Processes Controlling Dissolved Oxygen and pH in the Upper Willamette River Basin, Oregon, 1994

U.S. GEOLOGICAL SURVEY
Water-Resources Investigations Report 95–4205

Prepared in cooperation with
OREGON DEPARTMENT OF ENVIRONMENTAL QUALITY and
WILLAMETTE RIVER TECHNICAL ADVISORY STEERING COMMITTEE

Cover photograph. Looking upstream at the Willamette River with Mt. Hood and Portland Harbor in the background, February 7, 1993. *(Photograph by Dennis A. Wentz, U.S. Geological Survey.)*

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Portland, Oregon
1995

U.S. DEPARTMENT OF THE INTERIOR
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CONVERSION FACTORS

Multiply	By	To obtain
acre	4,047	square meter (m^2)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter (m^3/s)
inch	25.4	millimeter (mm)
foot (ft)	0.3048	meter (m)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
cubic yard (yd^3)	0.7646	cubic meter (m^3)
cubic foot per second (ft^3/s)	0.02832	cubic meter (m^3/s)

Temperature in degrees Celsius (°C) as follows:

$$^\circ C = (^\circ F - 32)/1.8.$$

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Abstract

In July and August of 1994, the U.S. Geological Survey in cooperation with the Oregon Department of Environmental Quality (ODEQ) collected data to document the spatial extent and diel variability of dissolved oxygen (DO) concentrations and pH levels in selected reaches of streams in the upper Willamette River Basin. These data were also collected to identify primary factors that control DO concentrations downstream from major point sources as well as to provide ODEQ with data to refine calibration of their steady-state DO and nutrient models for the upper Willamette River Basin.

All of the reaches studied had diel variations in DO and pH. The magnitude of the diel variations in DO ranged from 0.2 to 3.9 milligrams per liter (7 to 50 percent-saturation units based on ambient water temperature and barometric pressure) and in pH from 0.3 to 1.4 units. However, of the reaches studied, only the Coast Fork Willamette River from river mile (RM) 21.7 to 12.5 and the Willamette River from RM 151 to 141.6 had field measured violations of State standards for DO and pH.

DO concentration and pH in water depend on many factors. Data were collected to examine several major factors, including BOD (biochemical oxygen demand), carbonaceous BOD, nitrogenous BOD, and measures of photosynthetic activity. Of the four study reaches, only a short stretch of the Coast Fork Willamette River has potential for important levels of oxygen consumption from BOD or nitrification. Additionally, water-column primary-productivity measurements indicated that respiration and photosynthesis by free-floating algae did not explain the observed diel variations in DO in the study reaches.

Results from a simple mathematical model incorporating measures of community respiration and net primary productivities indicated that periphyton are capable of producing a diel variation of the order of magnitude observed during the August study period. In the Willamette River near Peoria, the combined periphyton DO consumption and production estimate at RM 151 (2.4 mg/L) and RM 144.6 (1.7 mg/L) would account for 90 and 63 percent, respectively, of the observed diel fluctuation. The estimates for the Corvallis reach at RM 132.6 (0.4 mg/L) and RM 130.7 (2.9 mg/L) had a considerably larger range of 36 to 264 percent of DO saturation, respectively. Therefore, because BOD and phytoplankton do not appear to be important contributors to diel DO fluctuations, periphyton are likely the primary contributor to diel fluctuations in the upper Willamette River Basin during July and August.

INTRODUCTION

Water quality in the Willamette River Basin in western Oregon has been intensively studied under the auspices of the Willamette River Basin Water Quality Study since 1991. This study was funded and administered by the Willamette River Basin Technical Advisory

Steering Committee (WRTASC), which was formed in 1989 at the request of the Legislature of the State of Oregon and the Oregon Department of Environmental Quality (ODEQ). Providing the impetus for this study was a perception that water quality in the Willamette River Basin was degrading after several years of improvement. Complementing the work directed by the WRTASC in 1991, the U.S. Geological Survey (USGS) began a study of the basin under its National Water-Quality Assessment (NAWQA) program (Wentz and McKenzie, 1991). ODEQ contributed much of the funding for both Phases I and II of the Willamette River Basin Water-Quality Study—USGS components of the study were funded cooperatively by ODEQ and the USGS.

Study components during Phase I of the study, from 1991 to 1993, included (1) point-source water-quality modeling, (2) nonpoint-source water-quality modeling, (3) evaluations of the aquatic community, (4) evaluations of nutrient and periphyton growth conditions (Gregory, 1993), (5) time-of-travel and hydrologic-flow modeling (Lee, in press; Antonius Laenen and J.C. Risley, USGS, unpub. data, 1994), (6) sediment transport (Laenen, 1995), and (7) reconnaissance of trace-contaminant occurrences (Tetra Tech, Inc., 1993).

Results from study components 1 and 4 indicated that more data were needed regarding dissolved oxygen (DO) and pH in the Willamette River Basin, particularly in the main stem and upper tributaries, during summer low-flow conditions. Additionally, in accordance with provisions of the Clean Water Act of 1986, the State of Oregon was considering the necessity of imposing Total Maximum Daily Loads (TMDL’s) on reaches designated “water-quality limited.” Certain reaches of the river and its tributaries were known to exhibit significant diel (24-hour) fluctuations in DO and pH during summer low-flow periods. Additionally, DO and pH in these reaches were known to violate State of Oregon water-quality standards. State of Oregon standards are a minimum of 90-percent saturation for DO and less than 8.5 for pH for streams in this study (Oregon Department of Environmental Quality, 1995a). To what extent these conditions prevailed elsewhere in the main stem and upper tributaries, however, was unknown. Furthermore, in order to adequately evaluate conditions of DO and pH in these reaches of the river basin, better resolution of the diel and seasonal variations in water temperature, DO, and pH, were needed, as well as information concerning the importance of BOD (biochemical oxygen demand), algae, and nutrients, which may affect DO concentrations.

Phase II of the Willamette River Basin Water Quality Study began in July, 1993. Phase II study components were based in part on the initial study objectives identified prior to the initiation of Phase I and were adapted to the results of Phase I. Work conducted by the USGS as part of the Phase II study included (1) additional investigations of trace elements and organic chemicals and their associated land uses, (2) measurements of sediment-oxygen demand (SOD) in the bottom sediments of the Willamette River from Newberg (river mile [RM] 50.5) to Portland (RM 3.1), and (3) investigation of factors controlling DO and pH in the upper Willamette River and major tributaries. Additional Phase II study components were conducted by Tetra Tech, Inc., environmental consultants, and included calibration of a steady-state DO model, investigations of nonpoint-source contamination, ecological monitoring, and a final report integrating the results of the individual Phase I and Phase II studies (Tetra Tech, Inc., 1994).

Purpose and Scope

This report addresses the third USGS component of the Phase II study, which was to determine the factors controlling DO and pH in the upper main stem Willamette River and its major tributaries. Objectives of this report are to:

(1) Document the diel and spatial variability of DO concentrations and pH levels in selected reaches of streams in the upper Willamette River Basin,

(2) Identify primary factors that control DO concentrations in selected reaches of streams in the upper Willamette River Basin, and

(3) Provide the ODEQ with data to refine calibration of their steady-state DO and nutrient models of the river basin. These data are in supplemental data tables at the back of the report.

Description of the Study Area

The Willamette River Basin of western Oregon (fig. 1) has an area of approximately 11,500 square miles. It contains Oregon's three largest cities—Portland, Salem, and Eugene—and 68 percent of the State's population. Forested areas, much of which are in the headwaters of the Willamette River and in tributary basins, cover approximately 60 percent of the basin. Agricultural areas cover about 35 percent of the basin, and the remaining 5 percent is urban (Wentz and McKenzie, 1991).

The climate of the Willamette River Basin is typical of the temperate weather west of the Cascade Range in the Pacific Northwest: cool, wet winters and warm, dry summers. These climatological conditions lead to smaller flows and warmer water temperatures during the summer months. Topography strongly affects the areal distribution of precipitation within the basin. Local mean annual precipitation for 1961–90 ranged from about 40 inches on the valley floor to as high as 175 inches in the Coast and Cascade Ranges. Basinwide the mean annual precipitation for the 1961–90 period averaged 62 inches (Taylor, 1993).

The Willamette River flows south to north from the confluence of the Middle Fork and the Coast Fork Willamette Rivers (RM 187) to Portland Harbor (RM 11.2–RM 4), and empties into the Columbia River. For purposes of description, the river can be divided into an upper section and a lower section, which are distinguished by differences in flow, velocity, and gradient (Rickert and others, 1977). The upper section, extending from RM 187 near Springfield to RM 52 near Newberg, as well as the Coast Fork Willamette and McKenzie Rivers, have pool-riffle morphology and are characterized by lower flows, swifter velocities, and shallower depths than in the lower section. Because of these physical differences, the aquatic biological communities in the upper basin, including the primary producers (plants that photosynthesize and respire), are significantly different from those in the lower sections of the river. Primary production is dominated by periphyton (attached algae) in the upper reaches (Gregory, 1993) and by phytoplankton (free floating algae) in the lower reaches (Rickert and others, 1977).

Mean summertime (July–September) flow in the Willamette River at Harrisburg (RM 161.0) from 1969–93 was 5,672 ft^3/s (cubic feet per second) (U.S. Geological Survey, 1994). Summer flows in the main stem are largely controlled by releases from reservoirs operated by the U.S. Army Corps of Engineers (Corps) located primarily on the McKenzie, Middle Fork Willamette, and Coast Fork Willamette Rivers, as well as on the Long Tom and Santiam Rivers (fig. 1).

The Corps maintains minimum streamflow at Albany (RM 119.3) of 5,000 ft^3/s through manipulation of reservoir outfalls (U.S. Army Corps of Engineers, 1989). However, the streamflow in any of the three major tributaries, the McKenzie, Coast Fork Willamette, and Middle Fork Willamette Rivers, may vary substantially depending on the time of year. The Middle Fork Willamette and the McKenzie Rivers contributed approximately 52 and 45 percent, respectively, of the flow observed in the Willamette River at Harrisburg (RM 161) and Willamette River at Albany (RM 119.3) during the July 24–29 and August 22–26, 1994, study periods. During the same periods, the Coast Fork Willamette River, which received two-thirds of its flow from the Row River (RM

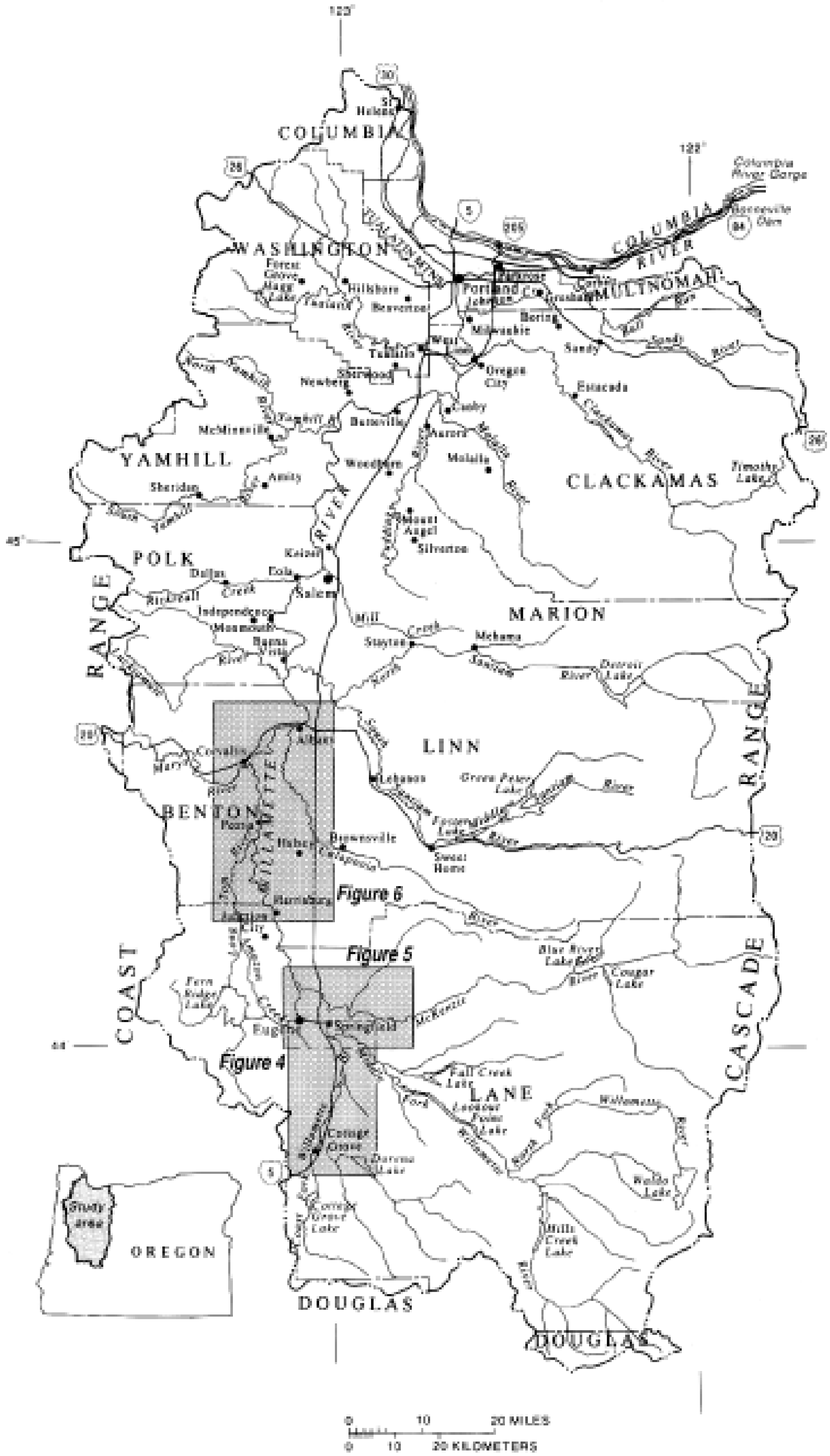


Figure 1. Location of study reaches in the Willamette River Basin, Oregon.

20.7), contributed only 2 to 3 percent of the streamflow at Harrisburg and Albany (figs. 2 and 3). Streamflow at Harrisburg and Albany for the July (approximately 5,000 and 5,200 ft^3/s, respectively) and August (approximately 5,500 and 5,700 ft^3/s, respectively) study periods was near or greater than 5,000 ft^3/s.

Previous Studies

Previous studies of diel variation of DO concentrations for the Upper Willamette River Basin are few and generally limited in scope. Hines and others (1977) found diel DO fluctuations from a minimum of 85 percent of saturation to a maximum of 125 percent of saturation to exist in the upper Willamette River during the summers of 1973 and 1974, and attributed them to the activity of periphytic algae. Rinella and others (1981) indicated that although diatom periphyton produced diel fluctuations, carbonaceous and nitrogenous BOD (biochemical oxygen demand) were the primary cause of DO saturation below 90 percent in the upper Willamette River from RM 185.0 to RM 86.5 during August 1978. However, a study of historical data for the Coast Fork of the Willamette River showed diel variations due to periphytic activity to be the major process controlling DO saturation (Oregon Department of Environmental Quality, 1995b). Although these studies found median DO saturation to be approximately 100 percent, they suggest diel variability in DO due to periphyton productivity to be an important process which may produce, particularly in the morning hours, minimum DO levels below 90-percent saturation.

Although studies have indicated that diel variations in DO of 20 to 40 percent of saturation due to periphyton have existed in the main stem since at least 1973, the species of periphyton appear to have changed markedly. Rinella and others (1981) showed diatoms to be the primary class of periphytic algae in the Upper Willamette River (RM 185.0–RM 86.5) in August 1978. After intensive sampling, Gregory (1993) found that blue-green algae dominated periphyton communities in the Coast Fork Willamette River from RM 32.8 to RM 6.3 and the upper Willamette River from RM 191.2 to 113.1 during August and September 1992. This may represent an important shift in the assemblage of periphytic algae that has implications with respect to nutrient limitation, biomass accumulation, aesthetics, and ultimately on water quality.

Acknowledgments

The authors express their gratitude to the following individuals and organizations: Oregon Department of Environmental Quality, for logistical assistance and nutrient analyses; the City of Corvallis Department of Public Works, for access to their water treatment plant as a monitor location; the Cities of Cottage Grove and Corvallis, as well as the Weyerhaeuser and Pope and Talbot Corporations, for providing access and assistance for effluent sampling. The following private citizens allowed the installation of data-collection monitors on their property: Al Duman (Cottage Grove), C.J. Riddle (Cottage Grove), Grace Hamer (Springfield), Jane Batterson (Springfield), Douglas and Carol Greig (Corvallis), and Dave Gilmore (Corvallis). The WRTASC is expressly acknowledged for their contributions to the design and support of the study.

APPROACH

The period of concern for DO and pH in streams in the Willamette River Basin is the low-flow period, generally July and August. During this time, algal biomass is usually at its annual maximum, water temperatures are warmest, and flows are lowest. During low-flow periods, stream quality is sensitive to point-source inputs and the diel changes resulting from production and respiration of aquatic biota. For these reasons, this study was designed to examine DO and pH conditions during the perceived worst-case conditions.

