.5K_a[1-e^{-K_a}]}{[1-e^{(-0.5K_a)}]^2}\Delta_{DO}$$

From this, Thomann and Mueller (1987) show that nutrient uptake rates (S_{PO_4}) can be estimated using stoichiometry from the estimates of benthic production:

$$S_{PO_4} = \frac{\alpha_{pc}\, p_a}{2.67}$$

Where α_{pc} is the phosphorus to carbon ratio (0.01–0.02) and 2.67 is the DO to carbon production ratio. Units are in mg/L-day, and critical travel times (t_p) can be estimated as:

$$t_p = \frac{PO_{4_0} - PO_{4_c}}{S_{PO_4}}$$

Knowing stream velocity, the distance required for uptake to reduce instream nutrient levels to a selected critical concentration may then be estimated using measures of the diurnal range of dissolved oxygen.

The steady state simplification used does not provide a means to assess seasonal differences in uptake, successional changes in algae that may influence uptake rates, or variable uptake rates dependent on nutrient supply. However, the method does provide a means to assess conditions observed during the relatively constant summer flow and load regimes observed in the Coast Fork.

The continuous diurnal measures were used to estimate production rates as modified by Chapra and Di Torro (1991) for streams where K_a are less than 5/day. The uptake rates are sensitive to the indirect measure of aeration. The estimated uptake rates using this method were equal to those calculated from the mass balance. Assuming that production would remain similar as long as nutrients were in abundance, the distance required for uptake to reduce nutrients to limiting levels was estimated for alternative WLAs and stream flow conditions. Typical flows are near 150 cfs and minimum flows are near 125 cfs, indicating the controlling influence of regulation by reservoirs. Increased flow decreases instream concentration through dilution (Table A-8).

Without the STP discharge, the phosphorus concentrations would be above suggested threshold ambient phosphorus concentration of near 10 μg/l. Even a slight increase in WLAs would act to increase the distance that the stream remains above threshold levels. The uptake rates may be reduced as nutrient concentrations are reduced and approach threshold levels (Table A-9).

Nutrient spiraling, the process of cycling nutrients through the periphyton community, provide nutrients that may not be directly measured in the water column. The estimate of removal using mass balance and uptake based on diurnal production neglect nutrient spiraling. As a result, the distance that a nutrient source will influence periphyton growth rates is likely underestimated.

Welch et al. (1989) formalized a hypothesis that the critical distance for which periphyton biomass could potentially be greater than a define threshold should be the ratio of the mass of available phosphorus divided by expected

Table A-9. Treshold Distance

DISTANCE TO THRESHOLD UNDER 0, AND 0.8 LBS/DAY WLAs @ 125 cfs		
Pc	**0 WLA**	**0.8 lbs/day**
10	20.8	20.8
5	18.7	18.0
0	15.5	14.8

demand. The mass of available phosphorus is dependent on the mass originating at an upstream condition and the recycle rate within the periphyton mat:

$$D_c = \frac{Qr(PO_{4_i} - PO_{4_c})}{\dfrac{P}{Chl_a\text{-}Day} B_n TW10^3 \dfrac{m}{km}}$$

Where:

D_c = The critical distance in Kilometers (*0.625 in miles).

PO_{4_i} = Ortho-phosphorus mg/m^3 inflow, estimated from simple mass balance, with 15 and 7 μg/l in the Coast Fork and Row Rivers, respectively.

PO_{4_c} = Critical concentration supporting the threshold biomass levels, assumed either as 1 or 4 μg/l.

Q = Flow rate in m^3/day (4.25).

r = Recycle rate (1.5) from Newbold et al. (1982).

P/Chl$_a$-d = Nutrient uptake rate per day normalized to chlorophyll a measure of biomass production (0.2) from Horner et al. (1983), Seeley (1986). These authors report ranges of 0.1 to 0.24 P/Chl$_a$ for *maugeotia*. At the B$_n$ of 100 and a depth of 0.52 meters, uptake would be 38 μg/l-D. Estimates of uptake using Di Torro and data from the diurnal curves at Cresswell ranged from 21 to 36 μg/l-d. The lower rates appeared to be more consistent with the uptake estimated from the simplified mass balance (0.11p/Chl$_a$-d), and would be similar to the lower ranges reported by Seeley.

T = Trophic consumer retention factor 1.2, a 20% retention.

W = Stream width in meeters.

B$_n$ = Biomass nuisance reference level as 100 mg chl$_a$/m^3, based on limited measure of existing periphyton accumulation as chlorophyll a in the Coast Fork. Welch uses 150 mg/m^3.

Results from application of the equation show that the length of the stream where B$_n$ is exceeded due to the CGSTP is linearly proportional to the mass load of limiting nutrient, assumed to be phosphorus. The estimated length where biomass may exceed threshold levels in the Coast Fork is calculated by multiplying the ratios (miles/pound) and adding the influence of background water (0 WLA). Each pound of phosphorus may extend the zone of influence downstream by ≈1.25 miles. Even without the CGSTP discharge, the available nutrients may allow periphyton to attain relatively elevated levels of biomass as the stream enters the more open sections below confluence with the Row River (Table A-10).

The selection of a critical concentration, above which a nuisance biomass level is supported by ambient nutrient concentrations, is uncertain. The selection of 1 to 4 μg/l is consistent with values reported by Welch et al. (1989), Bothwell (1989), and others and is consistent with the existing theory that relatively low threshold biomass (~100 mg/Chl$_a$/M^3) can be attained at relatively low (~1-4 μg/l) ortho-phosphorus concentration. A threshold concentration of 5 μg/l was used and provides a reference for

Table A-10. Biomass Increase

CALCULATION OF STREAM MILES EXCEEDING B_n PER POUND OF AVAILABLE PHOSPHORUS		
PO_{4_c} (μg/l)	Miles/ Pound	0 WLA
At Uptake Rate 0.11P/Chl_a-day		
1	1.244	8.71
4	1.244	5.67
5	1.243	4.66
At Uptake Rate 0.20P/Chl_a-day		
1	0.684	4.79
4	0.684	3.12
5	0.684	2.56

other uptake estimates and is the lower reporting limit for ortho-phosphorus by DEQ.

Several authors including, Horner et al. (1983), Seeley (1986), and Bothwell (1985) suggest that some control on maximum biomass occurs at higher nutrient levels. Selecting a higher threshold ~ 10 μg/l, for instance, would greatly reduce D_c. This equation does not include the potentially dominant influence of grazing on periphyton biomass. Welch et al. (1989) suggest that predictions will generally exceed actual periphyton accumulation due to the influence of invertebrate grazing.

Inherent in all these uptake models is the assumption of similar benthic conditions along the course of the stream. Stream morphology is not as consistent as implied, and uptake rate may reflect the influence of variable stream morphology on benthic metabolism and biomass accrual. For example, deeper pools may develop different accumulations of periphyton than do riffles or glides. However, these efforts provide a method for discussing the current theories on periphyton accumulation as related to nutrient control.

The uptake rate of 0.11 mg/L-P/Chl_a-Day appears consistent with observed conditions in the Coast Fork. A WLA of 0.8 lbs/day could result in threshold biomass similar to observed values extending nearly 1 mile further downstream from the Row River than the 4.5 to 9 miles that may occur due to upstream nutrient loads. A WLA of 8 lbs/day could result in threshold biomass similar to observed values extending 10 miles further downstream than supported by background concentrations (Table A-11).

BIOMASS ACCRUAL/GROWTH KINETICS

The rate at which biomass accumulates in a stream may depend in part on the available nutrient concentration. The concentrations of

Table A-11. Threshold D_c

RIVER MILE TO REDUCED BIOMASS AT A 5 μg/l THRESHOLD BY WLA @ 0.11P/Chl_a-day	
WLA	RM
0.0	**16.2**
0.8	**15.1**
4.0	11.1
8.0	06.1

nutrients required to saturate periphyton in streams may be significantly greater than that observed in laboratory experiments (Bothwell 1989). Bothwell provides a growth curve that has multiple phases. These phases include an initial cellular uptake phase where the growth rate is limited by cellular uptake. This phase is similar to growth rates estimated using a 0.5 μg/l half saturation coefficient using Michaleis-Menton kinetics. The second phase is less dramatic, where the growth rate of periphyton is limited by diffusion of nutrients within the periphyton mat. The third phase is where the growth measurements of the saturated mat are lowered and nutrient are abundant enough to maintain diffusion gradients into the benthic mat.

Bothwell (1989) noted that filamentous forms of periphyton have higher extracellular nutrient requirements than diatoms. He suggests that the inflection point noted by Horner and Welch (1981) at 25 μg/l may be the inflection point between cellular uptake and mat diffusion for the filamentous algae studied by Horner.

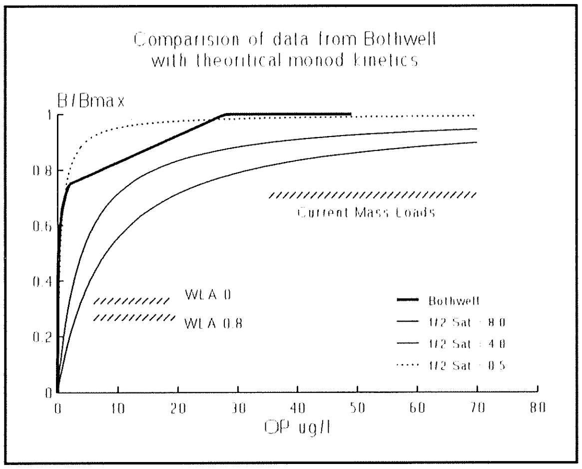


Figure A-21. Biomass Accrual

Figure A-21 illustrates the curves developed by Bothwell (1989) and Michaelis-Menton growth curves with one-half saturation coefficients of 8, as suggested by Seeley (1986), 4 and 0.5 μg/l. Superimposed on this figure is the current and anticipated interquartile range of ambient orthophoshorus concentrations below the Row River under a WLA of 0.8 lbs/d concentrations of orthophosphorus in the Coast Fork below the Row River. This figure reflects the conventional wisdom that threshold levels for periphyton limitation are near 20 μg/l, and significant (80% of maximum) limitation may not occur until levels fall to below 10 μg/l. A WLA of 0.8 lbs/day will result in maximum ortho-phosphorus concentrations within levels reported as limited by diffusion into the periphyton mat. A WLA of 8 lbs/day (not illustrated, Table A-9) will result in maximum ortho-phosphorus concentrations near 12–30 μg/l that are at the upper end range reported for limitation by diffusion into the mat as reported by Bothwell (1989) and suggested by Welch et al. (1989).

A simple procedure proposed by Horner et al. (1983) and discussed by Welch et al. (1989) provides a steady state kinetic predication of the potential accrual of periphyton biomass of periphyton based on the physical and chemical characteristics of the river and their influence on algae growth rates and accumulation (Welch et al. 1989). The model does not include invertebrate grazing, and may therefore overestimate accrual rates and maximum biomass.

The model was originally calibrated against the growth of filamentous green algae in artificial channels over a range of velocities and phosphorus concentrations (Horner et al. 1983). As presented, the model is:

$$B = \left(\frac{B_{\max} - (K_2 V^0)}{[K_1 \mu L (K_f + K_{fo})]}\right) * [1 - e^{-K_1 \mu L (K_f + K_{fo}) t}]$$

Where:

B = Periphyton biomass.

$B_{\max}$ = Maximum biomass sustained in a mat (560 mg-chl$_a$/m^2) as reported by Horner et al. (1983) for channels, recent communications suggest a value as high as 1000 mg-chl$_a$/m^2.

μ = $^{\mu_{\max} + P}/_{K_s + P}$ is the uptake rate of phosphorus based upon Michaelis-Menton kinetics.

$\mu_{\max}$ = Maximum uptake as described by Eppley, 1972, in Horner et al. (1983) as $\mu_{\max} = 0.22e^{\frac{t}{10}}$.

L = Light limiting factor, for this analysis as 1, indicating no light limitation. No light limitation is supported by work of Jasper and Bothwell (1986) who showed a wide range of light available for periphyton and the relatively open nature of the Coast Fork. Similarly, at least some preliminary research indicates that periphyton are adaptable to high light intensities (Gregory, 1992).

K_1 = An empirical constant of 1.2 when SRP < 13 μg/l (25 μg/l inflow), or 0.022P + 1.592 when SRP > 13. The constant provides a transitional function and some discrepancy occur between Horner et al. (1983) who uses 15 μg/l of SRP rather than the 13 μg/l reported by Welch et al. (1989).

K_2 = The scour coefficient at 0.3 mg-chl$_a$/m^2.

θ = 0.45.

V = Velocity as estimated from dye studies on the Coast Fork published by USGS at 150 cfs.

K_{fo} = The non-turbulent mass transfer coefficient = 0.0094 cm/s.

K_f = The turbulent mass transfer coefficient $(DV/\pi l)^{0.5}$ with d = 1.5×10^{-5} cm^2/s.

t = The growth period in days. For the Coast Fork, the algal growth period was assumed to be near 90 days of constant low flow periods due to flow regulation from upstream reservoirs. The growth period was undefined in Welch et al. (1989). Horner et al. (1983) used a 12-day period for calibration of the model to algal growth in experimental channels.

For application to the Coast Fork, the B_{max} was divided by the calculated B to provide the percent biomass developed over time (t).

The analysis is based upon Michaelis-Menton Kinetics, and turbulent transfer of nutrients to the periphyton mat. Values of 4 μg/l and 0.5 μg/l were selected as the one-half saturation constant (Figure A-22).

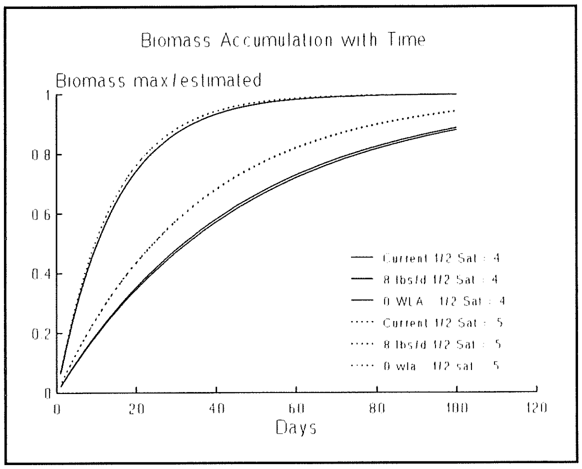


Figure A-22. Biomass Accrual Base

A 4 μg/l constant is less than the recommended 8 μg/l from Welch et al. (1989) as described by Seeley (1986) based upon uptake rates from filamentous algae. The lower value may be more reflective of the algal growth requirements for nonfilamentous algae. The one-half saturation coefficient is likely to be less for saturation of benthic mats of filamentous algae and may be compared to the saturation levels near 20–30 μg/l reported in available literature. A half saturation coefficient of 0.5 μg/l would be consistent with the single cellular rates defined by Bothwell (1988). However, the 0.5 μg/l coefficient would result in greater growth rates than the community limited diffusion defined by Bothwell (1992) when ortho-phosphorus exceeds levels near 1 to 2 μg/l.

The only site specific inputs for the Coast Fork to this theoretical equation are data on temperature, stream velocity, and nutrient concentration. For the applications, the concentrations were assumed based on median values estimated from the distributions of mass balance estimates of instream concentrations under alternative wasteload allocations.