This study entailed three major data-collection activities: (1) operating a

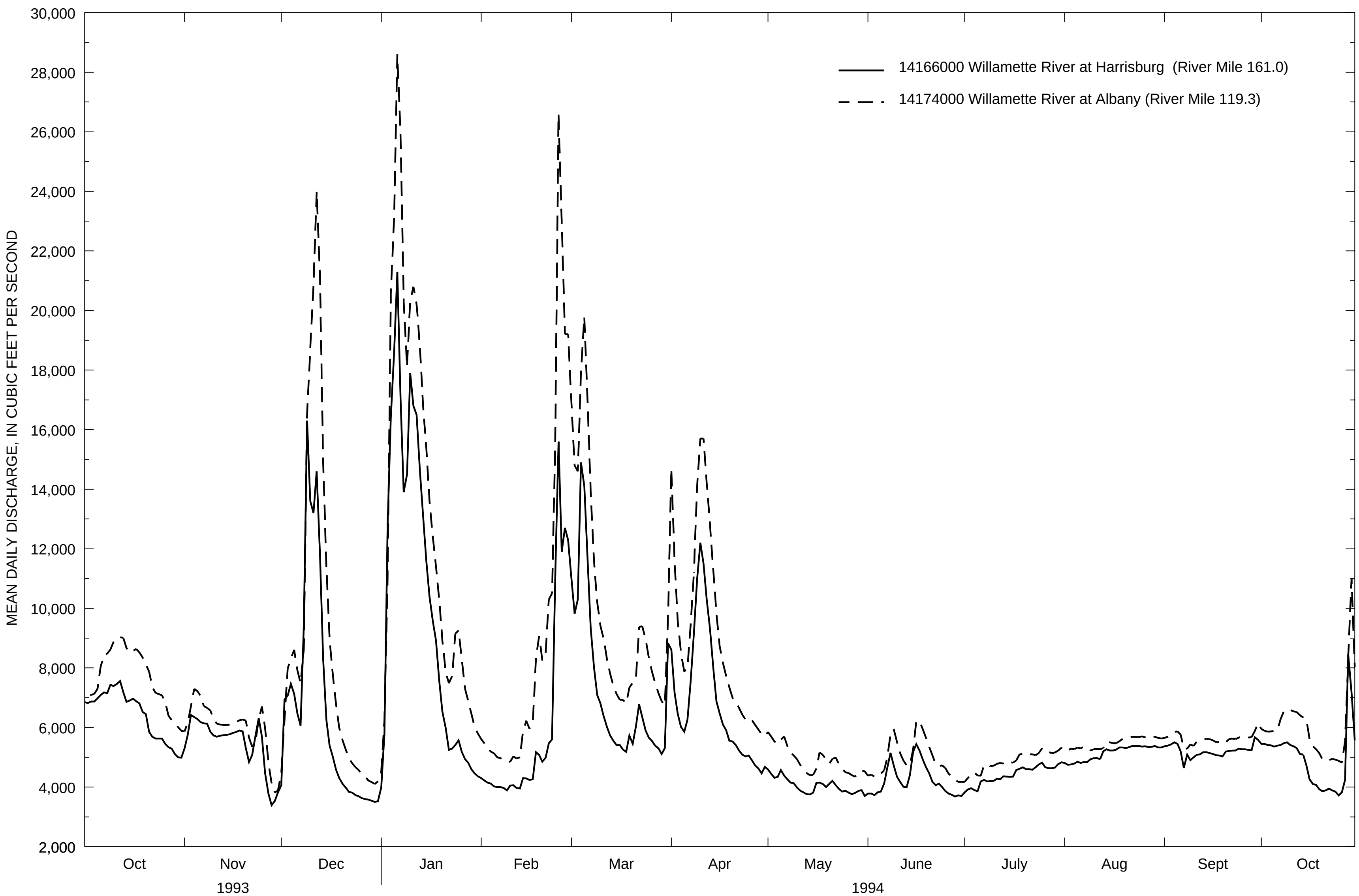


Figure 2. Streamflow in the Willamette River at Harrisburg (river mile 161.0) and the Willamette River at Albany (river mile 119.3) from October 1, 1994, to October 30, 1994.

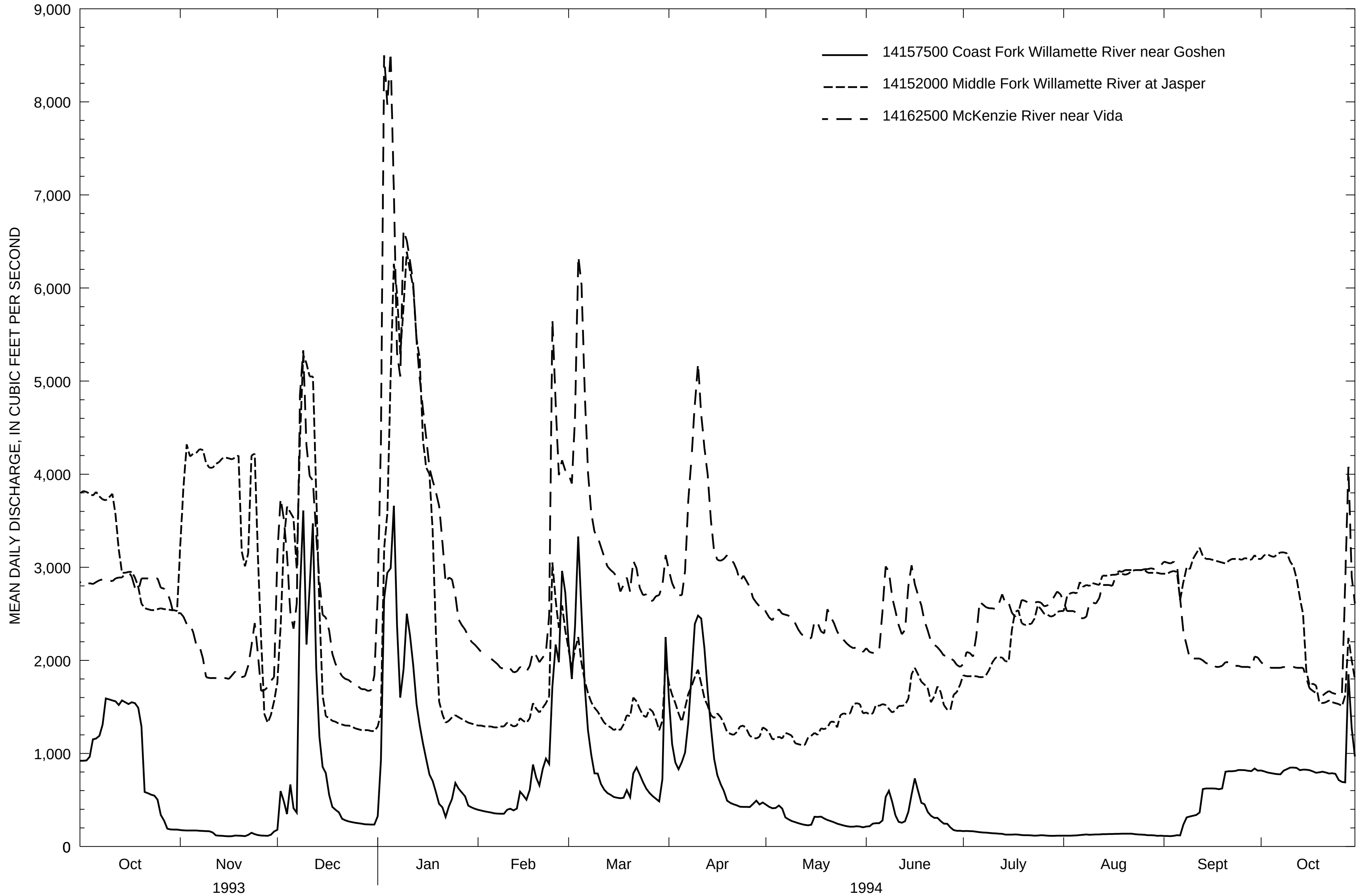


Figure 3. Streamflow in three major tributaries of the Willamette River from October 1, 1994, to October 30, 1994**.**

continuous monitor from July though October, 1994, at the Corvallis Water-Treatment Plant (WTP), which recorded hourly measurements of water temperature, specific conductance, pH, and DO, (2) a reconnaissance-level synoptic survey of diel DO and pH conditions in five selected reaches during July 1994, and (3) an intensive synoptic survey (August 1994) of diel DO and pH conditions, as well as measurements of parameters that can influence DO and pH in four reaches selected from the July survey. The constituents measured are listed in table 1. Data from all three data collection activities are provided in tables 8–13 at the back of this report.

Water-column and biological constituents measured during the August synoptic survey (table 1) were selected on the basis of their potential importance in understanding the dynamics of DO and pH in the Willamette River Basin. DO and pH in rivers can be affected by numerous processes, including primary production, BOD, nitrification, reareation, sediment oxygen demand, and water temperature. Primary production in the water column was measured to ascertain whether planktonic algal production contributed significantly to observed diel fluctuations of DO and pH. Periphyton biomass and chlorophyll *a* were measured to determine if the algal community was of adequate size and health to produce observed diel DO fluctuations. Planktonic biomass and chlorophyll *a*, although not originally specified or proposed in the study design, were measured at several sites that appeared to have potentially significant planktonic populations. Nutrient samples were collected and analyzed for each site to provide ancillary data for interpreting biological information.

BOD and CBOD (carbonaceous biochemical oxygen demand— BOD inhibited to prevent nitrification) were measured to determine their effect on DO in the water column. NBOD (nitrogenous biochemical oxygen demand), which results from oxidation of ammonium to nitrate (nitrification) can consume large quantities of oxygen in aquatic systems if ammonia concentrations and nitrifying bacterial populations are large enough (Velz, 1970; Rickert and others, 1980). NBOD was determined as the mathematical difference between BOD and CBOD. In addition, the rates of BOD and CBOD were estimated.

The study reaches (table 2; figs. 4, 5, and 6) were selected on the basis of the locations of known point sources, findings from previous studies (Oregon Department of Environmental Quality, 1994, 1995a and b; Bothwell, 1992) and consultations with the ODEQ (Robert Baumgartner, oral commun., 1994). The reaches selected for the initial reconnaissance survey in July included (1) Coast Fork reach—Coast Fork Willamette River from Cottage Grove (RM 21.7) to Creswell (RM 12.5), (2) McKenzie reach—McKenzie River from Camp Creek (RM 19.3) to Armitage Park (RM 7.1), (3) Peoria reach—Willamette River from Irish Bend (RM 151.4) to Peoria (RM 141.6), (4) Corvallis reach—Willamette River from Willamette Park (RM 132.6) to Half Moon Bend (RM 126.7), and (5) Albany reach—Willamette River from Hyak Park (RM 121.5) to Spring Hill (RM 114.5).

The Coast Fork Willamette River (fig. 4) was selected for study because it is currently undergoing review for establishing TMDL's based upon documented violations of State standards for DO and pH. Monthly-monitoring stations operated by the ODEQ on the Coast Fork Willamette River provide a considerable amount of instantaneous data during daylight hours. However, these data are inadequate for modeling needs and for defining diel variations of DO and pH. An increased spatial frequency of data also was needed downstream from the largest point source on the river, the Cottage Grove Sewage Treatment Plant (STP).

In general, the McKenzie River Basin (fig. 5), which is mostly forested, is characterized by good to outstanding water quality. However, in the lower 15 miles, from Marcola Road (Hayden Bridge) to the mouth, as it meanders through the cities of Springfield and Eugene (fig. 1), the McKenzie River has been proposed for listing as "water-quality

Table 1. Physical, chemical, and biological measurements made during July 24–29 and August 22–26, 1994

[Nutrients were analyzed at the U.S. Geological Survey National Water-Quality Laboratory in Denver, Colorado. All other constituents were measured either in the field or in the U.S. Geological Survey Oregon District's laboratory. Percent saturation of dissolved oxygen is calculated based on water temperature, barometric pressure, and dissolved oxygen concentration. WATSTORE, WATer data STOrage and REtrieval system; NA, not applicable or not available; LC, laboratory code; ^oC, degrees Celsius; mm of Hg, millimeters of mercury; MRL, method reporting limit; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; O, oxygen; total, unfiltered; filtered, sample passed through a 0.45-micrometer filter; N, nitrogen; P, phosphorus; g/m^2, grams per square meter; mg/m^2, milligrams per square meter; BOD, biochemical oxygen demand]

Parameter name	WATSTORE Parameter Code	Method Code[a]	MRL
Parameters sampled July 24–29 and August 22–26, 1994			
Temperature, water (^oC)	00010	NA	0.1
Barometric pressure (mm of Hg)	00025	NA	1.0
Specific conductance (µS/cm at 25^oC)	00095	NA	1.0
Oxygen, dissolved (mg/L as O_2)	00300	NA	.1
Oxygen, dissolved, percent saturation	00301	NA	1.0
pH (standard units)	00400	NA	.1
Discharge (cubic feet per second)	00060	NA	NA
Parameters sampled August 22–26, 1994			
Nitrogen, ammonia, filtered (mg/L as N)	00608	LC0830	.002
Nitrogen, ammonia plus organic, filtered (mg/L as N)	00623	LC1687	.2
Nitrogen, ammonia plus organic, total (mg/L as N)	00625	LC1688	.2
Nitrogen, nitrite, filtered (mg/L as N)	00613	LC0827	.001
Nitrogen, nitrate plus nitrite, filtered (mg/L as N)	00631	LC0826	.005
Phosphorus, total (mg/L as P)	00665	LC0837	.001
Phosphorus, filtered (mg/L as P)	00666	LC0829	.001
Phosphorus, orthophosphate, filtered (mg/L as P)	00671	LC0828	.001
Carbonaceous deoxygenation rate at 20^oC (Day^{-1})	82049	NA	NA
Carbonaceous BOD 5-day (mg/L as O_2)	80082	NA	NA
Carbonaceous BOD ultimate (mg/L as O_2)	NA	NA	NA
Deoxygenation rate at 20^oC (Day^{-1})	NA	NA	NA
BOD 5-day (mg/L as O_2)	00310	NA	NA
BOD ultimate (mg/L as O_2)	00319	NA	NA
Productivity, primary, gross [mg O_2/m^3/day]	70959	NA	.1[b]
Chlorophyll *a*, phytoplankton, fluorometric (µg/L)	70953	NA	.1
Chlorophyll *a*, periphyton, fluorometric (mg/m^2)	70957	NA	.1
Periphyton, biomass, total dry weight (g/m^2)	00573	NA	.001
Periphyton, total ash weight (g/m^2)	00572	NA	.001

[a]Applies to field or NWQL analyses.
[b]Estimated from Strickland and Parsons, 1972.

Table 2. Sampling sites and periods for the upper Willamette River Basin dissolved oxygen and pH study, 1994

[Station ID, station identification number; Site code, code defining each study site, where A, Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie River reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P, Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork River reach from RM 21.7 to RM 12.5; Site type where M, main stem, T, tributary; River mile, river mile associated with main stem, including tributary-main stem confluence; Sampling period where J, July 25-29, 1994, A, August 21-25, 1994; ND, not determined]

Station ID	Latitude	Longitude	Site name	Sampling period	Site code	Site type	River mile
434830123025400	434830	1230254	Coast Fork Willamette River at Cottage Grove, OR	J,A	C1	M	21.7
ND	ND	ND	Cottage Grove sewage treatment plant at Coast Fork Willamette River at Cottage Grove, OR	A	C2	P	21.5
434839123024800	434839	1230248	Coast Fork Willamette River at RM 21.4 at Cottage Grove, OR	J,A	C3	M	21.4
434850123121700	434850	1230217	Row River at I-5 Bridge at Cottage Grove, OR	A	C4	T	20.7
434958123022800	434958	1230228	Coast Fork Willamette River at Saginaw, OR	J,A	C5	M	20.0
435150123005600	435150	1230053	Coast Fork Willamette River at Lynx Hollow near Saginaw, OR	J,A	C6	M	16.9
435357122595500	435357	1225955	Coast Fork Willamette River at RM 13.9 near Creswell, OR	J,A	C7	M	13.9
435457122591800	435457	1225918	Coast Fork Willamette River at Cloverdale Road near Creswell, OR	J,A	C8	M	12.5
440402122540600	440402	1225406	McKenzie River at RM 19.3 at Camp Creek, OR	J,A	M1	M	19.3
440413122541800	440413	1225418	McKenzie River at RM 18.9 at Bellinger Landing, OR	J	M2	M	18.9
440357122552000	440357	1225520	McKenzie River at RM 17.9 at Springfield, OR	J	M3	M	17.9
440418122561200	440418	1225612	McKenzie River at RM 16.8 at Springfield, OR	J	M4	M	16.8
440400122565600	440400	1225656	McKenzie River at RM 16.4 at Springfield, OR	J	M5	M	16.4
440342122571400	440342	1225714	McKenzie River at RM 16.0 at Springfield, OR	J	M6	M	16.0
440351122580300	440351	1225803	McKenzie River upstream of Marcola Road at Springfield, OR	J	M7	M	15.3
440420122574700	440420	1225747	McKenzie River at Marcola Road at Springfield, OR	J,A	M8	M	14.8
ND	ND	ND	Kraft mill at McKenzie River at Springfield, OR	A	M9	P	14.5
440430122575500	440430	1225755	McKenzie River at RM 14.5 at Springfield, OR	J	M10	M	14.5
440442122580400	440442	1225804	McKenzie River at RM 14.3 downstream of Marcola Road at Springfield, OR	J,A	M11	M	14.3
14165000	440534	1225720	Mohawk River at Springfield, OR	A	M12	T	13.7
440508122581200	440508	1225812	McKenzie River at RM 13.6 at Springfield, OR	J,A	M13	M	13.8
440508122583100	440508	1225831	McKenzie River at RM 13.6 at Springfield, OR	J	M14	M	13.6
440458122583700	440458	1225837	McKenzie River at RM 13.4 at Springfield, OR	J,A	M15	M	13.4
440451122590400	440451	1225904	McKenzie River at RM 13.0 at Springfield, OR	J,A	M16	M	13.0
440443123000000	440443	1230000	McKenzie River at RM 12.1 at Springfield, OR	A	M17	M	12.1
440444123002000	440444	1230020	McKenzie River at RM 11.8 at Springfield, OR	J	M18	M	11.8
440454123012000	440454	1230120	McKenzie River at RM 10.4 at Springfield, OR	J,A	M19	M	10.4

Table 2. Sampling sites and periods for the upper Willamette River Basin dissolved oxygen and pH study, 1994—Continued

[Station ID, station identification number; Site code, code defining each study site, where A, Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie River reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P, Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork River reach from RM 21.7 to RM 12.5; Site type where M, main stem, T, tributary; River mile, river mile associated with main stem, including tributary-main stem confluence; Sampling period where J, July 25-29, 1994, A, August 21-25, 1994; ND, not determined]

Station ID	Latitude	Longitude	Site name	Sampling period	Site code	Site type	River mile
440527123012300	440527	1230123	McKenzie River at RM 9.5 at Deadmond Ferry, OR	J,A	M20	M	9.5
14165500	440645	1230245	McKenzie River at Armitage RR Bridge near Springfield, OR	J	M21	M	7.1
442136123132700	442136	1231327	Willamette River at RM 151.4 near Peoria, OR	J,A	P1	M	151.4
442146123130800	442146	1231308	Willamette River at RM 151.0 at Irish Bend near Peoria, OR	J,A	P2	M	151.0
44211123132300	442111	1231323	Willamette River at RM 150.4 near Peoria, OR	J	P3	M	150.4
442235123142400	442235	1231424	Willamette River at RM 149.4 upstream of Norwood Island near Peoria, OR	J,A	P4	M	149.4
442320123134200	442320	1231342	Willamette River at RM 147.6 upstream of kraft mill near Peoria, OR	J,A	P5	M	147.6
ND	ND	ND	Pulp and Paper mills at Willamette River near Peoria, OR	A	P6	P	147.4
442340123131900	442340	1231319	Willamette River at RM 147.4 at pulp and paper mills near Peoria, OR	J,A	P7	M	147.4
442343123132000	442343	1231320	Willamette River at RM 147.2 downstream of pulp and paper mills near Peoria, OR	J	P8	M	147.2
442411123133000	442411	1231330	Willamette River at RM 146.6 downstream pulp and paper mills near Peoria, OR	J,A	P9	M	146.6
442439123135700	442439	1231357	Willamette River at RM 146.0 upstream of Long Tom River near Peoria, OR	A	P10	M	146.0
442444123135800	442444	1231358	Long Tom River at Mouth near Peoria, OR	A	P11	T	145.9
442445123135600	442445	1231356	Willamette River downstream of Long Tom River near Peoria, OR	J,A	P12	M	145.8
442511123130300	442511	1231303	Willamette River at RM 144.8 near Peoria, OR	J	P13	M	144.8
442519123131300	442519	1231313	Willamette River at RM 144.6 near Peoria, OR	J,A	P14	M	144.6
442623123121900	442623	1231219	Willamette River at RM 142.5 near Peoria, OR	J,A	P15	M	142.5
442713123123500	442713	1231235	Willamette River at RM 141.6 at Peoria, OR	J,A	P16	M	141.6
443207123145500	443207	1231455	Willamette River at water treatment plant at Corvallis, OR	J,A	W1	M	134.2
443311123150600	443311	1231506	Willamette River at Willamette Park at Corvallis, OR	J,A	W2	M	132.6
443138123120901	443138	1231209	Muddy Creek at Peoria Road near Peoria, OR	A	W3	T	132.6
443315123150600	443315	1231506	Muddy Creek at mouth at Corvallis, OR	A	W4	T	132.6
443316123152300	443316	1231523	Willamette River at RM 132.3 downstream of Muddy Creek at Corvallis, OR	A	W5	M	132.3
443320123153500	443320	1231535	Willamette River at RM 132.2 upstream of Marys River at Corvallis, OR	J	W6	M	132.2
443321123153800	443321	1231538	Marys River at mouth at Corvallis, OR	A	W7	T	132.1
443330123153600	443330	1231536	Willamette River at RM 131.9 at Highway 99 Bridge at Corvallis, OR	J,A	W8	M	131.9

Table 2. Sampling sites and periods for the upper Willamette River Basin dissolved oxygen and pH study, 1994—Continued

[Station ID, station identification number; Site code, code defining each study site, where A, Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie River reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P, Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork River reach from RM 21.7 to RM 12.5; Site type where M, main stem, T, tributary; River mile, river mile associated with main stem, including tributary-main stem confluence; Sampling period where J, July 25-29, 1994, A, August 21-25, 1994; ND, not determined]

Station ID	Latitude	Longitude	Site name	Sampling period	Site code	Site type	River mile
443342123152900	443342	1231529	Willamette River at RM 131.7 upstream of Highway-34 Bridge at Corvallis, OR	J,A	W9	M	131.7
443354123151500	443354	1231515	Willamette River at RM 131.4 at Highway 34 Bridge at Corvallis, OR	J,A	W10	M	131.4
443413123151300	443413	1231513	Willamette River at RM 131.1 upstream of wastewater treatment plant at Corvallis, OR	J,A	W11	M	131.1
ND	ND	ND	Corvallis waste water treatment plant at Willamette River at Corvallis, OR	A	W12	P	131.0
443427123150000	443427	1231500	Willamette River at RM 130.7 downstream of waste water treatment plant, OR	J,A	W13	M	130.7
443456123135200	443456	1231352	Willamette River at RM 129.5 near Corvallis, OR	J,A	W14	M	129.5
443504123125500	443504	1231255	Willamette River at RM 128.7 near Corvallis, OR	J	W15	M	128.7
443512123115800	443512	1231158	Willamette River at RM 128.0 near Corvallis, OR	J,A	W16	M	128.0
443509123112400	443509	1231124	Willamette River at RM 127.4 at Half Moon Bend near Corvallis, OR	J	W17	M	127.4
443515123110100	443515	1231101	Willamette River at RM 127.1 at Half Moon Bend near Corvallis, OR	J,A	W18	M	127.1
433536123105500	433536	1231055	Willamette River at RM 126.7 downstream of Half Moon Bend near Corvallis, OR	J,A	W19	M	126.7
443815123090100	443815	1230901	Willamette River at RM 121.5 near Albany, OR	J	A1	M	121.5
443813123084800	443813	1230848	Willamette River at RM 121.3 near Albany, OR	J	A2	M	121.3
443817123081900	443817	1230819	Willamette River at RM 121.0 near Albany, OR	J	A3	M	121.0
443825123063400	443825	1230634	Calapooia River at Mouth at Albany, OR	J	A4	M	119.5
443820123061100	443820	1230611	Willamette River at RM 119.2 at Albany, OR	J	A5	M	119.2
443828123054300	443828	1230543	Willamette River at RM 118.7 at Albany, OR	J	A6	M	118.8
443837123050700	443837	1230507	Willamette River at RM 118.3 at Albany, OR	J	A7	M	118.3
443846123043600	443846	1230436	Willamette River at RM 117.8 at Albany, OR	J	A8	M	117.8
443853123042400	443853	1230424	Willamette River at RM 117.6 downstream of Albany, OR	J	A9	M	117.6
443937123042700	443937	1230427	Willamette River at RM 116.8 downstream of Albany, OR	J	A10	M	116.8
444002123050500	444002	1230505	Willamette River at RM 116.1 downstream of Albany, OR	J	A11	M	116.1
444021123051100	444021	1230511	Willamette River at RM 115.7 upstream of 4th Lake near Albany, OR	J	A12	M	115.6
444034123053100	444034	1230531	Willamette River at RM 115.4 downstream of 4th Lake near ALBANY OR	J	A13	M	115.4
444029123062100	444029	1230621	Willamette River at RM 114.5 downstream of Albany, OR	J	A14	M	114.5

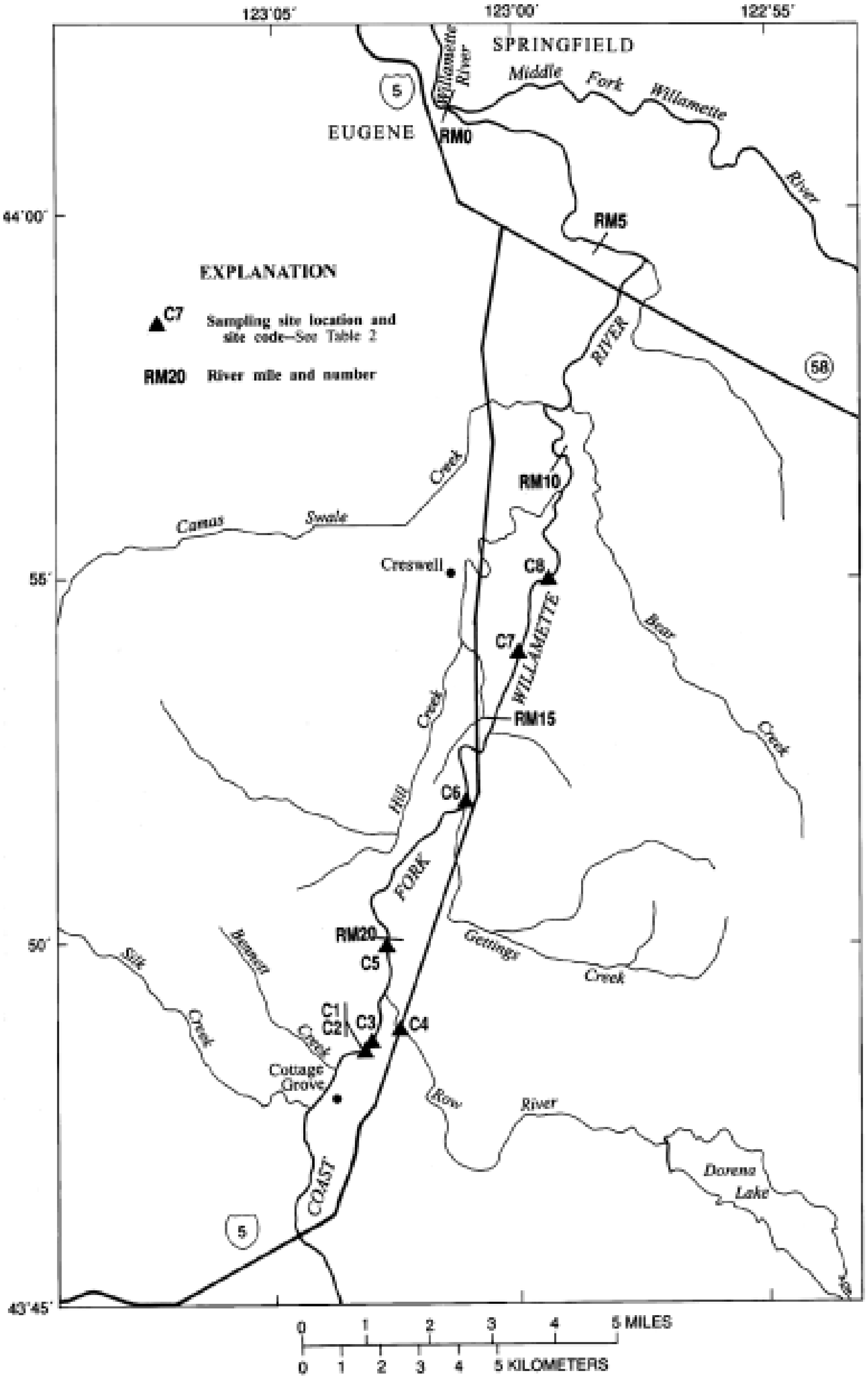


Figure 4. Sampling locations in the Coast Fork Willamette River Basin, July and August 1994.

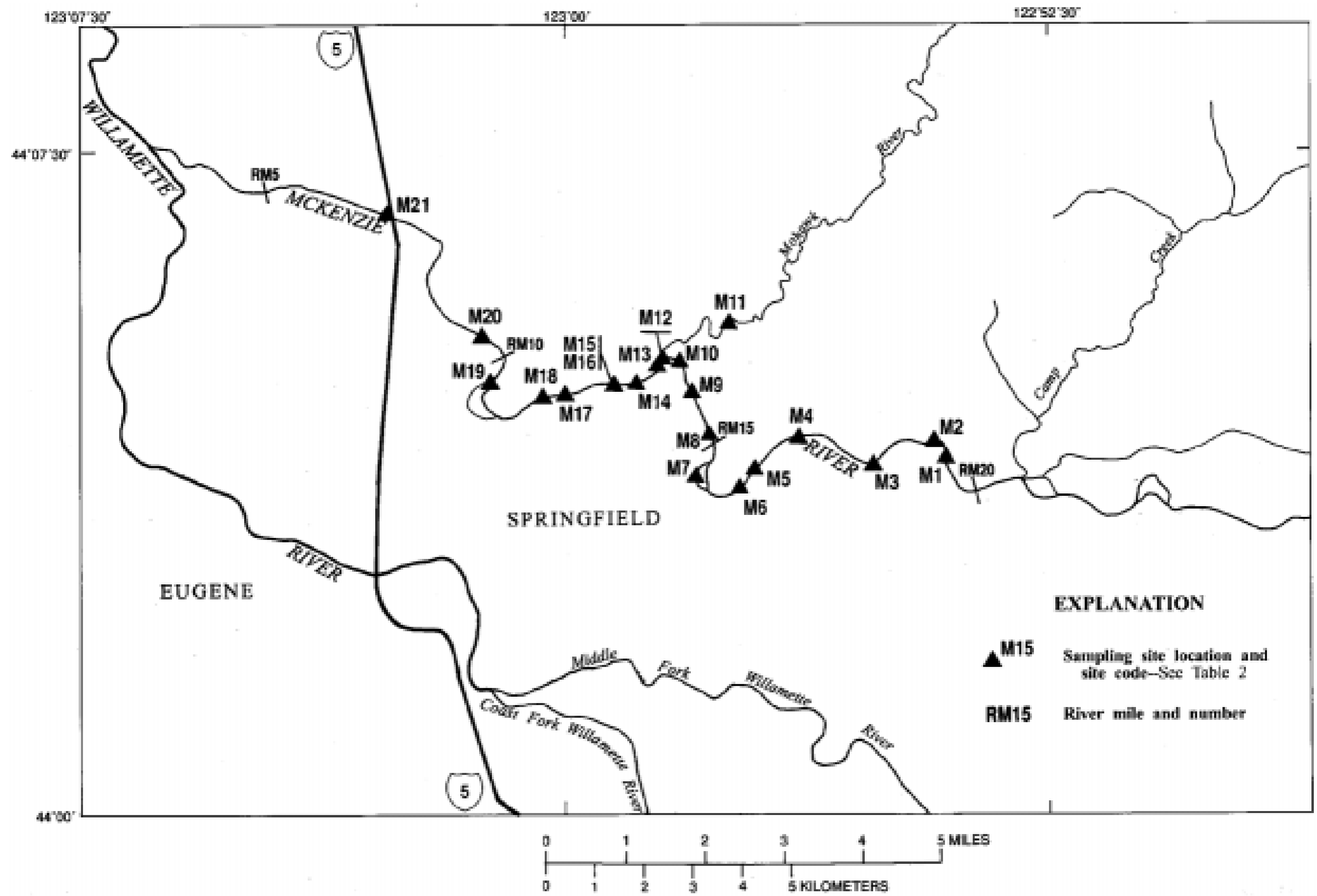


Figure 5. Sampling locations in the McKenzie River Basin, July and August 1994.

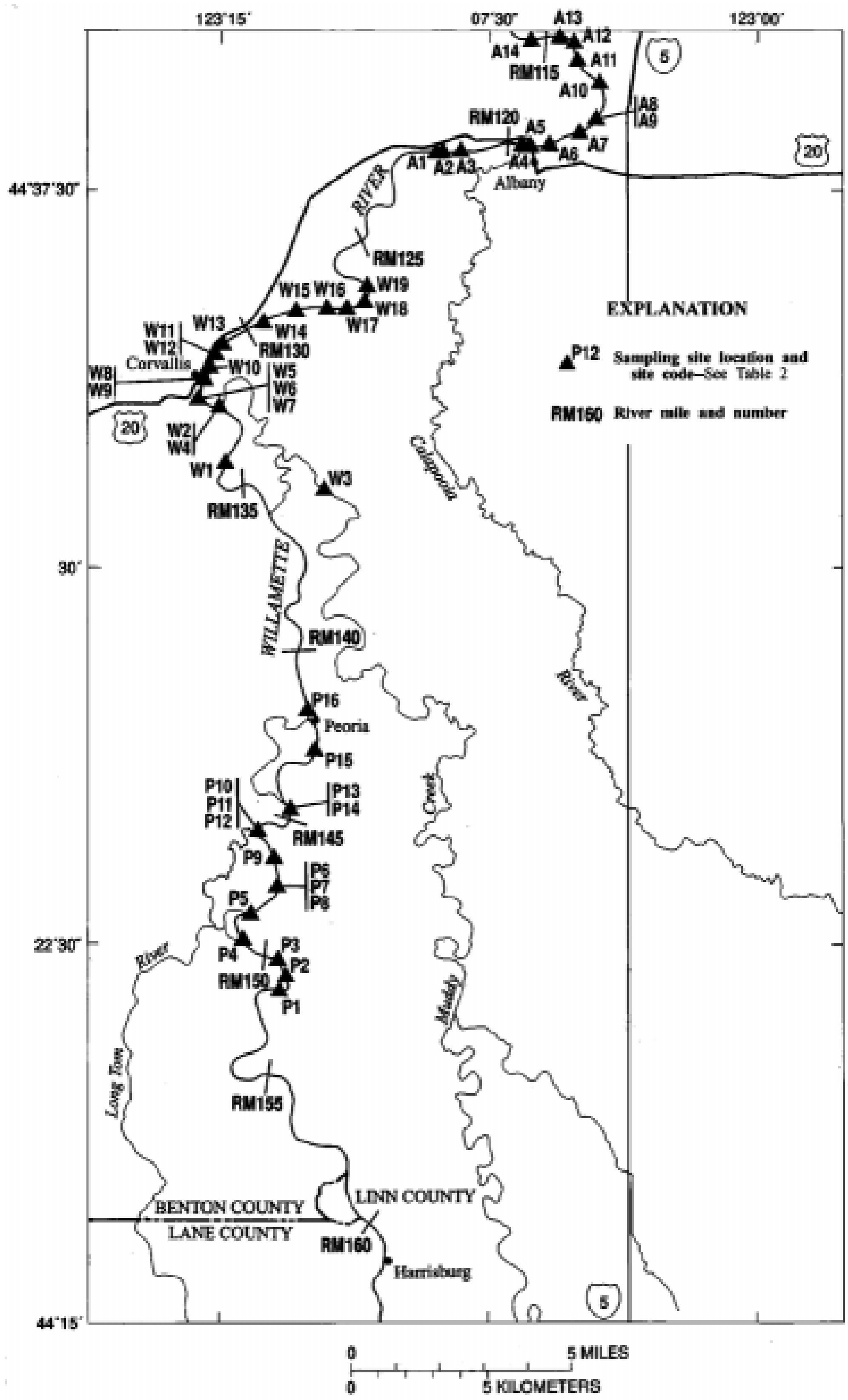


Figure 6. Sampling location in the Peoria, Corvallis, and Albany reaches of the main stem Willamette River, July and August 1994.

limited” for DO (Oregon Department of Water Quality, 1994). Within this lower reach, the river receives several point-source effluents and a tributary input from an agricultural subbasin. The most significant point-source effluent entering the river is from a kraft pulp mill at RM 14.6; the effluent has been shown to contribute to increased nutrient concentrations and algal productivity in a laboratory channel (Bothwell, 1992). The agricultural subbasin, drained by the Mohawk River, which enters the McKenzie River at RM 13.7, is a source of local concern for several water-quality constituents, including nutrients, fecal-indicator bacteria, and pesticides (Oregon Department of Environmental Quality, 1995a). Additionally, local interest in water quality in the McKenzie River has increased recently with the formation in 1994 of the McKenzie River Watershed Council (McKenzie River Watershed Council, 1994).