Application of this model show that the biomass accumulation curves are nearly superimposed for WLAs of 0 and 8 lbs/day. The results are sensitive to the assumed half saturation constant under the assumed WLAs of 8 and 0 lbs/day, with lower rates of biomass developed under the higher half saturation coefficients. Under current loads, the model result were not sensitive to half saturation coefficients indicating that nutrient levels were well in excess of algal growth requirements. These results indicate that the rate of biomass development is reasonably expected to be reduced under either a WLA of 8 or 0 lbs/day even with uncertainty about the limiting concentration of phosphorus.

At current phosphorus levels below the STP, the periphyton would be expected to approach maximum biomass in the order of weeks. The biomass accumulation would not be expected to be limited by nutrients since both phosphorus and nitrogen are in excess of nutrient limiting concentrations. Estimates of bioaccumulation rates are not sensitive to estimates of the one-half saturation coefficients since the available nutrients would appear to saturation growth requirements.

The rate at which biomass approaches maximum is reduced as nutrients are reduced to near background, and phosphorus is reduced to limiting proportion and concentrations. The biomass accumulation developed using this equation was always much greater with median concentrations of 20 μg/l (8/lbs/day WLA) as compared to the instream criteria near 10 μg/l. The rate of bioaccumulation would be expected to decrease as uptake removed concentrations downstream in the Coast Fork.

This exercise also indicates that given enough time that even at low concentrations periphyton approaches maximum biomass. Such a conclusion would be consistent with theories proposed by Grimm and Fisher (1986). However, most authors conclude that growth rate and ultimately biomass may be controlled by nutrients in limiting concentrations Welch et al. (1989). At lower rates of biomass, accrual invertebrate grazing may have a relatively greater effect on controlling biomass than at the more rapid rates of development. Substantially higher flows and colder temperatures in the Coast Fork during the fall-spring likely control periphyton accrual more so than nutrient concentration.

The importance of winter storms or reservoir releases scouring and ''resetting'' the accumulation of periphyton is demonstrated by this analysis. The effect of nutrient reduction, assuming everything else is negligible, is to increase the time required for biomass to accumulate. Maximum biomass may not be attained during the growth period between. During the winter, high flows and colder temperatures are presumed to limit accumulation and production. Scour events which reset the growth of the periphyton mat may control the maximum standing crop of periphyton biomass attained.

INFLUENCE OF PERIPHYTON PRODUCTIVITY ON pH

The observed pH standards violations in the Coast Fork appear to the result of photosynthesis consumption of carbon: $106CO_2 + 16NO_3 + HPO_4 + 122\,H_2O + 18H \Leftrightarrow \text{Algae} + 138O_2$. Algal growth produces DO and increases pH through decreasing inorganic carbon concentration. The consumption of CO_2 has no influence on alkalinity. Since alkalinity is associated with a charge balance, the consumption of carbon results in a shift of equilibrium, increasing the pH. However, it is not strictly true that photosynthesis does not change alkalinity, the assimilation of other charged ions that influence alkalinity.

The amount of free CO_2 in water is dependent upon the alkalinity, pH, and temperature. Total Alkalinity is usually reported as mg/L of $CaCO_3$. There are 50 milliequivalents (meq) in a mg/L of $CaCO_3$. Total alkalinity as $CaCO_3$ divided by 50 converts to meq of alkalinity. Carbonated alkalinity can then be determined as:

$$c_{t_{CO_3}} = \frac{Alkalinity - \frac{K_w}{[H]} + [H]}{(\alpha_1 + 2\alpha_2)}$$

The free CO_2 ($[H_2CO_3]^*$) can then be determined as:

$$[H_2CO_3]^* = \alpha_0 C_{t_{CO_3}}$$

Where:

$$\alpha_0 = \frac{[H^+]^2}{[H^+]^2 + [H^+]K_{a1} + K_{a1}K_{a2}}$$

and

$$\alpha_1 = \frac{[H^+]K_{a1}}{[H^+]^2 + [H^+]K_{a1} + K_{a1}K_{a2}}$$

and

$$\alpha_2 = \frac{K_{a1}K_{a2}}{[H^+]^2 + [H^+]K_{a1} + K_{a1}K_{a2}}$$

and C_{TCO_3} is the total inorganic carbon, and Kw is [H]/[OH]. The equilibrium coefficients are dependent upon temperature.

Carbon is replaced by equilibrium with the atmosphere through aeration. By assuming that the uptake of carbon and equilibrium reactions occur at a greater rate than replacement of carbon through aeration, the response of pH to reduced carbon concentration can be illustrated. The Coast Fork Willamette may be characterized as a weakly to moderately buffered stream, with typical alkalinities near 20 mg/L – $CaCO_3$. The buffering capacity of the carbonate system would be anticipated to be fairly weak at pH values near the state standard of 8.5. The pH changes near the standard due to uptake of carbon would be anticipated to be rapid (Figure A-23).

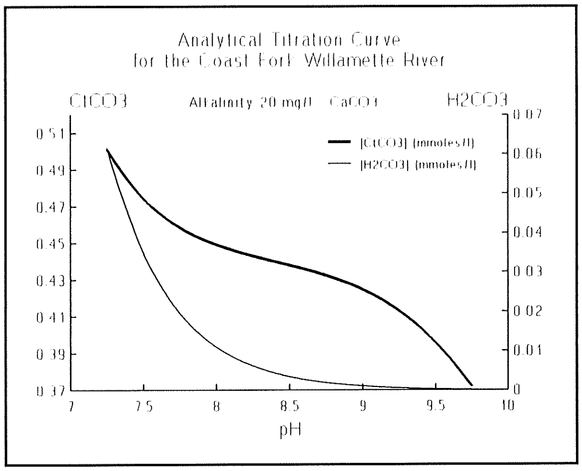


Figure A-23. Analytical Titration Curve

It is not strictly true that photosynthesis does not change alkalinity. Limited alkalinity changes will occur through the uptake of other charge ions, such as phosphorus and ammonia nitrogen. By making this assumption, the impact of algal production on pH can be determined by a mass balance of the carbonate species. Assuming that the consumption of carbon is consistent along the river bottom, the change in total carbonate species can be estimated as the amount of free CO_2 plus the amount brought in by aeration, minus the amount of carbon consumed over time:

$$(C_{TCO_{3_0}} - C_{TCO_{3_t}}) - ([(C_{CO_2aq_0} - C_{CO_2aq_t})e^{-K_{a_{CO_2}}t} + [1-e^{-K_{a_{CO_2}}t}][\frac{P_a}{K_{a_{CO_2}}}])]$$

Where:

C_{TCO_3} = Total Carbonate Species (mg/L).
0 = Initial time zero.
t = Time (day).
$K_{a(CO_2)}$ = Inorganic carbon gas transfer rate /day
C_{CO_2aq} = Dissolved CO_2 $[H_2CO_3]$ (mg/L).
Pa = Primary Production/Respiration rate for consumption/production of CO_2 (mg/L–day)

This equation is analogous classical dissolved oxygen balances, with the exception that only the free carbon ($CO_2aq \approx H_2CO_3$) portion of part of the total carbonate concentration is involved in the aeration equilibrium calculations. Neglecting the influence of buffers other than the carbonate system, and assuming that total alkalinity does not change, the pH can then be estimated from the equations listed above. The original equilibrium carbonate concentration is estimated from the observed conditions of pH and total alkalinity occurring in early morning prior to significant photosynthetic activity. The available information on the rate of pH change, benthic production, and aeration rates is inadequate to support calibration and verification of this simple model. However, the general relationships between the stream characteristic and pH can be illustrated and the relative effect of alternative WLA strategies estimated.

From the above equations, it can be shown that decreased gas transfer or increased benthic consumption rates act to increase the rate the CO_{aq} deficit is developed, and therefore increase instream pH. Increased depth of water over the surface of the stream acts to decrease the relative production rates. The distance or time required to exceed water quality standards is dependent on the available inorganic carbon concentration of water entering the section of river, or from other sources such as waste treatment effluent, tributary, or groundwater inflow.