Selection of the Peoria reach (fig. 6) was based on historical data indicating that this reach regularly violated State standards for DO and pH. Concern also existed about the impact on the river of the combined effluent from two pulp mills located near RM 148 and the inflow from the Long Tom River, which drains an agricultural subbasin and enters the Willamette River at RM 145.9. The Long Tom River is considered “water quality limited” for fecal coliform bacteria and DO (Oregon Department of Environmental Quality, 1995a). Additionally, the City of Corvallis withdraws drinking water from the Willamette River at RM 134.2, adding concern regarding the quality of water upstream from the intake.

Within the Corvallis reach, two significant tributaries, the Marys River and Muddy Creek, drain agricultural lands and possibly contribute nutrients, BOD, and water low in DO to the Willamette River. Additionally, the Corvallis Wastewater Treatment Plant discharges to the Willamette River at RM 131, contributing nutrients and BOD to the river. The Willamette River has been proposed for listing as “water-quality limited” for DO within the Corvallis reach (Oregon Department of Environmental Quality, 1994). Also, data collection in the Corvallis reach complements the hourly monitor data from the Corvallis WTP intake (RM 134.2).

The Albany reach (fig. 6) incorporates flow from the Calapooia River, a tributary that drains agricultural lands, and several point sources, including industrial and municipal waste effluents (Oregon Department of Environmental Quality, 1994). The Willamette River at Albany has been proposed for listing as “water-quality limited” by ODEQ (1994) at their Albany monitoring location (RM 119.3) because of fecal coliform bacteria.

Several factors contribute to the timing of diel cycles of DO and pH. At a physical level, warming of the water during the day reduces oxygen solubility in water, contributing to a reduction in the DO concentration. Conversely, photosynthesis by aquatic plants during the day exceeds respiration and increases the DO concentration in the water. The DO concentration usually reaches a peak in the early evening as light begins to wane. Subsequently, respiration by plants at night consumes oxygen and reduces the DO concentration of water. This cycle also affects the pH of water consumption of carbon dioxide (CO_2) during photosynthesis raises the pH, whereas production of CO_2 during respiration lowers the pH. The result is that both pH and DO tend to increase and decrease simultaneously, with daily minima in the morning, prior to the onset of photosynthesis, and daily maxima in the evening, prior to the cessation of photosynthesis. This pattern is especially pronounced in rivers that are subject to periphyton growth and has been noted previously in streams in the western slope of the Cascades (D.Q. Tanner and C.W. Anderson, USGS, unpub. data, 1994).

In order to measure DO and pH at the daily minima and maxima in their cycles, the hourly record at the continuous monitor at the Corvallis WTP (RM 134.2) was examined to ascertain the times that those occurred. The daily minimum DO generally occurred between 0530 and 0900 hours, whereas the daily maximum generally occurred between 1600 and

1900 hours. Times for daily minimum and maximum pH were similar to those for DO. On the basis of these data, diel sampling for minimum DO and pH during the July and August synoptic surveys was done between 0530 and 0900 hours, and sampling for the maximum DO and pH was done between 1530 and 1900 hours (table 3). As a check on the timing and patterns of diel measurements in individual reaches of DO and pH reach monitors were installed at the upstream and downstream ends of each reach except where otherwise noted. The monitors recorded field measurements hourly or semi-hourly.

The July synoptic survey was primarily a reconnaissance, providing data to determine the reaches of interest for intensive study in August. The July and August periods are of interest relative to streamflow, sunlight, and water temperature, which affect photosynthetic activity and water quality. July and August are typically the warmest and driest months in the Willamette Valley. Although streamflow is augmented by reservoir releases, discharge in the Willamette River and its tributaries tends to be at a minimum and relatively stable over these 2 months, maximizing the adverse effects of point sources. These conditions also promote maximum photosynthetic activity and algal abundance. Other demands on DO, such as BOD, are generally constant throughout the year and therefore maximized by low-flow conditions, making July and August critical in assessing total water-quality impacts on DO and pH. Therefore, July and August were selected for intensive study to provide a worst-case scenario for DO and pH conditions in the upper Willamette River Basin. It should be noted, however, that DO concentrations may be low in June, September, and October as well, but resources were unavailable to sample throughout the summer season.

Table 3. Reach sampling times and reach dissolved oxygen saturation minimum and maximum times in the upper Willamette River Basin, July 24–29 and August 22–26, 1994

[--, no data; Coast Fork, Coast Fork Willamette River from RM 21.7 to 12.5; McKenzie, McKenzie River from RM 19.3 to 7.1; Peoria, Willamette River from RM 151.4 to 141.6; Corvallis, Willamette River from RM 132.6 to 126.7; Albany, Willamette River from RM 121.5 to 114.5]

River reach	River mile of monitor location	Morning sampling			Afternoon sampling		
		Sampling date	Reach sampling time	Monitor minimum time	Sampling date	Reach sampling time	Monitor maximum time
July 25–29, 1994							
Coast Fork	21.7	7/25	0541–0707	0700	7/24	1518–1838	1800
Coast Fork	16.9	7/25	0541–0707	0600	7/24	1518–1838	1630
McKenzie	19.3	7/26	0621–0808	0630	7/25	1602–1905	1600
McKenzie	10.4	7/26	0621–0808	0600	7/25	1602–1905	1700
Peoria	141.6	7/27	0609–0758	0730	7/26	1615–1900	1830
Corvallis	126.7	7/28	0557–0736	0700	7/27	1613–1809	1830
Albany	121.5	7/29	0557–0748	0900	7/28	1602–1823	1800
Albany	114.5	7/29	0557–0748	0900	7/28	1602–1823	1800
August 22–26, 1994							
Coast Fork	21.7	8/23	0559–0722	--	8/22	1529–1749	1700
Coast Fork	16.9	8/23	0559–0722	0630	8/22	1529–1749	1600
McKenzie	10.4	8/24	0716–0827	0630	8/23	1548–1700	1630
Peoria	151.4	8/25	0648–0841	0730	8/24	1558–1745	1800
Peoria	141.6	8/25	0648–0841	0830	8/24	1558–1745	1800
Corvallis	126.7	8/26	0702–0825	--	8/25	1549–1721	1730

METHODS

Sample Collection and Analysis

In the Coast Fork Reach, all sites were accessible by road and were wadeable for purposes of making field measurements and collecting water samples. In the four other reaches, all field measurement and sampling was done by boat except at point sources and in some tributaries. Discharge was measured at miscellaneous sites according to standard USGS guidelines (Buchanan and Somers, 1984). River water samples were collected using the Equal Width Increment (EWI) method—a depth-width integrating technique described by Edwards and Glysson (1988)—and were composited into 8-liter churn splitters. ODEQ personnel collected point-source samples, which were either grab samples or time composited samples.

Field measurements of temperature, specific conductance, pH, and DO were made with calibrated Hydrolab multiparameter water-quality instruments adapted for low-ionic strength waters. Field measurements at a site generally were made in at least three locations in a cross-section and the values averaged. Field parameters were measured in the early morning (0530–0900) and late afternoon (1530–1900) to obtain daily minimum and maximum pH and DO concentrations. Field parameters were also measured during water-sample collection at all sites regardless of time of day.

In each reach, field parameters were measured hourly or semi-hourly at two sites using Hydrolabs attached to stakes driven into the river bottom. Where possible, probes were positioned near the centroid of flow; otherwise, they were located at the river's edge. These monitors were installed prior to the evening peaks in DO and pH and were removed after the morning minimum, providing records 16 to 20 hours in length. Additionally, the continuous monitor at the Corvallis WTP was in place for approximately 4 months, July through October, to record seasonal variation. Data recorded automatically were downloaded to a laptop computer and subsequently transferred to a USGS database.

Water samples for nutrient analyses were processed immediately in the field and prepared for shipment to the USGS National Water Quality Laboratory (NWQL). Subsamples were taken from a churn splitter, with unfiltered subsamples drawn first. Subsamples for filtered nutrient analysis were filtered through a prerinsed, 47-millimeter diameter, 0.45-micrometer pore-size membrane filter. Nutrient samples were preserved with mercuric chloride and stored on ice in opaque polypropylene bottles. Preserved samples were shipped on ice to the NWQL where they were kept chilled at 4 ^{o}C (degrees Celsius) until analysis. Nutrient analyses were performed within 7 days of delivery to the NWQL. Analyses were performed according to the procedures described by Fishman and Friedman (1989).

BOD and CBOD samples were withdrawn in duplicate from the churn splitter in precleaned glass BOD bottles and stored on ice. Samples were transported nightly to the USGS Oregon District Laboratory (ODL). Once in the ODL, the CBOD sample was inhibited with sodium sulfate. The BOD and CBOD samples were adjusted to 20 ^{o}C, saturated with air, and the DO concentrations measured with a Yellow Springs Instruments DO probe fitted with a stirrer. After initial saturation with air, no further aeration was needed. Samples were incubated at 20 ^{o}C in a dark incubator. DO was measured daily in each bottle for the first 5 days, followed by measurements every other day until day 15, followed by measurement every 3rd or 4th day until at least day 24. BOD and CBOD rates and ultimates were calculated utilizing a least-squares regression of the Lee's Grid method (log base 10) described by Velz (1970). Five-day BOD and CBOD were determined for each site using the calculated rates to ensure consistency. NBOD was determined by calculating the difference between BOD and CBOD.

Water-column primary-productivity samples were analyzed in duplicate. Two light BOD bottles and two dark BOD bottles were filled from the churn splitter, and the initial DO was recorded. The bottles were incubated for 2 to 4 hours in the river at the sampling location or (to allow mobility) in a river-water bath kept at a temperature near that of the sampling location. The final DO was measured at the end of the incubation period. In some instances, insufficient light was available for incubation due to the time of sample collection. These samples were chilled on ice overnight. The following day, samples were allowed to equilibrate to ambient river-water temperature and then incubated during full sunlight.

Water-column samples of phytoplankton algae were collected from the churn splitter. Samples for chlorophyll *a* were filtered through 47-millimeter glass-fiber filters and the sample volume noted. Filtered samples were then stored on dry ice and sent to the ODL for analysis.

Periphyton algae samples for chlorophyll *a* and biomass were collected from rocks using the method described by Porter and others (1993). Rocks for sampling were selected primarily from the richest habitat available (usually a riffle or other area of higher relative velocity). Due to the large number of sites sampled and time considerations associated with working by boat, the prescribed number of rocks and scrapings was altered from 25 scrapings (5 scrapings on 5 rocks) to 9 scrapings (3 scrapings on 3 rocks). The resulting algal slurry from each set of 9 scrapings was blended and diluted to 500 milliliters with distilled-deionized water. Known aliquots for biomass were filtered in triplicate through pretared 47-millimeter glass-fiber filters. Known aliquots for chlorophyll *a* were filtered in triplicate through 47-millimeter glass-fiber filters. The filters were stored on dry ice and sent to the ODL for analysis.

Periphyton and phytoplankton chlorophyll *a* was analyzed flourometrically at the ODL, according to methods described in American Public Health Association (1989). Periphyton biomass was analyzed gravitimetrically at the ODL, also according to methods described in American Public Health Association (1989) at the ODL.

Quality Assurance

Quality assurance was incorporated into the sampling design in a variety of ways, including (1) pre- and post-calibration of multiparameter water-quality probes (Hydrolabs), (2) weekly to biweekly calibration of the continuous monitor located at the Corvallis WTP, and (3) collection of field and equipment blank samples.

On a daily basis, Hydrolabs were calibrated immediately before to use, according to the manufacturers recommendations. Calibration results were recorded in maintenance logbooks for each instrument. Slight linear shifts were applied to temperature, specific conductance, pH, and DO when calibration differences exceeded 0.2 ^{o}C, 5 percent, 0.2 pH units, and 0.2 mg/L (milligrams per liter), respectively. Similarly, the continuous monitor at Corvallis was calibrated weekly to semi-monthly. Data from the hourly monitor near Corvallis WTP were shifted on the basis of field calibration results. USGS techniques for the computation of streamflow records (Kennedy, 1983) were used to shift and correct water-quality data from these monitors.

Field blank samples were collected during the August synoptic sampling trips. Blank water, free of inorganic compounds, was obtained from and certified by the USGS field supply laboratory in Ocala, Florida. Blanks were preserved and treated identically to field samples. No evidence of sample contamination was noted. All data, including blank results, are stored in the USGS WATer STOrage and REtrieval System (WATSTORE).

Due to logistical and financial constraints, quality assurance for algae samples was limited to determination of analytical variability. For chlorophyll *a* and ash-free dry weight (AFDW), each of the filters from the triplicate filtering of each algae sample was analyzed independently. The triplicate analyses for each sample were averaged to minimize analytical variability. No replicate sampling was done.

STATUS OF DISSOLVED OXYGEN AND pH

DO and pH in the study reaches of the upper Willamette Basin varied temporally and spatially during the study periods of July 24–29 and August 22–26, 1994. The record of the continuous monitor from the Willamette River at the Corvallis WTP at RM 134.2 from July 21 to October 26, 1994, gives further evidence of temporal variability. Examination of the study period data in conjunction with the continuous monitor record reveals temporal and spatial patterns of DO and pH.

Temporal Variability

The record from the continuous monitor at the Corvallis WTP (RM 134.2) typifies the pattern of diel variations observed in the study reaches (figs. 7, 8, 9). The variations were cyclical, with minimum DO and pH measured in the morning, approximately 0530 to 0900 hours, and maximum DO and pH measured in the afternoon, approximately 1530 to 1900 hours. DO saturation at the continuous monitor typically ranged from 85 to 90 percent of saturation in the morning to 105 to 115 percent of saturation in the afternoon, a fluctuation from minimum to maximum of about 1.5 to 2 mg/L. Values of pH ranged from 7.2 to 7.3 in the morning and 8.0 to 8.4 in the afternoon. Additionally, during the July 21 through October 25 period, the Corvallis WTP continuous monitor recorded seasonal variation in DO and pH.

The magnitude of daily DO and pH fluctuation was generally constant from July through September with some notable exceptions. From August 11 to 24, 1994, daily minimum and maximum DO saturation generally increased. From August 24 to 30, 1994, daily minimum and maximum DO saturation generally decreased. During these periods, daily minimum DO saturation increased from 86 percent on August 11 to a peak of 96 percent on August 24 and then decreased to 87 percent on August 30, 1994 (fig. 8). Maximum DO saturation had similar patterns.

Although no definite cause is known, the variation in DO saturation might have been due to the increase in flow from the McKenzie River during this period. During August 11–30, the McKenzie River had flows approximately 300 to 500 ft^3/s higher than in July and early August. The resultant 5 to 10 percent increase in main stem flow due to the introduction of additional cooler McKenzie River water might have increased DO saturation. However, the record from the continuous monitor at Corvallis WTP exhibited no coincident drift in pH or water temperature, as might be expected from an increased proportion of McKenzie River water. Also, comparison between the July and August surveys indicates little variation in DO saturation in individual study reaches, as will be discussed below.

The magnitude of diel fluctuations in DO saturation and pH decreased from late September through October at the continuous monitor. Daily maximum DO saturation, pH, and water temperature decreased from 115 percent, 8.4 pH units, and 19^{o}C, respectively, on September 18, 1994, to 99 percent, 7.7 pH units, and 13^{o}C, respectively, on October 24, 1994 (figs. 7, 8, 9). However, daily minimum DO saturation and pH did not change appreciably during the same period. The decrease in magnitude of diel fluctuations was associated with the effects of cooler water temperatures and decreased insolation on stream processes, suggesting seasonal changes that are related to the transition from summer to fall.

Individual reaches had only minor differences in morning DO saturation and afternoon pH between the July and August study periods (figs. 10 and 11). Median morning DO saturations measured in the Coast Fork, McKenzie, Peoria, and Corvallis reaches

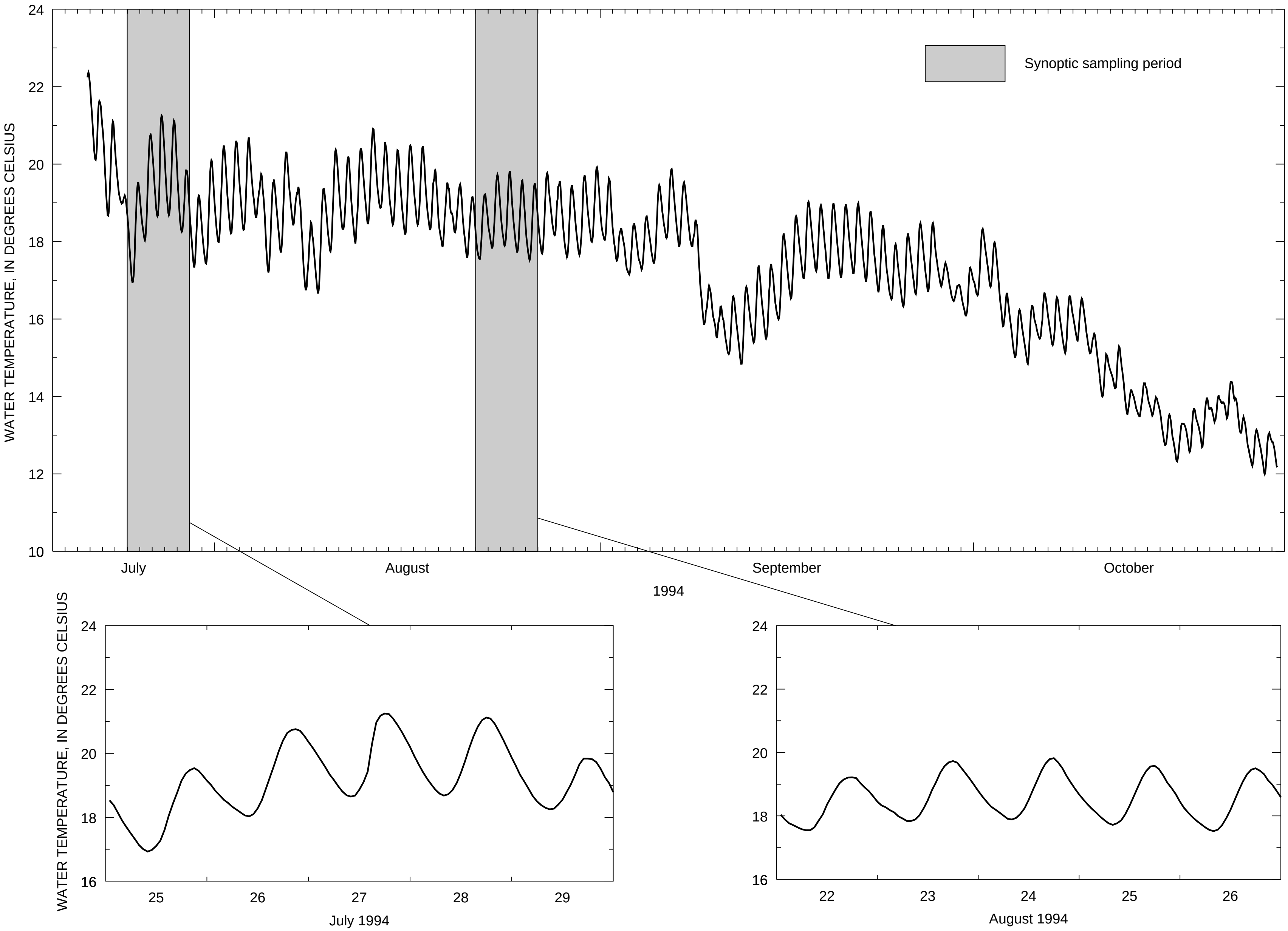


Figure 7. Hourly water temperature in the Willamette River near the Corvallis Water Treatment Plant (river mile 134.2), July 21 to October 25, 1994.

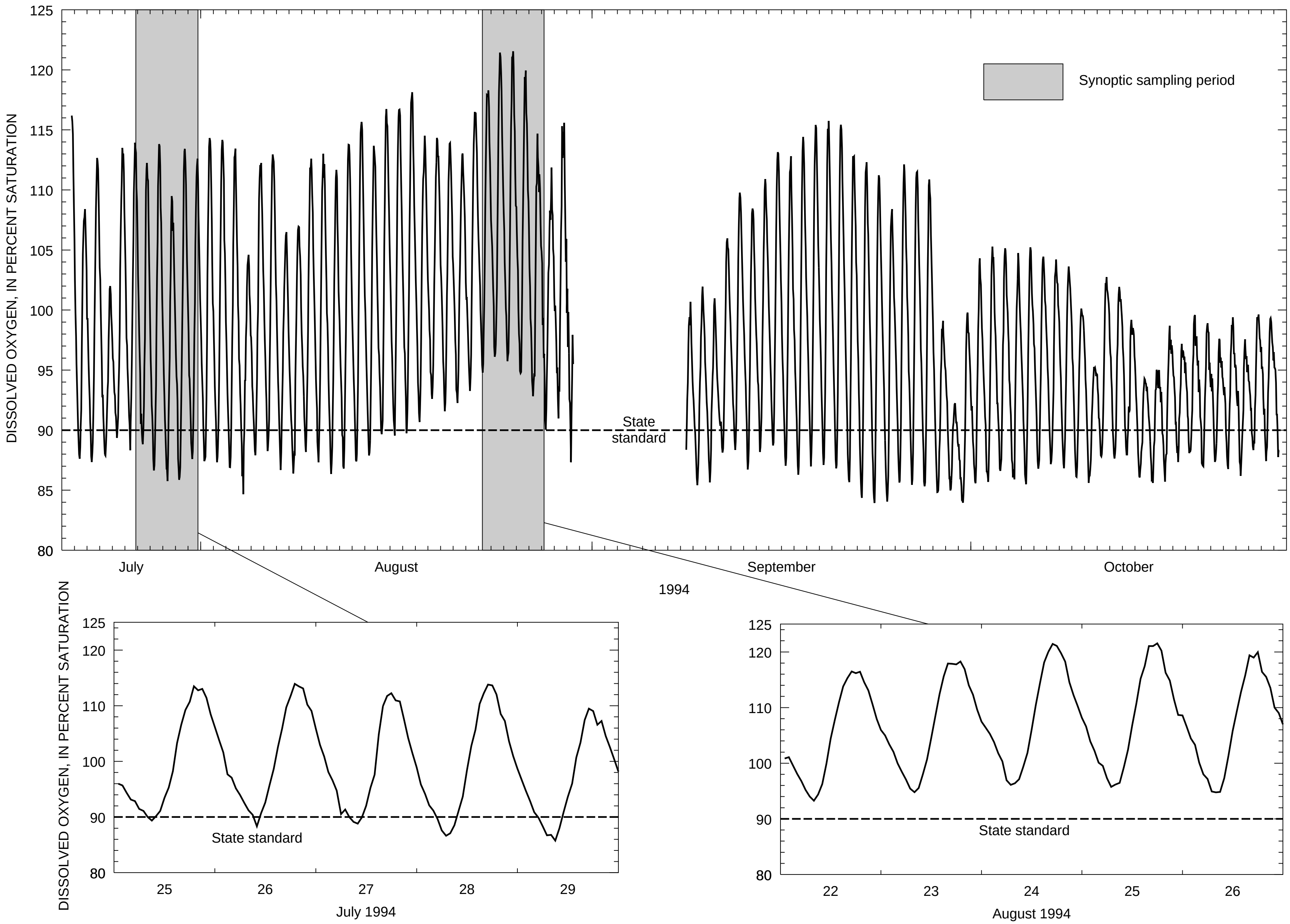


Figure 8. Hourly dissolved oxygen saturation in the Willamette River near the Corvallis Water Treatment Plant (river mile 134.2), July 21 to October 25, 1994.

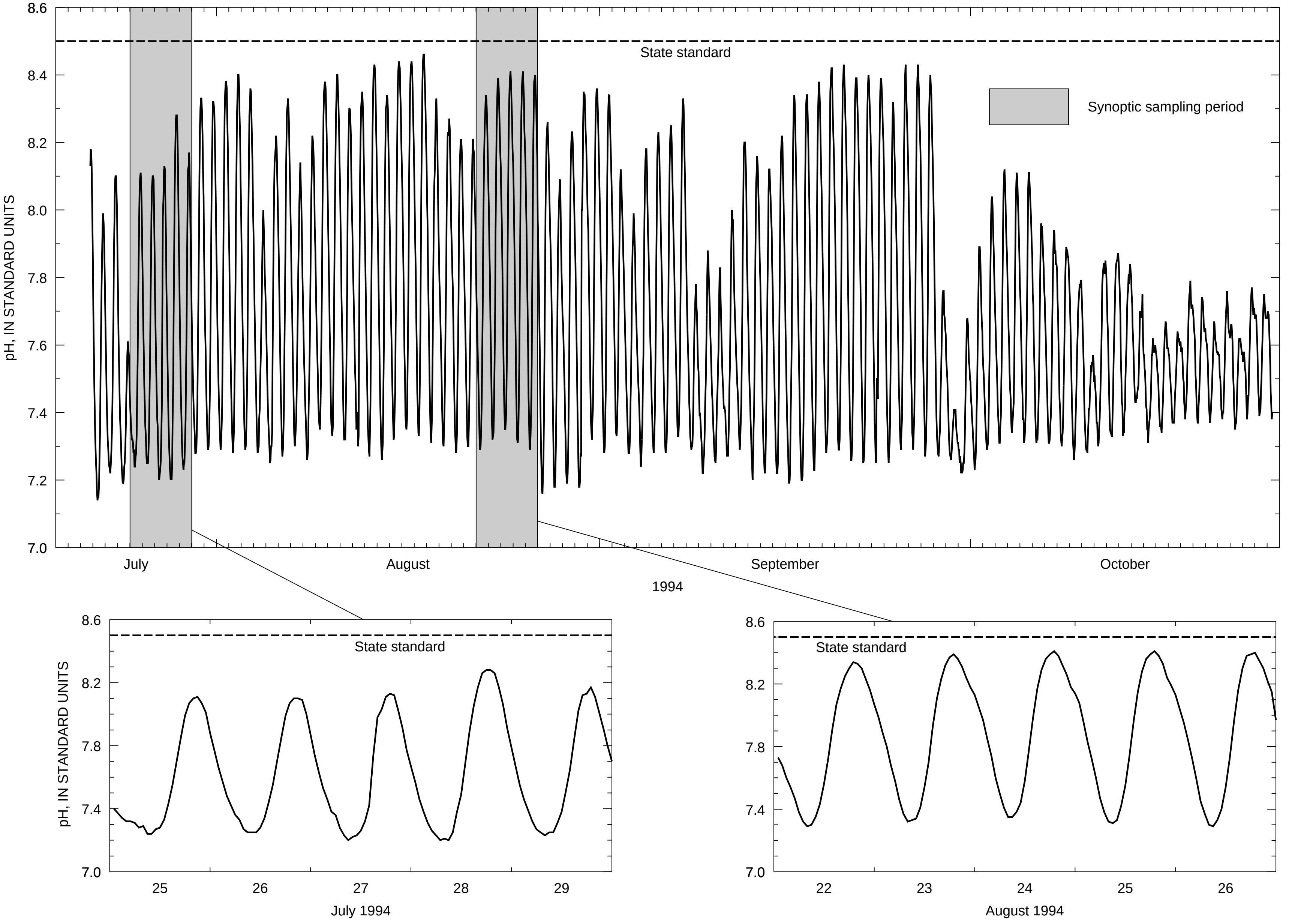
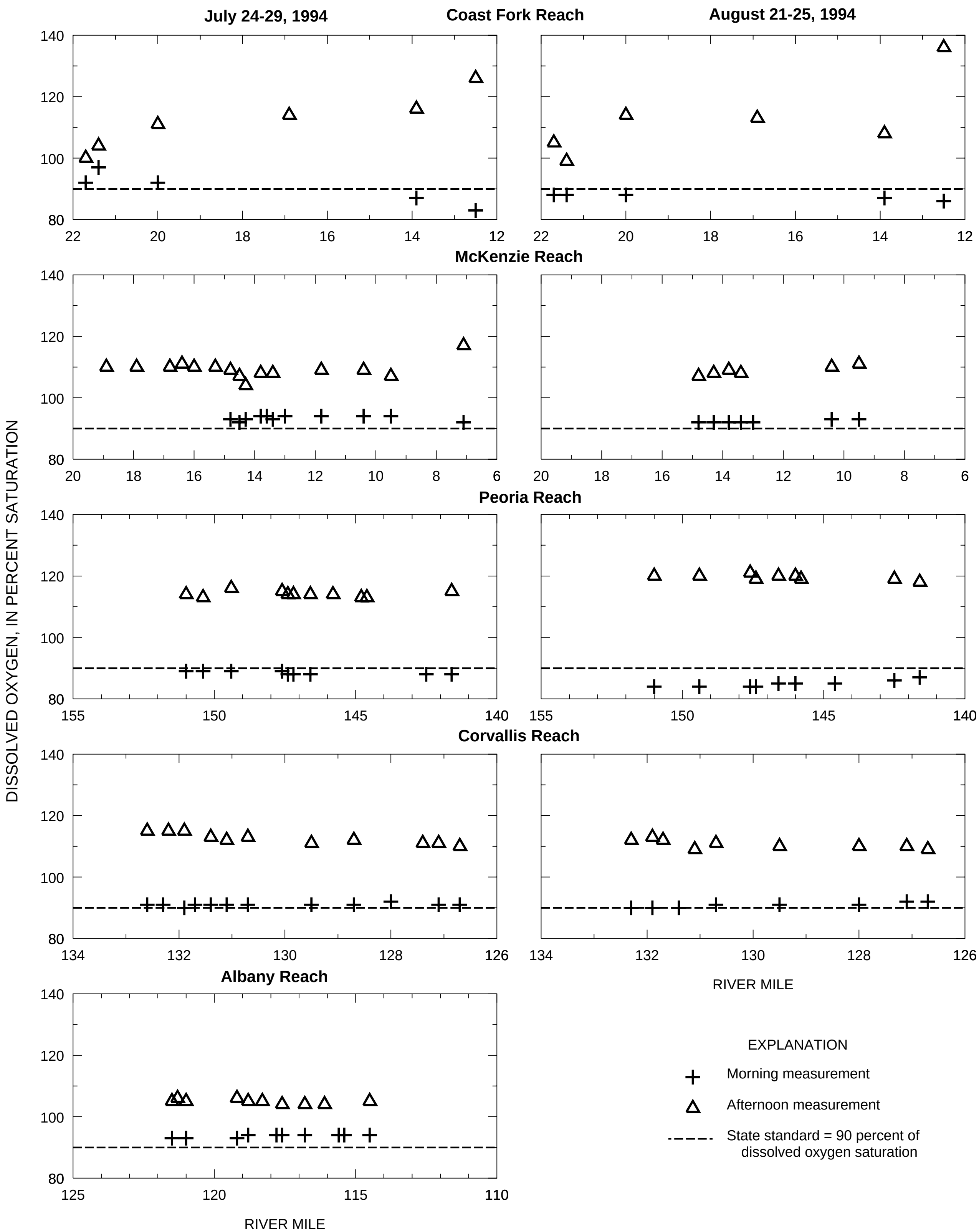
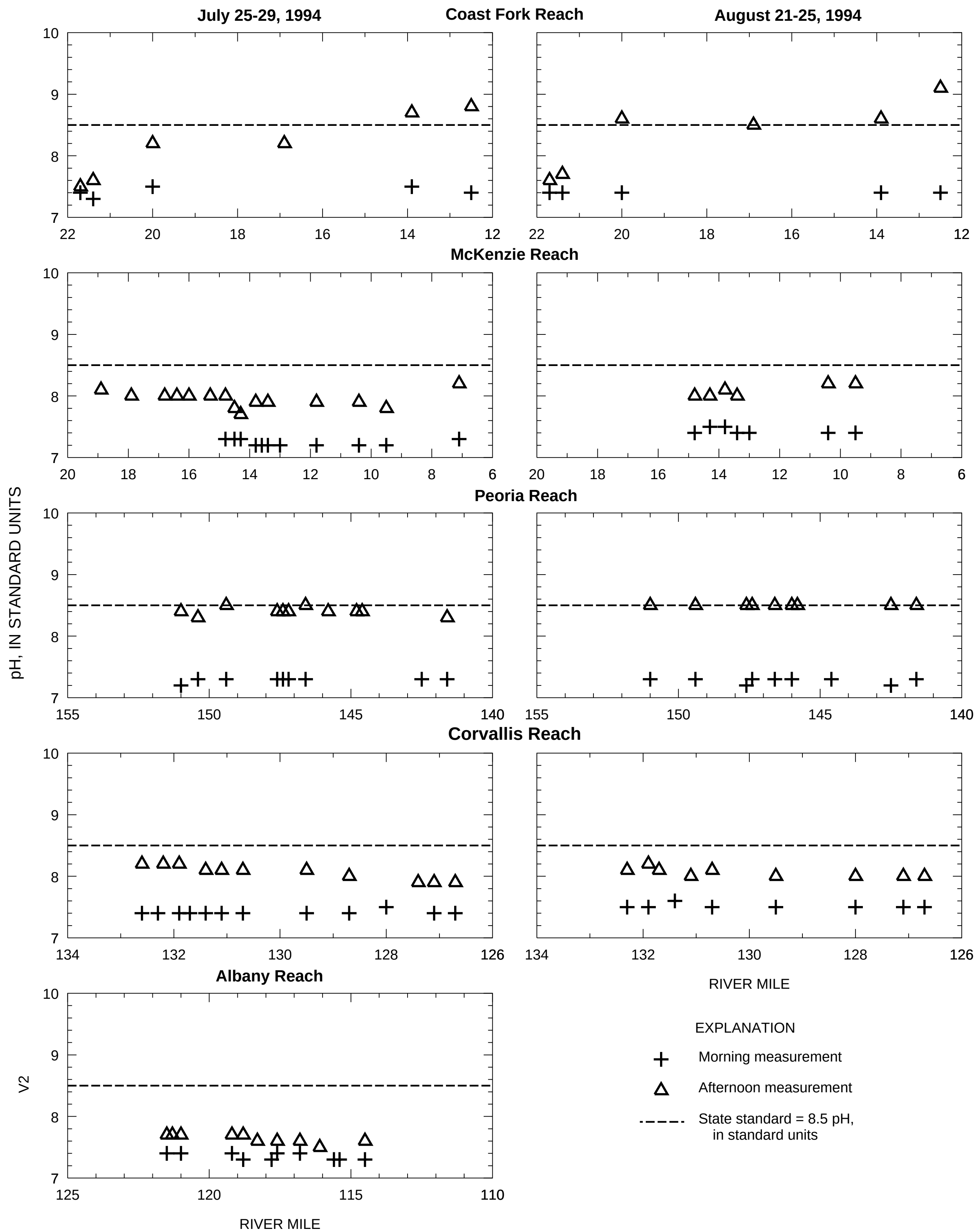


Figure 9. Hourly pH in the Willamette River near the Corvallis Water Treatment Plant (river mile 134.2), July 21 to October 25, 1994.
July 21 to October 25, 1994.