The higher pH values observed in the lower portions (below RM 14) of the Coast Fork may be influenced by changes in photosynthesis or aeration rates. Aeration rates are often extremely variable in a stream, being high in riffles, and low in pools. The ability to achieve the pH standard will be dependent upon the actual aeration rates that occur above where samples are collected. The aeration rates estimated for the lower portions of the Coast Fork River were lower than those estimated for the upper portions of the Coast Fork and Row Rivers.

A simple steady state analysis does not provide information on how effective nutrient control may be downstream of the wastewater as uptake from benthic algae reduce the available nutrient supply. To assess this potential influence, a time dependent solution of the inorganic carbon balance was used. The diurnal pattern of photosynthetic activity was assumed to follow a sinusoidal curve described as:

$$P_t = \cos\frac{2\Pi}{\alpha}t; \; - \frac{\alpha}{4}|t|\frac{\alpha}{4}; \; p = 0$$

(Simonsen and Harremoest, 1978)

where alpha is the diurnal period. These calculations do not simulate algal biomass accrual, rather it provides a method for calculating an assumed diel production pattern. Maximum production was estimated using observed diel production patterns for dissolved oxygen.

The proposed WLAs were determined to result in phosphorus being in limiting proportion below the CGSTP. Production $^{(P}/_{Pmax)}$ limitation due to phosphorus was assumed to occur according to the multistage process described by Bothwell (1985). The production rate was also used to estimate uptake rates of phosphorus. A phosphorus recycle rate was assumed as presented by Newbold et al. (1981). Production limitation was assumed to occur through the micronutrient in limiting proportion. There was no assumption of increased production due to the presence of micronutrient, or other macronutrients.

Bothwell observed that addition of multiple nutrients have a greater stimulatory effect on periphyton than estimated from single nutrients as assumed in this exercise. Similarly, other researchers report that even low dilutions of sewage can stimulate algae. The simulations may therefore underestimate actual production rates that would be encountered.

Phosphorus uptake was assumed to occur in stoichiometric proportion to the production rate. The uptake rates varied throughout the day and were stoichiometrically reduced as nutrient limitation on maximum production occurred. A 16-hour day was the period of assumed production. It was further assumed that no nutrient uptake would occur during the 8-hour period when no photosynthetic production occurred.

Phosphorus uptake is an energy dependent reaction and either photosynthesis or respiration can supply the energy (Healy, 1973). Although light may stimulate phosphorus uptake, some phosphorus uptake may be expected to occur at night. Algae can take up more phosphorus than is required for cellular needs, and store this phosphorus for latter use. Bothwell (1992) and others report that slugs of nutrients released into a river, even for just a few hours, could be sufficient to increase algal growth for many days. Phosphorus starved periphyton have the ability to uptake phosphorus very rapidly (Rhee, 1973). A reduced nutrient uptake during the night will act to pulse a slug of nutrients downstream. This nutrient pulse will be available for uptake and growth by periphyton downstream. The extent of nutrient availability may be greater than estimated using uptake rates applied only during periods of maximum production.

Because of luxury uptake, the phosphorus uptake rates are not likely to be directly stoichiometrically related to production. Phosphorus starved algae can rapidly uptake phosphorus. Periphyton can store phosphorus in excess of cellular requirements. However, the assumptions used on nutrient uptake provide what may be an underestimate of the amount of phosphorus that will be removed through periphyton uptake. The uptake of phosphorus will reduce the nutrients available for periphyton production downstream.

Under conditions of insufficient phosphate (PO_4-P), algae appear to be able to induce enzymes, alkaline phosphatase activity, which allow the algae to utilize dissolved organic phosphorus. The potential use of dissolved organic phosphorus was not considered.

The influence of algal production was determined by solving the inorganic carbon mass balance and then the equilibrium equations for pH up to pH levels near 9.2. Above 9.2, the solution was assumed to be simply greater than 9.2 for convenience, and to simplify the calculations. At pH values $\geq$ 9.2, the available inorganic carbon is significantly curtailed. This calculation contains two assumptions that carbon provides the only significant buffering system, and that removal of carbon by algal uptake does not change alkalinity.

Carbon does not provide the only buffering capacity for water, but likely provides the principle buffering system. Although it is true that uptake of carbon does not change alkalinity, there would be some slight changes to alkalinity due to uptake of other charged ions during photosynthesis, such as phosphate and nitrogen. Alkalinity increases due to photosynthetic uptake of NO_3, or decreases due to respiration to NO_3, or by photosynthetic uptake of ammonia.

The inorganic carbon supplied by aeration does not change alkalinity, but does change pH. The aeration rates for carbon Ka_{CO_2} were estimated using the method described by O'Connor and Dobbins (1958) and data from four cross section profiles measured by DEQ, and velocity estimated from time of travel studies conducted by the USGS (Harris, 1968). The method for determining aeration by O'Connor and Dobbins has widespread use in determining dissolved oxygen balances.

The aeration rates determined for dissolved oxygen would not be the same as for inorganic carbon. There is little literature describing aeration rates for inorganic carbon. Tsivoglou (1967) found a mean ratio for dissolved oxygen and inorganic carbon aeration rates:

$$\frac{K_{a_{CO_2}}}{K_{a_{O_2}}}$$

to be 0.894 with a range of 0.845 to 0.940 and standard deviation of 0.034 in a series of laboratory tests. Simonsen and Harremoest (1977) determined aeration rates in a river using a twin curve method for both carbon and oxygen and found the Ka_{CO_2} averaged 0.57 Ka_{O_2} (Standard 0.29). Simonsen and Harremoest (1977) describe the difficulty of determining aeration for inorganic carbon. At the pH values between 7.4–9.2, only a few percent of the total inorganic carbon is $[CO_2]$ ($[H_2CO_3]^*$) and available for exchange with the air. The calculated total inorganic carbon:

$$\frac{H_2CO_3}{Total\ Inorganic\ Carbon}$$

for locations in the Coast Fork, provide a indication of the existing relationship between uptake and aeration, and pH.

The results of the application of the carbon mass balance equations are extremely sensitive to the estimated, or assumed, ratios between aeration and production rates. The estimated aeration rates in the Coast Fork varied from 1 to 5 per day. The increase in pH due to carbon uptake can be rapid under the low alkalinity (22 mg/L-$CaCO_3$) in the Coast Fork.

The ability to achieve a pH standard will be determined in part by the actual aeration rates that exists. Where relatively low aeration rates ($<=1.5$/day) are encountered for distances of several miles, the pH criteria may be exceeded due to the nutrients supplied regardless of the wastewater treatment plant discharge. However, periphyton uptake would reduce nutrients and subsequent production such that the impacted reach would be limited. Ambient observations on stream velocity and cross section profiles, inorganic carbon concentration, and pH were used as guidance for estimating representative aeration rates.

A WLA of 0.8 lbs/day ortho-phosphorus would result in similar conditions to a no-discharge option. The WLA of 0.8 lbs/day would increase available phosphorus compared to a no-WLA alternative and could slightly increase the areal extent of the pH exceedances compared to no discharge options. Uptake of nutrients would be expected to reduce ambient concentrations and thereby reduce benthic production as compared to existing conditions of excessive nutrient loads. The estimated reduction in maximum production rates would become significant as the available phosphorus approaches the cellular limitation zone as defined by Bothwell of 1 to 2 µg/l.

Under the 0.8 lbs/day WLA, averaged summer low flow phosphorus concentrations below the confluence of the Row River would be near 10 to 11 µg/l. Benthic uptake would be expected to reduce the instream concentrations to levels that would significantly reduce production prior to the historical monitoring locations in the lower river. Under maximum phosphorus concentrations near 20 µg/l below the Row River, there is less certainty that uptake of nutrients will reduce instream concentrations to levels near cellular limitation (Figure A-24).