[Coast Fork Reach, Coast Fork River from River MIle (RM) 21.7 to RM 12.5; McKenzie Reach, McKenzie River from RM 19.3 to RM 7.1; Peoria Reach, Willamette River from RM 151.4 to RM 141.6; Corvallis Reach, Willamette River from RM 132.6 to RM 126.7; Albany Reach, Willamette River from RM 121.5 to RM 114.5]

Figure 10. Morning and afternoon dissolved oxygen saturation in study reaches of the upper Willamette River Basin during July 24–29 and August 22–26, 1994



[Coast Fork Reach, Coast Fork River from RM 21.7 to RM 12.5; McKenzie Reach, McKenzie River from RM 19.3 to RM 7.1; Peoria Reach, Willamette River from RM 151.4 to RM 141.6; Corvallis Reach, Willamette River from RM 132.6 to RM 126.7; Albany Reach, Willamette River from RM 121.5 to RM 114.5]

Figure 11. Morning and afternoon pH in study reaches of the upper Willamette River Basin during July 24–29 and August 22-–26, 1994.

for the July study period (92, 93, 88, and 91 percent, respectively) equaled or exceeded the August measurements (88, 92, 84, and 91 percent, respectively). However, except for the Peoria and Coast Fork reaches, differences between July and August median morning DO saturation are within the measurement error (roughly 2 to 3 percent) associated with DO saturation (the DO saturation error is calculated from the DO concentration error of 0.2 mg/L at water temperatures between 13^{o}C and 21^{o}C).

Similarly, the median afternoon pH measured in the Coast Fork, McKenzie, Peoria, and Corvallis reaches for the July study period (8.2, 8.0, 8.4, and 8.1 in pH units, respectively) generally equaled or exceeded August measurements (8.6, 8.0, 8.5, and 8.0 in pH units, respectively). As with DO saturation, the differences between July and August median afternoon pH are generally within the measurement error (0.1 pH units) for pH, with the exception of the Coast Fork reach.

Spatial Variability

During the July and August study periods, substantial variation existed between study reaches for morning DO saturation and afternoon pH (figs. 10 and 11). However, within-reach variations tended to be small, except in the Coast Fork reach. For all reaches except the Coast Fork, morning DO concentration during the July and August study periods varied by 0.4 mg/L (3 percent saturation) or less within each reach for either sampling period. In contrast, the morning DO concentration in the Coast Fork reach ranged by 1.9 and 0.5 mg/L (14 and 2 percent saturation) in the downstream direction for the July and August study periods, respectively. Similarly, afternoon pH in all reaches except the McKenzie reach in July and the Coast Fork reach varied by 0.3 pH units or less during the July and August study periods. The slightly larger variability in the McKenzie reach during July (0.5 pH units) resulted from sampling within the effluent plume of a kraft mill at RM 14.5. In comparison, afternoon pH in the Coast Fork reach varied from 7.5 and 7.6 in July and August, respectively, at the upper end of the reach to 8.8 and 9.1, respectively, at the bottom of the reach. The comparatively large magnitude of variation in the Coast Fork reach is consistent with findings of previous studies (Oregon Department of Environmental Quality, 1995a)

Examination of DO saturation and pH data indicates that three of the five reaches—the McKenzie, Corvallis, and Albany reaches—are generally in compliance with the State standard. These three reaches have median morning DO saturation greater than 90 percent and median afternoon pH of 8.1 or less for the July and August study periods (table 4). However, data from the reach monitors for this group of reaches do not necessarily corroborate the reach samplings. During the August study period, the McKenzie reach monitor at RM 10.4 recorded a violation of the DO saturation standard with a measurement of 89 percent; however, the monitor at the same location in July showed no violation of the DO standard. The Corvallis reach monitor at RM 126.7 and continuous monitor at RM 134.2 also measured violations of the DO saturation standard. The continuous monitor recorded violations of the DO saturation standard during most of its period of operation, and the Corvallis reach monitor recorded violations of the DO saturation standard for both the July (estimated 86 percent) and August (89 percent) study periods. However, the Corvallis reach sampling measurements indicated no violations of the DO standard. Similarly, the Albany reach monitor at RM 121.5 measured a violation of 89 percent DO saturation in July with no associated violations detected by reach samplings.

It should be noted that the monitor data violate the State DO saturation standard by only 1 percent saturation, with the exception of the estimate at Corvallis (RM 126.7) in July and the continuous monitor record. Further, each individual reach monitor recorded at only one point in the river and was not necessarily indicative of reach-wide conditions. Monitors, except in the Coast Fork reach, were by

Table 4. Dissolved oxygen saturation and pH summary statistics for the upper Willamette River Basin, July 24–29 and August 22–26, 1994

[Coast Fork, Coast Fork Willamette River from river mile (RM) 21.7 to RM 12.5; McKenzie, McKenzie River from RM 19.3 to RM 7.1; Peoria, Willamette River from RM 151.4 to RM 141.6; Corvallis, Willamette River from RM 132.6 to RM 126.7; Albany, Willamette River from RM 121.5 to RM 114.5; N, number of observations; data are pooled from July and August sampling periods; reach monitor data are excluded]

River Reach	Morning DO (percent saturation)			Afternoon pH (pH units)		
	N	Median	Number of violations	N	Median	Number of violations
Coast Fork	10	88	9	10	8.4	6
McKenzie	18	93	0	21	8.0	0
Peoria	17	88	16	20	8.5	6
Corvallis	20	91	0	20	8.1	0
Albany	10	94	0	10	7.7	0

necessity located at the edges of the river and were not recording cross-sectional information. Cross-sectional measurements taken at each monitor indicate that monitor measurements exhibit a greater diel range in comparison to cross-sectionally averaged measurements. The difference between monitor and cross-sectional measurements may represent variation in DO between the midchannel and shallow nearshore areas.

Two reaches, the Coast Fork and Peoria reaches, had a median morning DO saturation less than 90 percent and median afternoon pH of 8.4 or greater. These two reaches had many violations of the State standard for DO saturation and pH. The reach monitor data from the Coast Fork and Peoria reaches corroborate the July and August sampling data. In the Coast Fork Reach, during the July and August study periods, the reach monitor (RM 16.9) recorded a morning minimum DO saturation of 89 percent. The monitor upstream from the Cottage Grove STP (RM 21.7), however, recorded a morning minimum DO saturation of 92 percent for July, which agreed with instantaneous sampling data for July. The monitor data at RM 21.7 from August were not recorded because of instrument failure. In the Peoria reach, the downstream monitor at Peoria (RM 141.6) recorded morning minimum DO saturations of 86 percent for both July and August, similar to the sampling data for the same periods. Additionally, DO saturation recorded by the Peoria monitor remained below 90 percent from 0500 to 0830 hours for both July and August. With the exception of the monitor at the Coast Fork Willamette River (RM 16.8) in August (maximum pH 8.6), none of the reach monitors recorded violations of the State standard for pH in either the Coast Fork (maximum pH 8.2) or the Peoria reach (maximum pH 8.3).

In general, the study reaches were characterized by diel variations in both DO saturation and pH. The Coast Fork and Peoria reaches had many violations of State standards for both constituents during the July and August study periods (table 4). In contrast, the McKenzie, Corvallis, and Albany reaches maintained DO and pH within State standards.

FACTORS CONTROLLING DISSOLVED OXYGEN AND pH

DO and pH in the water column depend on many factors. A detailed investigation of all factors controlling DO and pH in the upper Willamette Basin is beyond the scope of this study. However, data to examine several major factors were collected, including BOD, CBOD, NBOD, and measures of photosynthetic activity.

Biochemical Oxygen Demand

Ambient water-column BOD in the upper Willamette River Basin during the August study period was small (5-day BOD less than 1 mg/L) in all reaches (table 5). Bottle measurements of BOD indicated that potential 1-day oxygen consumption was generally less than 0.2 mg/L in all study reaches. At the ambient DO concentration of 7.7 to 9.0 mg/L in the study reaches, BOD is not considered an important factor in explaining the diel DO fluctuations.

The calculated 5-day NBOD values (BOD minus CBOD) between 0.0 and 0.5 mg/L for the four study reaches indicate that nitrification was minimal. However, these values must be interpreted with care. It is difficult, if not impossible, to reliably measure NBOD from a water-column sample in a bottle. The bottle does not sample or simulate the substrate environment that nitrifying bacteria occupy. Nonetheless, the NBOD values do give an indication that the nitrification potential was small.

Worst-case estimates of potential instantaneous nitrification were made based on the assumption that ammonia from point sources is nitrified instantaneously (Velz, 1970). The worst-case nitrification estimates indicate a maximum consumption of 1 to 2 percent of available DO in all reaches except in the Coast Fork reach. Two measurements of ammonia in effluent from the Cottage Grove STP (RM 21.5) (table 6) indicated a maximum potential oxygen consumption between 4 and 21 percent (0.3 and 1.8 mg/L, respectively) of available DO in the 0.8 miles above the mouth of the Row River. Downstream from the Row River, the maximum possible effect decreases to approximately 1 to 5 percent of available DO in the main stem due to dilution by the Row River.

Of the four study reaches, only the 0.8 mile stretch above the Row River in the Coast Fork reach has potential for important levels of resultant oxygen consumption (greater than 4 percent) from BOD or nitrification relative to observed minimum DO saturations within the study reaches. However, the BOD bottle measurement for 1-day oxygen consumption (0.3 mg/L) below the Cottage Grove STP (RM 21.5) on the Coast Fork reach does not agree with the nitrification estimate for this 0.8-mile section. The lack of agreement is probably due in part to the aforementioned difficulty of measuring NBOD in a bottle. The lack of agreement may also be due to the oversimplification of the worst-case nitrification estimates, which probably overestimate the actual effect of nitrification.

Table 5. Summary statistics for biochemical oxygen demand of selected reaches in the upper Willamette River Basin, August 22–26, 1994

[mg/L, milligrams per liter; BOD, biochemical oxygen demand; Coast Fork, Coast Fork Willamette River from RM 21.7 to RM 12.5; McKenzie, McKenzie River from RM 19.3 to RM 7.1; Peoria, Willamette River from RM 151.4 to RM 141.6; Corvallis, Willamette River from RM 132.6 to RM 126.7; N, number of observations; rates are calculated for log base 10]

		BOD (5-Day)				Carbonaceous BOD (5-Day)			
Reach	N	Median rate (day^{-1})	Minimum (mg/L)	Median (mg/L)	Maximum (mg/L)	Median rate (day^{-1})	Minimum (mg/L)	Median (mg/L)	Maximum (mg/L)
Coast Fork	5	0.03	0.5	1.0	1.1	0.03	0.5	0.6	0.7
McKenzie	4	.03	.3	.5	1.1	.03	.4	.6	.7
Peoria	6	.03	.6	.7	1.1	.03	.6	.7	1.0
Corvallis	4	.03	.7	.9	1.0	.03	.5	.6	.8

Table 6. Nutrient concentrations of selected effluents and tributaries in the upper Willamette River Basin, August 22–26, 1994

[Coast Fork, Coast Fork Willamette River from RM 21.7 to RM 12.5; McKenzie, McKenzie River from RM 19.3 to RM 7.1; Peoria, Willamette River from RM 151.4 to RM 141.6; Corvallis, Willamette River from RM 132.6 to RM 126.7; mg/L, milligrams per liter; cfs, cubic feet per second; values in parenthesis are duplicate measurements; STP, sewage treatment plant; WWTP, wastewater treatment plant; SRP, soluble reactive phosphorus; Filtered, passed through a 0.45 micrometer filter prior to analysis]

Site name	River reach	Main-stem river mile	Estimated discharge (cfs)	Ammonia (mg/L as N)	Nitrite plus nitrate[b] (mg/L as N)	SRP[b] (mg/L as P)
Cottage Grove STP[c]	Coast Fork	21.5	1.3	1.8[a] (10.6)	17 (9.4)	3.3 (3.8)
Row River[d]	Coast Fork	20.7	92	<0.002[b]	0.098	0.005
Kraft Mill[c]	McKenzie	14.5	15	2.8[a]	0.2	0.55
Mohawk River[d]	McKenzie	13.7	24	0.003[b]	0.013	0.004
Pulp and paper mills[c]	Peoria	147.4	26	5.5[a]	0.34	2.25
Long Tom River[d]	Peoria	145.9	37	0.016[b]	0.958	0.017
Corvallis WWTP[c]	Corvallis	131	8	0.32[a]	9.3	7.39

[a]Unfiltered sample.
[b]Filtered sample.
[c]Collected and analyzed by Oregon Department of Environmental Quality.
[d]Collected and analyzed by U.S. Geological Survey.

Photosynthetic Activity

Simultaneous diel fluctuations of DO saturation and pH are indicative of the photosynthetic activity of aquatic biota (Odum, 1956; Vollenweider, 1974). The primary photosynthetic biota in aquatic ecosystems include vascular plants, planktonic algae, and periphytic algae. Except in portions of the McKenzie reach, vascular plants are not present in large quantities. Data were collected to examine both water-column and attached algal communities as possible sources of diel fluctuations in DO and pH.

Algal Water-Column Productivity

Water column productivity (light-bottle/dark-bottle method) and chlorophyll *a* data were collected at selected sites in the study reaches of the upper Willamette River Basin during the August study period. Light-bottle/dark-bottle measurements indicated gross production (respiration plus photosynthesis) in all reaches to be less than 0.2 mg/L/day of DO. Water-column photosynthetic productivity of 0.2 mg/L/day at 20^{o}C results in a maximum variation in DO concentration of 2.7 percent of ambient river DO concentration, which is much less than the observed diel variations of 11 to 50 percent of saturation observed in the study reaches in August.

In support of the light-bottle/dark-bottle results, water column chlorophyll *a* measurements in the Peoria and Corvallis reaches indicated small concentrations of planktonic algae relative to of periphytic algae (table 7). Using a hydrologic model to estimate an effective depth of the river (Antonius Laenen and J.C. Risley, USGS, unpub. data, 1992), the periphyton chlorophyll *a* measurements were divided by the effective depth to mathematically integrate them into the water column in order to compare water column and benthic algal density. Periphyton chlorophyll *a* concentrations integrated into the water column in the Peoria reach ranged from 41 to 230 μg/L (micrograms per liter), whereas the concentrations in the Corvallis reach ranged

Table 7. Algal measurements in selected reaches of the upper Willamette River Basin, August 22–26, 1994

[--, no data; µg/L, micrograms per liter; mg/m^2, milligrams per square meter; g/m^2, grams per square meter; Coast Fork, Coast Fork Willamette River from RM 21.7 to RM 12.5; McKenzie, McKenzie River from RM 19.3 to RM 7.1; Peoria, Willamette River from RM 151.4 to RM 141.6; Corvallis, Willamette River from RM 132.6 to RM 126.7]

River reach	River mile	Chlorophyll *a*		Periphyton ash-free dry weight (g/m^2)
		Phytoplankton (mg/L)	Periphyton (mg/m^2)	
Coast Fork	21.7	--	32.2	10.6
Coast Fork	21.4	--	35.5	12.2
Coast Fork	20.0	--	75.6	20.5
Coast Fork	13.9	--	75.0	17.0
Coast Fork	12.5	--	58.4	36.2
McKenzie	13.4	--	7.2	5.5
McKenzie	9.5	--	157	32.1
Peoria	151.0	2.8	81.4	20.2
Peoria	148.1	3.7	101	27.6
Peoria	146.0	5.1	81.7	21.8
Peoria	144.6	4.9	232	50.4
Peoria	141.6	5.6	299	65.4
Corvallis	132.6	4.6	172	6.4
Corvallis	130.7	7.4	102	46.8
Corvallis	127.1	4.3	87.9	26

from 52 to 90 µg/L. These calculated benthic concentrations are 8 to 46 times the magnitude of the water column chlorophyll *a* measurements for the two reaches, indicating that benthic algal populations were significantly greater and, therefore, had a potentially larger impact on the DO and pH of the study reaches than did planktonic populations. The integration calculation assumes periphyton chlorophyll *a* density remains constant along the entire stream-bottom cross section. However, the periphyton sample collection was not designed to represent the entire cross-sectional stream bottom and may have resulted in a degree of overestimation of periphyton chlorophyll *a* concentrations.

Benthic Algal Productivity

In order to estimate the potential effect of community respiration (CR) and net primary productivity (NPP) on ambient DO saturation, measurements of CR and NPP in the Willamette River Basin made by Gregory (1993) in a 1992 study were incorporated into a simple mathematical model to estimate periphyton oxygen consumption and production for the Peoria and Corvallis reaches during August 22–26. The measurements of CR and NPP by Gregory (1993) were normalized for difference in biomass between the two studies using AFDW and assuming an 8-hour photoperiod. Measurements of AFDW from this (1994) study ranged from 44 to 194 percent of those reported by Gregory (1993) for nearby sites. Differences in chlorophyll *a* measurements ranged from 103 to 145 percent. Only nearby sites were chosen for comparison because ratios of chlorophyll *a* and AFDW to NPP and respiration may vary from location to location. The study sites from the 1992 and 1994 studies, respectively, used for normalization were, in river miles, 151.0 and 151.0, 143.3 and 144.6, 133.7 and 132.6, 133.7 and 130.7. The inclusion of the measurement at 130.7 was necessary to obtain a range for the Corvallis reach, because the biomass at the RM 132.6 site is not representative of the RM 130.7 and RM 127.1 sites within the reach, and no other measurements from Gregory's study are available. The normalized CR and NPP measurements for the Peoria and Corvallis reaches were applied uniformly to their respective reaches using an effective depth for the reach (1.7 and 1.4 meters, respectively) and a travel time within the reach (5.5 and 3.3 hours, respectively) determined from the hydrologic model developed by Antonius Laenen and J.C. Risley (USGS, unpub. data, 1992). The model does not incorporate certain parameters that affect DO, including reareation, as well as respiration and primary productivity upstream of the modeled reaches. BOD and water-column productivity contributions to DO were assumed to be negligible.

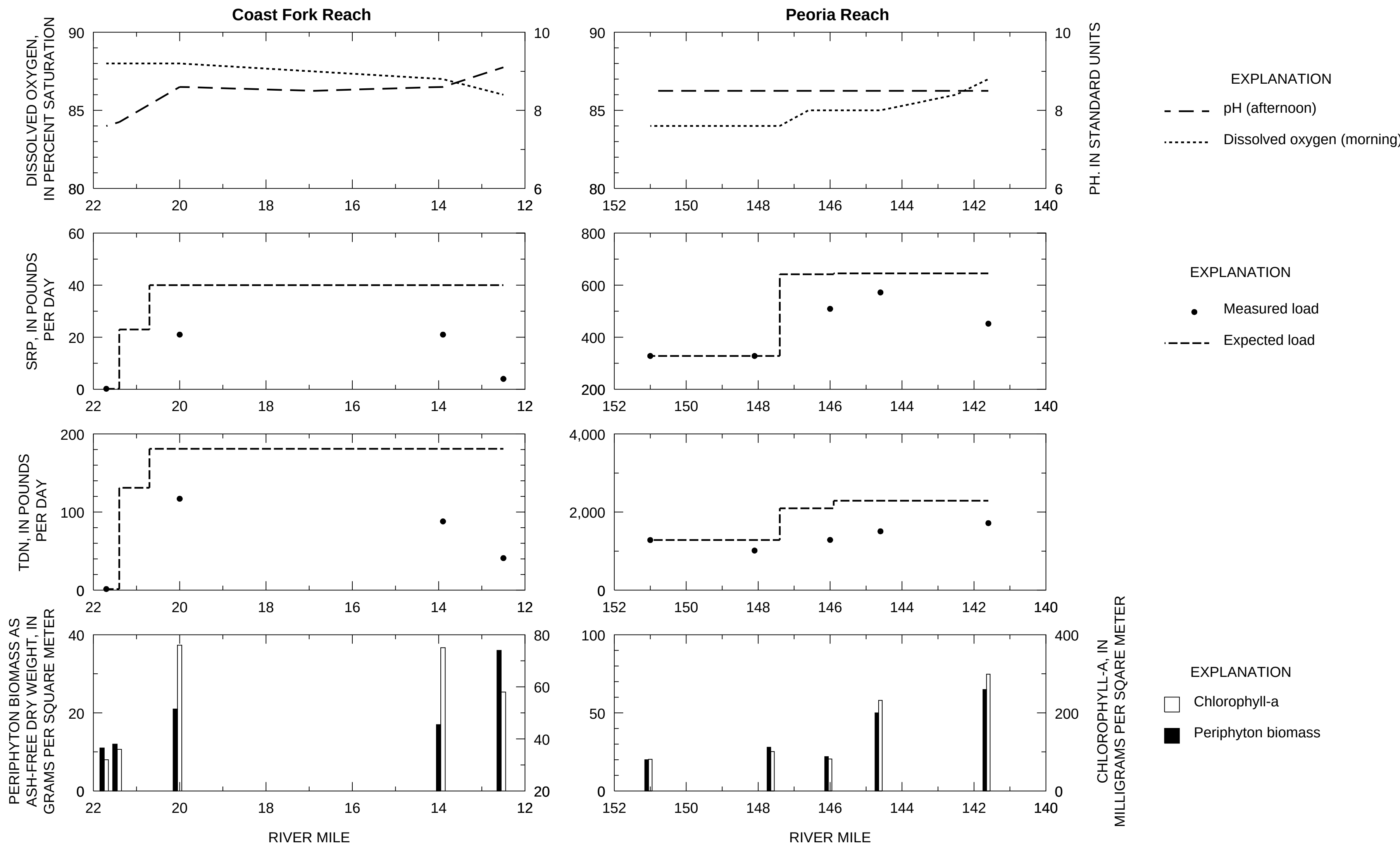
The resultant estimates of DO consumption and production account for an important portion of the DO variations observed for the August study period. The observed DO concentration for the Peoria and Corvallis reaches had ranges of 2.7 and 1.1 mg/L, respectively, after compensation for variation in saturation due to water temperature variation. In the Peoria reach, the combined estimates of periphyton night CR and daytime NPP at RM 151.0 (2.4 mg/L) and RM 144.6 (1.7 mg/L) accounted for 90 and 63 percent, respectively, of the observed diel fluctuation. The estimates in the Corvallis reach at RM 132.6 (0.4 mg/L) and RM 130.7 (2.9 mg/L) had a considerably larger range of 36 to 264 percent, respectively. Estimates of DO consumption at all sites, except at RM 103.7, underestimated the observed DO loss, as measured by the difference between measured minimum DO concentration and expected DO concentration at saturation. The underestimation is probably due in part to the absence of reareation, BOD, and other aquatic respiration in the model. The simplified conceptual model results indicate that the periphyton population of the two reaches was capable of producing a diel variation of the order of magnitude observed during the August study period within each reach; however, the precise periphytic influence on diel variation of DO is unknown due to the large number of dynamics ignored by the model.

Additionally, in the Peoria reach, diel DO curves were used to estimate oxygen consumption and production within the reach, which were compared to the measurements of Gregory (1993). The single-station model, a FORTRAN program, was applied at the Peoria reach monitors at RM 151.4 and RM 144.6 for the August study period, utilizing the 24-hour DO concentration and water temperature curves, stream velocity (2.7 ft^3/s), time of sunrise (0630) and sunset (2000), barometric pressure (757 mm of Hg), a reareation coefficient (1.8 per day), and channel depth (1.74 m) to estimate daytime NPP and night CR (Stephens and Jennings, 1976). The channel depth and stream velocity within the reach were determined from the hydrologic model developed by Antonius Laenen and J.C. Risley (USGS, unpub. data, 1992). The reareation coefficient (K_2) was derived from a mathematical formula (O'Connor and Dobbins, 1958). The modeled NPP and CR were then compared to the measurements of Gregory (1993) after normalization for biomass (AFDW) using nearby sites. The study sites from the 1992 (Gregory, 1993) and this (1994) study, respectively, used for normalization were, in river miles, 151.0 and 151.4 (upstream site), 143.3 and 144.6 (downstream site). For the data from Gregory (1993), an 8-hour photoperiod and constant respiration was assumed for the purpose of comparison.

The modeled estimates of daytime NPP (0630–2000) and night CR (2000–0630) are comparable in magnitude to those of Gregory (1993) for periphyton. Modelled NPP at the upstream and downstream sites was 5,236 and 4,572 mg $0_2/m^2$/day (milligrams of 0_2 per meter square per day), respectively, whereas measurements by Gregory (1993) were 3,601 and 2,840 mg $0_2/m^2$/day, respectively, after normalization for biomass differences. Therefore, daytime NPP for periphyton measured in enclosed benthic chambers in 1992 was smaller than diel-curve modelled daytime NPP at the upstream and downstream sites by 31 and 38 percent, respectively. Modelled night CR at the upstream and downstream sites was 5,185 and 4,572 mg $0_2/m^2$/day, respectively; whereas measurements by Gregory (1993) were 3,218 and 1,878 mg $0_2/m^2$/day, respectively, after normalization for biomass differences. In a similar pattern to daytime NPP, the differences in night CR between the modelled and measured values, although of somewhat larger variation, result in a 38 and 59 percent difference for upstream and downstream sites, respectively. The observed differences between modelled and measured NPP and CR may be in part due to respiration from other aquatic organisms, variation in productivity to biomass ratio over time, or overestimation of diel fluctuations due to reach monitor location. In any case, periphyton NPP and CR appear to account for a large portion of the estimated daytime NPP and night respiration from the diel curve method during the August study period.

All study reaches during the August study period appeared to be nitrogen limited. The median ratios of nitrogen (filtered nitrite plus nitrate plus filtered ammonia, as N) to phosphorus (soluble reactive phosphorus, as P) were 6.3, 0.5, 3.1, and 3.2 for the Coast Fork, McKenzie, Peoria, and Corvallis reaches, respectively, which are below the neutral ratio of 7.2 (Welch, 1992). Nitrogen limitation is also supported by algal enumeration by Gregory (1993), who indicated that blue-green algae, many of which are capable of fixing nitrogen, were the dominant periphyton in the upper Willamette River Basin during August and September of 1992. Periphyton AFDW increases downstream from major point-source loadings in the Coast Fork, Peoria, and Corvallis reaches. Further, nutrient budget estimates indicate that some consumption of nutrients was probably occurring (fig. 12, tables 6 and 11), which might have been due to algal uptake or, in the case of nitrogen, nitrification. However, nutrient losses were not observed in some sections of the three reaches. This may have been due to nonpoint-source nutrient loading, recycling of nutrients in larger communities, or limitations of the nutrient data. Additionally, some difference between estimates of ammonia loading and measured loads was probably due to the use of “total” (acidified, laboratory filtered) ammonia data from point sources (Doug Drake, ODEQ, oral commun., 1995) in contrast to filtered (unacidified, field filtered) ammonia data from the river downstream.

In the case of the McKenzie reach, some uptake of nitrogen and phosphorus was apparent downstream from a point-source input in the upper portion of the reach. However, periphyton biomass data did not indicate a large population in the upper section of the McKenzie reach (table 7). The apparent uptake may have been due to vascular plants present in this section of the McKenzie reach (RM 15–RM 12) or, possibly, periphytic algae attached to the vascular plants. Additionally, no violations of DO or pH occurred in this portion of the reach. A comparatively large standing crop of periphyton as indicated by chlorophyll *a* and AFDW was present at the McKenzie River at Deadmond Ferry (RM 9.5) during the August study period. Also, nitrite-plus-nitrate concentrations increased from 0.008 mg/L as N at RM 12.5 to 0.01 mg/L at RM 9.5, indicating a possible nonpoint nutrient source that may have been partially masked by uptake. Finally, the only violation of DO in the McKenzie reach was measured just upstream from Deadmond Ferry at the monitor location (RM 10.4) during the August survey.



[SRP, soluble reactive phosphorus; TDN, total dissolved nitrogen calculated from filtered nitrite-plus-nitrate concentrations plus filtered ammonia concentrations; Measured load, load based on measured concentrations; Expected load, load based on calculation of inflows and outflows of water within a reach; Coast Fork Reach, Coast Fork River from River Mile (RM) 21.7 to RM 12.5; Peoria Reach, Willamette River from RM 151.4 to RM 141.6]

Figure 12. Summary of pH, dissolved oxygen, nutrient load, and periphyton biomass data for the Peoria and Coast Fork reaches, August 22–26, 1994.

SUMMARY

DO and pH in the Coast Fork, McKenzie, Peoria, Corvallis, and Albany reaches of the upper Willamette River Basin are characterized by diel fluctuations. The diel variations in DO were from 0.2 to 3.9 mg/L (milligrams per liter) (7 to 50 percent saturation based on ambient water temperature and barometric pressure) and in pH from 0.3 to 1.4 units. Many measurements of DO and pH in the Peoria and Coast Fork reaches were in violation of State standards. The violations, during the morning (DO) and afternoon (pH), were primarily the result of diel fluctuations.The McKenzie, Corvallis, and Albany reaches had only isolated, uncorroborated violations of the DO standard and no violations of the pH standard.

BOD (biochemical oxygen demand) and phytoplankton do not appear to be important influences on DO. Of the four study reaches, only a short stretch of the Coast Fork Willamette River has potential for important levels of oxygen consumption from BOD or nitrification. Additionally, water column primary-productivity measurements indicated that respiration and photosynthesis by free-floating algae did not explain the observed diel variations in DO in the study reaches.

Diel fluctuations, standing crops, and available nutrients indicate that attached algae control DO and pH. Additionally, results from a simplified mathematical model indicate that periphyton were capable of producing a diel variation of the order of magnitude observed during the worst-case (in terms of streamflow and temperature) August study period. In the Willamette River near Peoria, the combined periphyton DO consumption and production estimate at RM 151.0 (2.4 mg/L) and 144.6 (1.7 mg/L) accounted for 90 and 63 percent, respectively, of the observed diel fluctuation. The estimates in the Corvallis reach at RM 132.6 (0.4 mg/L) and RM 130.7 (2.9 mg/L) had a considerably larger range of 36 to 264 percent of DO saturation, respectively. Therefore, since BOD and phytoplankton do not appear to be important contributors to diel DO fluctuations, periphyton are likely the primary contributor to diel fluctuations in the upper Willamette River Basin during July and August. A possible exception is in the upper portion of the McKenzie reach, where vascular plants may be a factor, and the Coast Fork reach immediately downstream of the Cottage Grove STP, where BOD and nitrification may contribute to reductions in DO.

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SUPPLEMENTAL DATA

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Table 8. Summary statistics for the hourly monitor in the Willamette River at the Corvallis Water Treatment Plant (RM 134.2), July 22–October 24, 1994

[°C, degrees Celsius; Min., minimum; Max., maximum; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; DO, dissolved oxygen; "--, no data]

Date	Water temperature (°C)			Specific conductance (µS/cm)			DO concentration (mg/L as O_2)			pH (standard units)		
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
1994–07–22	20.1	21.0	22.0	75	76	78	8.0	8.8	9.6	7.1	7.5	8.0
1994–07–23	18.7	20.0	21.1	77	78	79	8.2	9.0	10.1	7.2	7.6	8.1
1994–07–24	18.7	19.3	20.4	73	76	78	8.1	8.8	9.4	7.2	7.4	7.9
1994–07–25	16.9	18.2	19.5	75	76	76	8.6	9.4	10.4	7.2	7.6	8.1
1994–07–26	18.0	19.2	20.8	75	76	76	8.4	9.3	10.2	7.2	7.6	8.1
1994–07–27	18.6	19.9	21.2	73	76	78	8.3	9.1	10.0	7.2	7.6	8.1
1994–07–28	18.7	19.8	21.1	72	73	73	8.1	9.1	10.2	7.2	7.7	8.3
1994–07–29	18.2	19.1	19.9	73	74	75	8.1	9.0	10.0	7.2	7.6	8.2
1994–07–30	17.3	18.3	19.2	75	75	76	8.2	9.3	10.5	7.3	7.8	8.3
1994–07–31	17.4	18.6	20.1	75	77	78	8.4	9.3	10.2	7.3	7.8	8.3
1994–08–01	18.0	19.1	20.5	75	77	78	8.3	9.2	10.3	7.3	7.8	8.4
1994–08–02	18.2	19.3	20.6	74	75	77	8.2	9.2	10.3	7.3	7.8	8.4
1994–08–03	18.3	19.4	20.7	75	76	77	8.2	9.1	10.2	7.3	7.8	8.4
1994–08–04	18.6	19.2	19.7	75	76	76	7.9	8.8	9.6	7.3	7.6	8.0
1994–08–05	17.2	18.5	19.6	73	74	75	8.4	9.3	10.3	7.2	7.7	8.2
1994–08–06	17.7	19.0	20.3	73	75	76	8.4	9.3	10.2	7.3	7.8	8.3
1994–08–07	18.3	18.9	19.5	73	75	76	8.2	9.0	9.8	7.3	7.7	8.1
1994–08–08	16.7	17.7	18.5	74	75	76	8.4	9.2	10.1	7.3	7.7	8.2
1994–08–09	16.7	18.0	19.4	74	75	76	8.6	9.5	10.4	7.4	7.9	8.4
1994–08–10	17.7	19.0	20.4	74	75	76	8.3	9.3	10.2	7.3	7.9	8.4
1994–08–11	18.3	19.2	20.2	72	75	76	8.1	9.1	10.1	7.3	7.8	8.3
1994–08–12	17.9	19.2	20.4	71	73	74	8.2	9.3	10.3	7.3	7.8	8.4
1994–08–13	18.4	19.6	20.9	71	73	73	8.2	9.3	10.3	7.3	7.9	8.4
1994–08–14	18.9	19.6	20.6	70	72	73	8.2	9.2	10.2	7.3	7.8	8.3
1994–08–15	18.4	19.3	20.4	71	73	74	8.4	9.4	10.5	7.3	7.9	8.4
1994–08–16	18.2	19.3	20.5	69	71	73	8.4	9.5	10.5	7.4	7.9	8.4

Table 8. Summary statistics for the hourly monitor in the Willamette River at the Corvallis Water Treatment Plant (RM 134.2), July 22–October 24, 1994—Continued