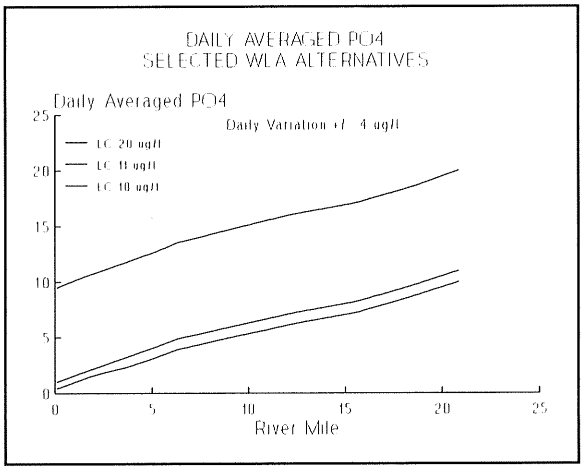


Figure A-24. Daily Average PO_4

A WLA of 4 lbs/day would measurably increase the ortho-phosphorous concentration below the confluence of the Row River by approximately 5 µg/l compared to no discharge options. This increase is on the order as the Department's minimum reporting level for phosphorous and may be undetectable as analytical results. The increased phosphorus may increase the areal extent of pH violations. Uptake may reduce the ambient levels to the levels of significant nutrient control in the lower more sensitive sections of the Coast Fork.

A wasteload allocation of 8 lbs/day would measurably increase the concentration of ortho-phosphorus. Maximum levels of 20 µg/l will be infrequently approached without the waste treatment plant discharge. At WLAs of 8 lbs/day ortho-phosphorus, the median instream concentration below the confluence of the Row River would be near 20 µg/l. A WLA of 8 lbs/Day would increase the probability and extent of pH exceedance throughout the Coast Fork (Figure A-25).

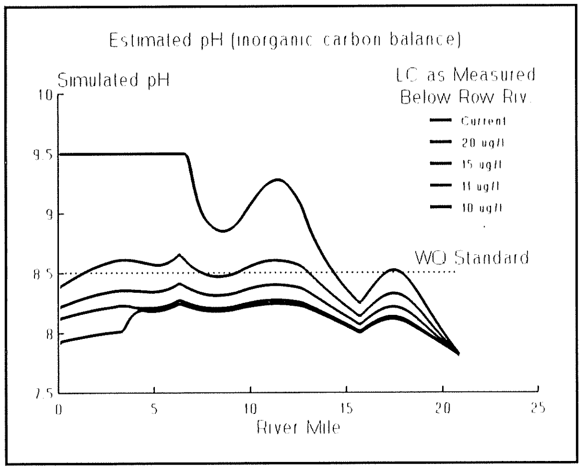


Figure A-25. Estimated pH

The discharge of wastewater also provides inorganic carbon, alkalinity, and additional buffering to the stream. The discharge of wastewater would be expected to initially decrease pH due to the addition of inorganic carbon. The inorganic carbon supplied by the discharge would also be expected to increase available supply of inorganic carbon for algal growth. Under conditions where a WLA results in similar nutrient concentrations to upstream water, the addition of carbons from the wastewater could further the distance downstream to where exceedances of the pH criteria may occur. Discharge of effluent would also be expected to increase heterotrophic respiration below the discharge.

No estimates were made on the potential of grazing by macroinvertabrates to influence standing crops and net production of the periphyton community. Grazing can have a controlling influence of periphyton biomass. Reduced production rates anticipated under a nutrient control strategy would likely increase the relative influence of grazing as a controlling influence on periphyton.

NONPOINT SOURCE

Limited data exist that indicate nonpoint source pollution problems in the Coast Fork Basin relative to nutrient loads. Observations from the limited sampling that has occurred indicates that some tributary streams are carrying elevated concentrations of phosphorus. The average of three samples for phosphorus concentration in Gettings Creek is 130 μg/l; a similar 130 μg/l reading was observed in Camass Swale in one sample, and 70 μg/l was observed in one sample from Silk Creek discharging to the Row River.

The nutrient concentrations upstream of the CGSTP are relatively high for both nitrogen and phosphorus. Although these concentrations have been evaluated as background levels, no assessment has been conducted which indicates that observed concentrations are naturally occurring levels. Field observations from USGS staff conducting water quality surveys in the Coast Fork Basin suggest that some tributaries such as Hill Creek, Gettings Creek, and Camas Swale as well as other potential nonpoint sources may be adding nutrients to the Coast Fork (Anderson, 1994). These observations are consistent with the field observations and limited data reported by the Department. The increased periphyton growth near Cresswell as compared to Saginaw may also indicate nonpoint sources of nutrients.

These, or other unidentified NPS loads of nutrients, are an instrumental component of the TMDL. However, since adequate resources will not be committed to evaluating the effect of potential NPS control and the CGSTP is the dominant source of nutrients, the CGSTP WLAs will not be influenced by the NPS component of a TMDL. Therefore, a phased approach to implementing the TMDL is proposed. The initial phase will focus on developing a WLA for the CGSTP. The second phase will be implemented as the Department priorities warrant and include interaction with the State Department of Agriculture to identify and control agriculturally related nutrient sources. Initial efforts would focus on identified streams with evaluated nutrients and on control of runoff from confined animal feeding operations in the basin.

Uncertainty with NPS and background loads is adequately covered in the TMDL margin of safety. To assure compliance with this TMDL and that future NPS loads do not lead to further water quality standards violations, the Department will implement a nonpoint source pollution control strategy for the Coast Fork Basin which is described by four (4) principal efforts.

1. DEQ will work with Oregon Dept. of Agriculture (ODA), the Designated Management Agencies (DMA) for agriculture, as resources allow to:
    - Inspect all CAFOs in the Coast Fork Willamette River Basin and identify all corrective actions needed to comply with permit conditions within 2 years.
    - Ensure that all corrective actions are completed within 4 years.
    - Report to the DEQ annually on progress toward accomplishing the above tasks including the number of inspections completed, permittees needing corrective actions, and permittees completing corrective actions).
2. The Department will work with the ODA to undertake efforts to reduce phosphorus loading to those tributaries identified as having high nutrient loads, such as Gettings Creek and Camass Swale, as resources allow. The strategy will include:
    - Identify significant sources of phosphorus in the subbasins.
    - Take actions to reduce the identified phosphorus loads.
    - Monitor the tributaries to determine whether phosphorus loads have been reduced.
3. The Department will continue to work with

the Dept. of Forestry (DOF) to implement the *Oregon Forest Practices Act.* These efforts will:

- Ensure that the required practices are being followed; document violations and pursue enforcement actions.
- Monitor activities that violate the FPA to determine the water quality impacts.
- Monitor water quality below selected forest activities (e.g., harvest, road building) to determine whether the forest practices are achieving the desired water quality results.

4. The Department will continue to work to implement memoranda of agreement between the DEQ and federal land management agencies within the basin to meet or exceed state forest practices requirements on forested land.

DEQ recognizes that control of the point sources alone may not entirely resolve the periphyton growth and dissolved oxygen problems in the Coast Fork of the Willamette River and its tributaries. The above identified tasks will further reduce the nutrient load to the river and its tributaries and contribute to the effort to limit dissolved oxygen problems resulting from excessive periphyton growth. More work may be needed in the future on the role of temperature, streamflow, and channel modifications to the water quality problems in the river.

One load allocation is assigned for nonpoint sources and background combined. Agriculture is not assigned an individual load allocation because we do not consider this basin a high priority for a full Agricultural Water Quality Management Plan under OAR Chapter 603, Division 90.

DISSOLVED OXYGEN WLA STRATEGIES

The observed dissolved oxygen standards in the Coast Fork below river mile 14 appear to be the result of benthic algal respiration and are not directly related to an oxygen sag resulting from effluent discharged from Cottage Grove. Although the observed DO violates the State's current standards, the proposed standards (ODEQ triennial standards review) do not appear to be violated also. The nutrient TMDL designed to reduce pH violations will reduce the observed diurnal variation in dissolved oxygen.

Multiple oxygen samples were collected above and below the Cottage Grove wastewater treatment on August 8–10, 1989. Measured oxygen saturation levels were at criteria values in the initial mid-morning samples above and below the STP discharge. The dissolved oxygen saturation levels may have fallen below criteria early morning prior to sample collection and significant photosynthetic production of oxygen.

Figure A-26 illustrates the difficulty in interpreting the existing criteria as absolute minimums and expecting to have any available assimilative capacity to distribute to point source discharges. Background conditions are already at or below the current standard. Any potential WLA would need to be determined on a basis of no measurable reduction in dissolved oxygen. Measurable levels have been defined as 0.10 mg/L DO.

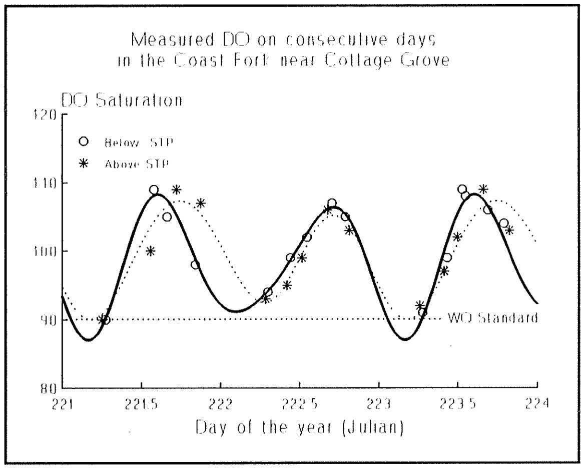


Figure A-26. Diel Oxygen

The waste discharge may influence dissolved oxygen through dilution with a low-oxygen effluent, and by increasing the concentration of oxygen demanding substances. The effluent dissolved oxygen concentration that will not result in a measurable decrease in dissolved oxygen after complete mixing with the receiving stream can be determined as:

$$DO_{eff.} = \frac{[Q_{eff.}Q_{riv.}(DO_{riv.} - \Delta DO)] - (Q_{riv.}DO_{riv.})}{Q_{eff.}}$$

If dilution uses the entire measurable dissolved oxygen deficit, then the oxygen used by the addition of oxygen demanding material must be offset by the aeration rates.

In shallow stream, the oxygen demand of ammonia is often the most rapid and largest component of the oxygen demand from a wastewater treatment plant. The ammonia discharged from the Cottage Grove STP results in a measurable increase in ammonia. Below the STP, the ammonia concentration is reduced by physical and biological reactions. Reduced concentration occurs by dilution with the Row River. Ammonia is the preferred nitrogen source for periphyton, and ammonia is converted to organic nitrogen through algal uptake. Nitrification converts the ammonia to nitrate and consumes oxygen. The conversion of one mg/L of ammonia is equal to the decay of 5.6 mg/L of carbonaceous BOD. During the summer months, most of the ammonia from the CGSTP is removed by river mile 14 (Figure A-27).

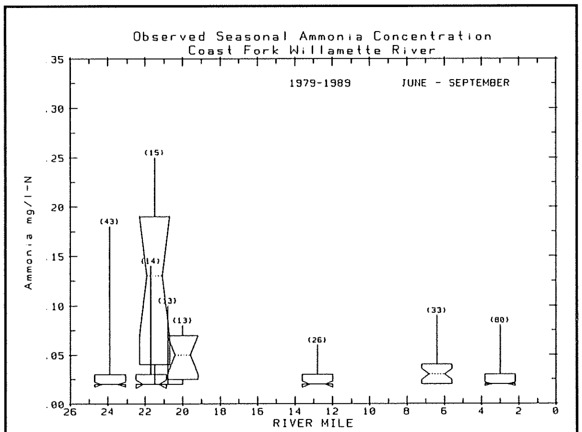


Figure A-27. Ammonia Nitrogen

The apparent decay rate of ammonia was estimated from the ambient data between the sites below the Row River (RM 20) and Saginaw (RM 14) as:

$$\frac{Log_n \frac{C_t}{C_0}}{t}$$

The apparent decay rate does not account for periphyton uptake. The estimated rates varied between 2.5 and 3.5 per day. Aeration rates near 2.0 to 2.5 per day were estimated from velocity and cross sectional measures made at limited locations.

Low effluent ammonia concentrations of 0.72 to 1.13 mg/L were observed during the August 8–10 surveys. The low oxygen demand and relatively high dilution rates in the Coast Fork explain why reduced dissolved oxygen levels were not observed in the surveys related to BOD. Much higher effluent ammonia concentrations during the summer have been reported by DEQ (14.4 mg/L) and by the City of Cottage Grove (21 mg/L). The much larger ammonia loads may have influenced dissolved oxygen to a greater extent than measured during the ambient surveys.

Potential WLA for ammonia assumed that carbonaceous BOD impact was negligible, and that ammonia BOD was stoichiometrically equivalent to 4.57 x ammonia concentration (L_0). The actual NBOD is often less than the stoichiometric equivalent, near 4.3, due to incomplete conversion of the ammonia. The WLA for ammonia was estimated by calculating the dissolved oxygen deficit:

$$D = (\frac{K_n}{K_a - K_n}[e^{-K_n t} - e^{-K_a t}])L_0 + D_0 e^{-K_a t}$$

Where t is the time to the critical deficit:

$$t = \frac{1}{K_a - K_n} Log_n(\frac{K_a}{K_N}[1 - \frac{DO_0(K_a - K_n)}{K_n L_0}])$$

The DO_0 was the initial DO after complete mixing, and the deficit (D) was 0.10 mg/L below a background of 90 percent saturation.

The potential ammonia WLAs (Table A-12) were estimated assuming an ammonia BOD decay (K_n) rate of 3.5/day, and an aeration rate of 2.0/day per day and a background concentration of 0.10 mg/L ammonia. The aeration coefficient (K_n) was described previously. The 7Q10 flows were used for the Coast Fork and the Combined Coast Fork and Row River. Higher flows, lower decay rates, or higher aeration rates result in higher WLAs. The LA for background and NPS is based on the upper range of ammonia concentrations (0.10) observed upstream of the STP. This analysis would indi-

Table A-12. Ammonia WLA Options

ESTIMATED WLAs CGSTP				
Qr	DOe	WLA	LA	Δ mg/l
42	7.1	9.3	22	Δ0.1
42	5.0	68	22	8.0 mg/l
125	5.0	44	67	Δ0.1
125	5.0	230	67	8.0 mg/l

cate that the observed loads during the August survey of 5.4 to 8.5 pounds per day of ammonia would not have been expected to result in a significant dissolved oxygen depression.

A WLA based on achieving no measurable change in dissolved oxygen, WLA of 9 lbs/day ammonia is estimated for the current discharge location. If the discharge location is shifted to the confluence with the Row River, a WLA of 44 lbs/day ammonia is defined. At 44 lbs/day and a design of 2 mgd, is equivalent to an effluent quality of 2.6 mg/L.

As plans are developed to achieve the TMDL requirements for nutrient control, some level of ammonia removal may be necessary to achieve the dissolved oxygen standard. The level of ammonia removal will be dependent upon where the discharge occur, either to the Coast Fork or the combined Row and Coast Fork. The WLA sold also will be dependent upon what dissolved oxygen criteria will be used to establish the TMDL.

The proposed criteria for cold water use during after emergence of juveniles from the gravel of 8.0 mg/L DO is similar to the 90 percent of saturation criteria. The proposed criteria is identified as a monthly mean. The proposed criteria identifies a 7-day mean minimum of 6.5 mg/L, which provides the reference for minimum diurnal variation. Because of the high dilution available, there is significantly greater WLA potential under the proposed criteria as compared to a no measurable reduction using the currently existing criteria. However, there is no certainty in that the proposed criteria will be adopted. The WLAs for the Cottage Grove STP should be established using the current water quality standards.

The background concentrations of BOD and ammonia do not influence the observed oxygen deficit and no activities to further limit background BOD and Ammonia are proposed.

AMMONIA TOXICITY

The USEPA established the un-ionized ammonia criteria for the protection of cold water fish in 1984. The toxicity of un-ionized ammonia and the fraction of total ammonia that is in the un-ionized form both change with temperature and pH. Both pH and temperature vary with time, and distance. The calculated total ammonia concentration resulting in chronic concentration criteria (CCC) of un-ionized ammonia for cold water fish was determined from the ambient field samples. It is not correct to determine the ammonia toxicity concentration from averaged temperature and pH values (Figure A-28).

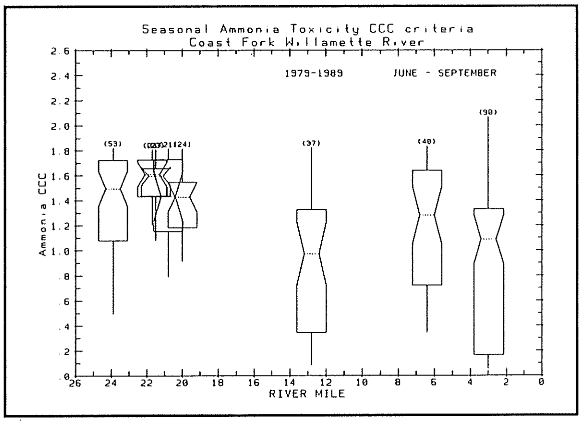


Figure A-28. Ammonia Criteria

The lower thresholds in the lower river are a result of the higher observed pH values. The ammonia limits, established for the CGSTP, need to account for both the removal mechanism of ammonia and the lower CCC due to higher pH levels downstream. Ammonia will be removed by nitrification and algal uptake as it moves downstream. The ability to achieve the ammonia CCC values downstream was estimated

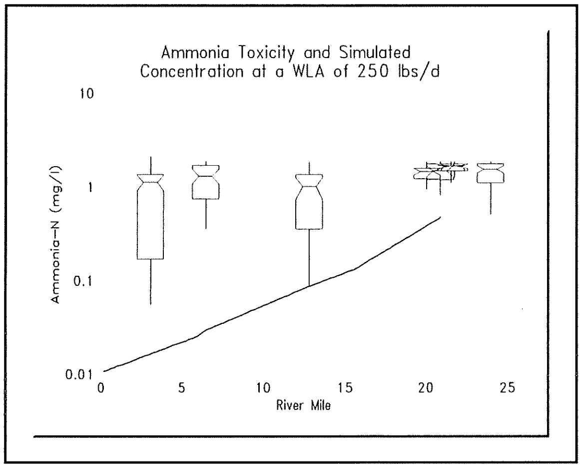


Figure A-29. Ammonia Toxicity

by comparing alternative mass loads to the measured chronic concentration criteria in the Coast Fork. Using the calculated decay rate of 2.5/day for ammonia, a discharge at the confluence of nearly 250 lbs/day would achieve the lower ammonia toxicity criteria downstream due to losses occurring from nitrification and algal uptake. Near field mixing zone limits may be more restrictive than the limits needed to achieve the lower toxicity standards downstream (Figure A-29).

The lowest ambient ammonia toxicity levels occur during the summer low flow season of June through September. Data collected in the afternoons had lower ammonia toxicity levels than did the early morning samples. The chronic criteria is expressed as a 4-day average with 3-year recurrence interval. When determining permit conditions, a 4-day average of the CCC should be used.

The ambient ammonia level for defining the potential WLAs was estimated from the distribution observed for both morning and afternoon field samples. Daily average ammonia CCC was estimated by averaging the morning and afternoon ammonia CCC values. From the resulting distribution, a chronic ammonia concentration in ambient receiving water of 1.35 mg/L total ammonia as nitrogen (NH_3-N) was estimated for the current discharge location and 1.25 mg/L NH_3-N for discharge to the combined Coast Fork and Row Rivers. These concentrations are well above the current concentrations observed by the Department of 0.18 and 0.07 mg/L for these locations, respectively. The City of Cottage Grove provides indication that higher ammonia concentrations may occur below the STP with maximum reported ammonia concentrations of 1.25 mg/L, and average of 0.55 mg/L for the period 5/23–10/24 1989.

The Department's mixing zone rules require that chronic criteria concentrations be achieved at the edge of the assigned mixing zone. The City of Cottage Grove proposes a discharge to the confluence of the Row and Coast Fork Rivers. This option has the advantage of greater discharge for dilution. The Oregon Department of Fish and Wildlife provides the opinion that the confluence is a popular cutthroat trout fishing hole during summer low flow conditions. An appropriately sized, mixing zone, and associated ammonia limits would be important in assuring that this resource is not jeopardized by the proposed discharge (Table A-13).

Table A-13. Ammonia Toxicity WLA

EXAMPLE AMMONIA ALLOCATION ASSUMING A MIXING ZONE USING 25 PERCENT OF AVAILABLE FLOW		
Allocation	**Coast Fk**	**Coast Fk + Row**
Q cfs	50	125
NH CCC (mg/l)	1.35	1.25
LC lbs/d	364	842
LA lbs/d	27	67
WLA lbs/d	84	194
Reserve [(LC-(WLA+LA)]	253	581

SUMMARY WLA OPTIONS

Several options were reviewed for the TMDL to address violations of the pH standard related to periphyton photosynthesis. These options included no discharge, a WLA strategy based upon an average instream concentrations of 11 μg/l dissolved ortho-phosphorus (DOP) below the confluence with the Row River (0.8 lbs/day DOP), a WLA strategy of 15 μg/l DOP below the confluence with the Row River (WLA of 4 lbs/day), a WLA strategy of 20 μg/l DOP below the Row River (8 lbs/Day DOP), a nitrogen limitation alternative, and a do-nothing WLA strategy.

Alternative ammonia WLA strategies to address dissolved oxygen include a WLA 44 of lbs/day ammonia, and a do-nothing strategy. Alternative WLAs based on the proposed dissolved oxygen criteria were not considered. The TMDLs describe what is necessary to achieve existing standard. There is no certainty that the proposed criteria will be adopted. If the proposed oxygen criteria are adopted, the ammonia loading capacity and associated WLAs will be reviewed.

No alternative WLAs were developed for ammonia toxicity. The levels of ammonia limitation will be determined by compliance with mixing zone criteria rather than the downstream effects.

Nutrients – No Discharge

The no-discharge option is anticipated to result in reduced biomass accumulation throughout the river and in significant nutrient limitation in the lower river. Even under the no-discharge option, there is no certainty that the pH criteria will be achieved. Nutrients, both nitrogen and phosphorus, are in adequate supply to support significant periphyton growth upstream of the STP. The levels upstream of the STP would indicate that phosphorus is in limiting proportions, and that phosphorus levels are in the range that would provide limitation on community production if no cellular production. Uptake of nutrients would be expected to reduce ambient phosphorus to near cellular limiting levels within a few miles of the confluence of the Row River. Benthic uptake will likely result in much less impact of periphyton on water quality in the lower river. The probability and extent of predicted pH violations is lowest under the no discharge option as compared to other WLA strategies.

Since the state criteria state that if numerical criteria cannot be achieved then natural background levels become the criteria. The background criteria are not defined, and would be significantly influenced by flow regulation by reservoirs. With lack of natural conditions, the influence of background upstream of the STP discharge provides the reference criteria for evaluating alternatives and the no-discharge option would therefore achieve water quality standards. Implementation on NPS controls could reduce ambient concentrations.

A Loading Capacity of An Average 10–11 μg/l Below The Row River, or WLA of 0.8 Lbs/Day Provides A Slight to No Measurable Increase in Ortho-Phosphorus

Concentration of phosphorus below the confluence of the Row River would be increased, but below measurable levels. Similar to the no-discharge option, this alternative will result in ortho-phosphorus being in limiting proportion, and initially at concentrations which result in community production limitation. In areas of low aeration, the pH criteria may not be achieved. However, uptake of nutrients will be expected to reduce ambient concentrations to levels limiting cellular production downstream. Production will be greatly reduced in the lower section of the river where historical data shows the most frequent pH violations.

Biomass accumulation is anticipated to be significantly reduced compared to existing conditions. The area of impact as indicated by a reference level of periphyton accumulation would be expected to be slightly longer than the no-impact alternative. The simulated inorganic carbon balance indicates a potential increase in pH, and the area of pH violations. However, it is not possible to confirm the probability and extent of this increase in ambient pH. Estimates of increased pH over background are also offset by the increase in inorganic carbon associated with the STP discharge. The initial distance to where pH violations may occur increase due to the addition of inorganic carbon.

Estimates of the impact of this WLA strategy on receiving water quality are indistinguishable from the no-discharge option, and could therefore be considered as consistent with water quality standards. It is reasonable to assume that there will be some areal increase in periphyton biomass as compared to a no-discharge option. Certainly other parameters such as nitrogen will increase, and even highly diluted effluent has been associated with increased eutrophication making predictions less certain than under the no-discharge alternative.

A Loading Capacity of A Median 15 μg/l Ortho-Phosphorous Below The Confluence With The Row River, Resulting in A Maximum WLA of 4 Lbs/Day Ortho-Phosphorus

The average concentrations below the confluence with the Row River would be expected to be within the range of community limitation for periphyton, but not result in cellular limitation. Increased phosphorous would be measurable. Benthic uptake of nutrients would result in significant reduction in ambient phosphorus concentrations downstream. However, there will be an extension of the area of high algal growth potential impacted by wastewater effluent compared to previous options. Depending on local conditions, the frequency and extent of pH exceedances may be greater than under the no-WLA or 0.8 mg/L WLA alternatives; however, the simulated organic carbon balance indicates that the ambient pH criteria may be achieved in the lower part of the river due to nutrient limitation. However, there is less certainty that nutrients will be reduced to significantly limiting concentrations in the lower portions of the river where historical pH violations have been observed.

A Loading Capacity of A Median of 20 μg/l Below The Confluence With The Row River, Resulting in A WLA of 8 Lbs/Day Ortho-Phosphorus

The criteria would result in average conditions approaching community level production limitation for periphyton, although maximum levels would occasionally exceed community level control. Concentrations would also be near levels cited in the available literature to provide production control for filamentous forms of periphyton.

Periphyton uptake would be expected to reduce ambient levels to cellular levels in the lower portions of the river. However, the ability to achieve cellular level of control is much less certain than would occur at the other alternatives. The areal extent of algae above reference levels used to indicate potential nuisance would increase as compared to other alternatives. The inorganic carbon balance indicates that there is greater risk of more extensive exceedance of pH criteria especially in the lower portions of the river.

The influence that grazing has on periphyton accumulation has not been estimated. A loading capacity of 20 μg/l, would be expected to result in slower potential rates of biomass accumulation than currently exists and become more important as uptake reduces ambient concentrations. As the production rates decrease, the relative impact of invertebrate grazing can be expected to increase.

Impacts of reduced nutrient supply on periphyton and resulting water quality are uncertain. It is reasonable to expect that reduction of instream concentrations to near 20 μg/l will influence biomass in the river. The uncertainty in what factors may combine to control biomass accumulation, such as invertebrate grazing, make predictions difficult and uncertain. However, improved water quality and reduced extent of pH standards may be expected with reduced nutrients at or below 20 μg/l over current conditions.

Nitrogen Limitation

The nitrogen limitation alternatives did not appear to be unilaterally effective. Nitrogen is currently the micronutrient in limiting proportion below the STP. However, upstream of the STP nitrogen does not appear to be in limiting proportions. A nitrogen limitation strategy is in effect a no discharge option. The advantage of

Table A-14. WLA PO_4-P

ONE ALTERNATIVE WLA STRATEGY FOR NUTRIENT CONTROL		
PO_4	LBS/D	µg/l
LC	13.0	16.0
LA Background	9.7	12.0
LA Reserve	2.3	2.8
WLA	1.0	1.2

the no-discharge option is in greater certainty of reducing the impact of periphyton on water quality. Limiting discharge removes macro and micronutrient, and reduces the potential of synergistic influences from multiple nutrients being available to periphyton below the Cottage Grove STP.

Do Nothing

Available data for evaluating the influence of source discharge on periphyton and resulting water quality in the Coast Fork are limited. Analytical methods and models for simulating periphyton and its impact on water quality are not well developed. Empirical measures of production and effects in the Coast Fork are limited. Available information suggest that temperatures in the lower river, near 25c, would limit the summer low flow use of the Coast Fork for the sensitive salmonids regardless of DO and pH violations. Most of the potential influence of nutrient control on pH and dissolved oxygen will occur in the lower river. The influence of nutrient control on protecting sensitive uses may be limited.

However, the available data clearly demonstrate water quality impairment due to exceedance of dissolved oxygen and pH standards violations.

AMMONIA CONTROL FOR DISSOLVED OXYGEN

WLA to The Upper Coast Fork of 9 Lbs/Day (TMDL 31 Lbs/Day)

Estimated to be consistent with the current standard for discharge to the Coast Fork above the confluence with the Row River — no measurable reduction in DO would be anticipated to occur due to loads of oxygen demanding material below the STP. The confluence of the Row River within 1 mile would result in further dilution and reduce the impact of the discharge on DO.

WLA to The Confluence of The Coast Fork and Row River of 44 Lbs/Day (TMDL 111 Lbs/Day)

The estimated no-measurable decrease in ambient dissolved oxygen for discharge to the confluence with the Row River — the confluence of the Row River and Coast Forks has been identified by ODFW as a popular location for angling for trout.

DO NOTHING FOR DISSOLVED OXYGEN

Standards violations due to discharge of oxygen demanding waste from the STP have not been observed. The current dissolved oxygen patterns in the Coast Fork are dominated by periphyton photosynthesis and respiration. Significantly greater WLAs would be available if the proposed dissolved oxygen criteria were used rather than the current criteria.

RECOMMENDATIONS

Based on the existing information, the TMDL (Table A-14) strategy has been developed for nutrient control. This WLA focuses on limiting discharge of the macronutirent in lowest proportion to algal growth requirements upstream of the STP. The Loading Capacity as defined is anticipated to provide the greatest loading capacity having a reasonable probability of achieving water quality standards. The Reserve LAs are intended to cover nonpoint source

Table A-15. Ammonia WLA

ONE ALTERNATIVE WLA STRATEGY FOR NUTRIENT CONTROL		
LC	LA	WLA
111	67	44

loads and the great uncertainty in estimates of the impact of nutrient loads on periphyton production. The WLA is assigned to the Cottage Grove STP. At design flows of 2 mgd a WLA of 1 lb/day is equivalent to 0.06 mg/L (60 μg/l) of ortho-phosphorus. The increase in orthophosphorus would not be measurable.

Ammonia WLAs (Table A-15) are determined to be certain that, without the dominating influence of periphyton growth, the discharge from the Cottage Grove STP would not measurably reduce dissolved oxygen due to mixing with low oxygen wastewater or decay of oxygen demanding material. Ammonia provides the largest and fastest acting component of oxygen demand discharged by Cottage Grove to the Coast Fork.

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