Date	Water temperature (^{o}C)			Specific conductance (μS/cm)			DO concentration (mg/L as O_2)			pH (standard units)		
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
1994–08–17	18.4	19.4	20.5	69	72	73	8.4	9.6	10.6	7.3	7.9	8.5
1994–08–18	18.3	19.0	19.8	71	73	73	8.5	9.5	10.4	7.3	7.9	8.3
1994–08–19	17.9	18.7	19.5	70	73	75	8.8	9.6	10.5	7.3	7.8	8.3
1994–08–20	18.2	18.8	19.5	71	72	73	8.6	9.6	10.5	7.3	7.8	8.2
1994–08–21	17.6	18.4	19.1	71	72	72	8.8	9.7	10.5	7.3	7.8	8.2
1994–08–22	17.5	18.4	19.2	70	71	72	8.9	9.9	10.8	7.3	7.8	8.3
1994–08–23	17.8	18.7	19.7	70	71	72	9.0	10	10.8	7.3	7.9	8.4
1994–08–24	17.9	18.7	19.8	70	71	72	9.1	10.	11.1	7.4	7.9	8.4
1994–08–25	17.7	18.6	19.6	71	73	75	9.1	10.	11.2	7.3	7.9	8.4
1994–08–26	17.5	18.5	19.5	72	73	73	9.1	10.	11	7.3	7.9	8.4
1994–08–27	17.7	18.7	19.8	71	73	74	8.9	9.7	10.6	7.2	7.7	8.3
1994–08–28	18.2	18.8	19.6	72	73	74	8.5	9.4	10.3	7.2	7.7	8.1
1994–08–29	17.6	18.5	19.4	72	73	73	8.7	9.6	10.6	7.2	7.7	8.2
1994–08–30	17.6	18.6	19.7	70	73	74	--	--	--	7.2	7.8	8.4
1994–08–31	18.0	18.9	19.9	70	71	72	--	--	--	7.3	7.9	8.4
1994–09–01	18.0	18.7	19.6	70	71	72	--	--	--	7.3	7.8	8.3
1994–09–02	17.5	18.0	18.4	70	71	72	--	--	--	7.3	7.8	8.1
1994–09–03	17.1	17.8	18.5	70	71	72	--	--	--	7.3	7.6	8.0
1994–09–04	17.3	17.9	18.6	71	72	72	--	--	--	7.2	7.7	8.2
1994–09–05	17.4	18.4	19.5	70	72	72	--	--	--	7.3	7.7	8.2
1994–09–06	18.1	18.9	19.9	71	73	73	--	--	--	7.3	7.7	8.2
1994–09–07	17.9	18.7	19.5	72	75	77	--	--	--	7.3	7.8	8.3
1994–09–08	17.1	18.2	18.8	73	75	77	--	--	--	7.3	7.5	7.9
1994–09–09	15.9	16.4	17.1	72	73	75	8.5	9.2	9.9	7.2	7.5	7.9
1994–09–10	15.5	16.0	16.3	73	74	74	8.5	9.2	9.9	7.2	7.5	7.8
1994–09–11	15.1	15.8	16.6	73	74	75	8.9	9.6	10.3	7.3	7.6	8.0
1994–09–12	14.8	15.8	16.8	73	75	77	9	9.8	10.7	7.3	7.7	8.2
1994–09–13	15.4	16.3	17.4	75	76	77	8.7	9.6	10.4	7.2	7.7	8.2

Table 8. Summary statistics for the hourly monitor in the Willamette River at the Corvallis Water Treatment Plant (RM 134.2), July 22–October 24, 1994—Continued

Date	Water temperature (^oC)			Specific conductance (μS/cm)			DO concentration (mg/L as O_2)			pH (standard units)		
	Min.	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**	**Min.**	**Mean**	**Max.**
1994–09–14	15.5	16.4	17.4	75	77	78	8.8	9.7	10.6	7.2	7.7	8.1
1994–09–15	16.0	17.0	18.2	76	77	77	8.7	9.7	10.7	7.2	7.7	8.2
1994–09–16	16.5	17.6	18.7	75	77	78	8.5	9.5	10.6	7.2	7.7	8.3
1994–09–17	17.1	18.0	19.0	75	77	79	8.4	9.5	10.6	7.2	7.7	8.3
1994–09–18	17.2	18.1	18.9	74	76	78	8.4	9.5	10.7	7.2	7.8	8.4
1994–09–19	17.1	18.0	19.0	74	75	77	8.4	9.6	10.7	7.3	7.8	8.4
1994–09–20	17.1	18..0	19.0	73	75	77	8.4	9.5	10.7	7.3	7.9	8.4
1994–09–21	17.2	18.0	19.0	71	74	76	8.3	9.4	10.5	7.3	7.8	8.4
1994–09–22	17.0	17.9	18.8	70	73	75	8.2	9.4	10.5	7.2	7.8	8.4
1994–09–23	16.7	17.5	18.4	70	72	73	8.2	9.4	10.5	7.2	7.9	8.4
1994–09–24	16.5	17.2	17.9	70	72	73	8.2	9.3	10.3	7.2	7.8	8.3
1994–09–25	16.3	17.2	18.2	71	72	73	8.4	9.5	10.6	7.3	7.8	8.4
1994–09–26	16.6	17.5	18.5	72	73	74	8.3	9.4	10.5	7.3	7.9	8.4
1994–09–27	16.7	17.6	18.5	72	73	74	8.3	9.4	10.4	7.3	7.9	8.4
1994–09–28	16.8	17.2	17.6	73	75	76	8.2	8.9	9.5	7.3	7.6	8.0
1994–09–29	16.5	16.7	17.1	72	73	75	8.3	8.7	9.2	7.3	7.4	7.6
1994–09–30	16.1	16.7	17.3	73	74	75	8.3	8.9	9.6	7.2	7.4	7.7
1994–10–01	16.6	17.4	18.3	73	75	76	8.4	9.0	9.8	7.2	7.5	7.9
1994–10–02	16.8	17.4	18.0	74	75	76	8.3	9.1	10.0	7.3	7.6	8.0
1994–10–03	15.8	16.3	17.1	74	76	77	8.6	9.4	10.3	7.3	7.7	8.1
1994–10–04	15.0	15.6	16.2	74	76	77	8.7	9.5	10.4	7.3	7.7	8.1
1994–10–05	14.8	15.6	16.3	77	78	79	8.7	9.6	10.4	7.3	7.7	8.1
1994–10–06	15.5	16.0	16.7	77	79	80	8.7	9.5	10.2	7.3	7.6	8.0
1994–10–07	15.3	15.9	16.6	76	77	78	8.7	9.5	10.2	7.3	7.6	7.9
1994–10–08	15.1	15.8	16.6	76	78	79	8.7	9.5	10.1	7.3	7.6	7.9
1994–10–09	15.4	16	16.5	78	79	80	8.6	9.3	9.8	7.3	7.6	7.8
1994–10–10	14.9	15.4	15.9	78	78	80	8.6	9.2	9.6	7.3	7.5	7.7
1994–10–11	14.0	14.6	15.1	74	77	79	9	9.7	10.4	7.3	7.6	7.9

Table 8. Summary statistics for the hourly monitor in the Willamette River at the Corvallis Water Treatment Plant (RM 134.2), July 22–October 24, 1994—Continued

Date	Water temperature (^{o}C)			Specific conductance (μS/cm)			DO concentration (mg/L as O_2)			pH (standard units)		
	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.	Min.	Mean	Max.
1994–10–12	14.2	14.7	15.3	74	77	79	9	9.7	10.2	7.3	7.6	7.9
1994–10–13	13.5	14.0	14.6	77	78	80	9.2	9.8	10.2	7.3	7.6	7.8
1994–10–14	13.5	13.9	14.3	77	79	80	9.1	9.5	10.0	7.4	7.6	7.8
1994–10–15	13.5	13.8	14.0	79	79	80	8.9	9.4	9.9	7.3	7.5	7.6
1994–10–16	12.7	13.2	13.6	79	82	83	9.1	9.7	10.3	7.3	7.5	7.7
1994–10–17	12.3	12.9	13.3	80	83	84	9.3	9.8	10.2	7.4	7.5	7.6
1994–10–18	12.6	13.2	13.7	81	84	85	9.4	9.9	10.4	7.4	7.6	7.8
1994–10–19	12.7	13.3	13.9	82	83	84	9.2	9.8	10.2	7.4	7.6	7.7
1994–10–20	13.3	13.7	14.0	83	85	86	9.1	9.6	10.1	7.4	7.5	7.7
1994–10–21	13.4	13.9	14.4	84	86	87	9	9.6	10.1	7.4	7.6	7.8
1994–10–22	12.9	13.4	13.9	84	86	87	9	9.7	10.2	7.4	7.5	7.7
1994–10–23	12.2	12.7	13.1	83	85	86	9.5	10..0	10.5	7.4	7.6	7.8
1994–10–24	12.0	12.6	13.1	83	85	86	9.4	10.0	10.5	7.4	7.6	7.7

Table 9. Field-parameter measurements in the upper Willamette River Basin, July 24–29 and August 22–26, 1994

[°C, degrees Celsius; Min., minimum; Max., maximum; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; DO, dissolved oxygen; mm Hg, millimeters of mercury; Site code, code defining each study site, where A, Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie River reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P, Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork Willamette River reach from RM 21.7 to RM 12.5 (see table 2 for additional site information)]

Site code	River mile	Sampling date	Sampling time	Water temperature (°C)	Barometric pressure (mm Hg)	Specific conductance (µS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
July Field Data									
C1	21.7	94–07–25	0700	15.5	749	68.0	9.0	92	7.4
C1	21.7	94–07–24	1518	18.0	749	67.0	9.3	100	7.5
C3	21.4	94–07–25	0707	15.5	749	75.8	9.5	97	7.3
C3	21.4	94–07–24	1838	18.0	749	77.9	9.7	104	7.6
C5	20.0	94–07–25	0629	16.0	749	62.0	8.9	92	7.5
C5	20.0	94–07–24	1720	18.5	749	63.0	10.3	111	8.2
C6	16.9	94–07–25	1630	20.0	749	62.9	10.2	114	8.2
C7	13.9	94–07–25	0601	18.0	749	67.0	8.1	87	7.5
C7	13.9	94–07–24	1814	21.0	749	64.0	10.2	116	8.7
C8	12.5	94–07–25	0541	18.5	749	65.0	7.6	83	7.4
C8	12.5	94–07–24	1746	21.0	749	65.0	11.0	126	8.8
M2	18.9	94–07–25	1602	16.5	756	45.0	10.7	110	8.1
M3	17.9	94–07–25	1631	16.5	756	45.0	10.6	110	8.0
M4	16.8	94–07–25	1641	16.5	756	46.0	10.6	110	8.0
M5	16.4	94–07–25	1653	17.0	756	45.0	10.7	111	8.0
M6	16.0	94–07–25	1702	17.0	756	45.0	10.6	110	8.0
M7	15.3	94–07–25	1713	17.0	756	46.0	10.6	110	8.0
M8	14.8	94–07–26	0621	13.5	756	45.0	9.5	93	7.3
M8	14.8	94–07–25	1715	17.0	756	46.0	10.4	109	8.0
M10	14.5	94–07–26	0627	13.5	756	74.3	9.4	92	7.3
M10	14.5	94–07–25	1739	17.5	756	88.0	10.1	107	7.8
M11	14.3	94–07–26	0633	14.0	756	73.3	9.6	93	7.3
M11	14.3	94–07–25	1743	18.0	756	122	9.8	104	7.7
M13	13.8	94–07–26	0647	14.0	756	65.0	9.6	94	7.2
M13	13.8	94–07–25	1758	17.5	756	70.0	10.2	108	7.9
M14	13.6	94–07–26	0653	14.0	756	59.7	9.5	93	7.2
M15	13.4	94–07–26	0658	14.0	756	60.0	9.5	93	7.2
M15	13.4	94–07–25	1808	17.5	756	57.8	10.2	108	7.9
M16	13.0	94–07–26	0704	14.0	756	56.0	9.6	94	7.2
M18	11.8	94–07–26	0724	14.0	756	54.0	9.6	94	7.2
M18	11.8	94–07–25	1835	17.5	756	59.0	10.3	109	7.9
M19	10.4	94–07–26	0742	14.0	756	58.0	9.6	94	7.2
M19	10.4	94–07–25	1848	18.0	756	57.0	10.3	109	7.9
M20	9.5	94–07–26	0808	14.5	756	58.0	9.6	94	7.2
M20	9.5	94–07–25	1905	18.0	756	57.0	10.0	107	7.8

Table 9. Field-parameter measurements in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
July Field Data									
M21	7.1	94–07–26	0705	14.5	756	61.9	9.3	92	7.3
M21	7.1	94–07–25	1757	18.0	756	61.3	10.9	117	8.2
P2	151.0	94–07–27	0609	18.5	759	61.4	8.4	89	7.2
P2	151.0	94–07–26	1600	19.5	759	60.2	10.4	114	8.4
P3	150.4	94–07–27	0620	18.0	759	61.8	8.4	89	7.3
P3	150.4	94–07–26	1615	19.5	759	60.2	10.3	113	8.3
P4	149.4	94–07–27	0625	18.5	759	61.8	8.4	89	7.3
P4	149.4	94–07–26	1645	19.5	759	60.4	10.5	116	8.5
P5	147.6	94–07–27	0641	18.5	759	61.8	8.4	89	7.3
P5	147.6	94–07–26	1703	20.0	759	60.5	10.5	115	8.4
P7	147.4	94–07–27	0650	18.5	759	62.0	8.3	88	7.3
P7	147.4	94–07–26	1715	20.0	759	67.8	10.3	114	8.4
P8	147.2	94–07–27	0656	18.5	759	74.2	8.3	88	7.3
P8	147.2	94–07–26	1723	20.0	759	71.3	10.3	114	8.4
P9	146.6	94–07–27	0707	18.5	759	76.4	8.3	88	7.3
P9	146.6	94–07–26	1733	20.0	759	73.1	10.3	114	8.5
P12	145.8	94–07–26	1750	20.0	759	77.3	10.3	114	8.4
P13	144.8	94–07–26	1801	20.0	759	76.6	10.2	113	8.4
P14	144.6	94–07–26	1813	20.0	759	76.4	10.2	113	8.4
P15	143.0	94–07–27	0747	18.5	759	79.2	8.3	88	7.3
P16	141.6	94–07–27	0758	18.5	759	79.0	8.2	88	7.3
P16	141.6	94–07–26	1900	20.5	759	76.8	10.1	115	8.4
W2	132.6	94–07–28	0557	19.0	762	72.1	8.5	91	7.4
W2	132.6	94–07–27	1613	21.0	762	77.7	10.2	115	8.2
W5	132.3	94–07–28	0610	19.0	762	72.2	8.5	91	7.4
W6	132.2	94–07–27	1621	21.0	762	77.7	10.2	115	8.2
W8	131.9	94–07–28	0620	19.0	762	74.6	8.4	90	7.4
W8	131.9	94–07–27	1635	21.0	762	78.2	10.2	115	8.2
W9	131.7	94–07–28	0628	19.0	762	73.2	8.4	91	7.4
W10	131.4	94–07–28	0633	19.0	762	73.7	8.4	91	7.4
W10	131.4	94–07–27	1648	21.0	762	78.3	10.1	113	8.1
W11	131.1	94–07–28	0640	19.0	762	73.2	8.4	91	7.4
W11	131.1	94–07–27	1705	21.0	762	78.8	10.0	112	8.1
W13	130.7	94–07–28	0645	19.0	762	73.4	8.4	91	7.4
W13	130.7	94–07–27	1715	21.5	762	79.8	10.0	113	8.1
W14	129.5	94–07–28	0655	19.0	762	73.4	8.4	91	7.4
W14	129.5	94–07–27	1730	21.0	762	79.0	9.9	111	8.1

Table 9. Field-parameter measurements in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (µS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
July Field Data									
W15	128.7	94–07–28	0708	19.0	762	74.6	8.4	91	7.4
W15	128.7	94–07–27	1744	21.5	762	78.8	9.9	112	8.0
W16	128.0	94–07–28	0721	19.0	762	73.7	8.5	92	7.5
W17	127.4	94–07–27	1800	21.5	762	79.3	9.8	111	7.9
W18	127.1	94–07–28	0731	19.0	762	73.7	8.4	91	7.4
W18	127.1	94–07–27	1803	21.5	762	80.1	9.8	111	7.9
W19	126.7	94–07–28	0736	19.0	762	73.8	8.4	91	7.4
W19	126.7	94–07–27	1809	21.5	762	79.9	9.8	110	7.9
A1	121.5	94–07–29	0557	19.5	758	73.0	8.4	93	7.4
A1	121.5	94–07–28	1602	21.0	758	74.0	9.4	105	7.7
A2	121.3	94–07–28	1620	21.0	758	75.0	9.4	106	7.7
A3	121.0	94–07–29	0631	20.0	758	73.0	8.5	93	7.4
A3	121.0	94–07–28	1630	21.0	758	74.0	9.4	105	7.7
A5	119.2	94–07–29	0638	20.0	758	73.0	8.5	93	7.4
A5	119.2	94–07–28	1647	21.0	758	75.0	9.4	106	7.7
A6	118.8	94–07–29	0646	20.0	758	73.0	8.5	94	7.3
A6	118.8	94–07–28	1717	21.0	758	75.0	9.3	105	7.7
A7	118.3	94–07–28	1733	21.5	758	75.0	9.3	105	7.6
A8	117.8	94–07–29	0659	20.0	758	73.0	8.5	94	7.3
A9	117.6	94–07–29	0704	20.0	758	74.0	8.5	94	7.4
A9	117.6	94–07–28	1800	21.5	758	76.3	9.2	104	7.6
A10	116.8	94–07–29	0716	20.0	758	74.0	8.5	94	7.4
A10	116.8	94–07–28	1811	21.5	758	76.0	9.2	104	7.6
A11	116.1	94–07–28	1823	21.5	758	78.0	9.2	104	7.5
A12	115.6	94–07–29	0725	20.0	758	75.0	8.5	94	7.3
A13	115.4	94–07–29	0731	20.0	758	84.0	8.5	94	7.3
A14	114.5	94–07–29	0748	20.0	758	82.0	8.5	94	7.3
A14	114.5	94–07–28	1830	21.5	758	81.5	9.2	105	7.6

Table 9. Field-parameter measurements in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
August Field Data									
C1	21.7	94–08–23	0706	16.0	747	78.0	8.5	88	7.4
C1	21.7	94–08–22	1530	18.0	747	78.0	9.7	105	7.6
C3	21.4	94–08–23	0722	16.0	747	83.0	8.5	88	7.4
C3	21.4	94–08–22	1641	18.5	747	88.0	9.1	99	7.7
C5	20.0	94–08–23	0650	16.0	747	68.0	8.5	88	7.4
C5	20.0	94–08–22	1615	20.0	747	70.0	10.2	114	8.6
C6	16.9	94–08–22	1529	20.0	747	67.2	10.0	113	8.5
C7	13.9	94–08–23	0623	17.5	747	69.0	8.2	87	7.4
C7	13.9	94–08–22	1749	21.5	747	69.0	9.3	108	8.6
C8	12.5	94–08–23	0559	18.0	747	69.0	8.0	86	7.4
C8	12.5	94–08–22	1550	21.0	747	70.0	11.9	136	9.1
M8	14.8	94–08–24	0716	14.0	750	47.2	9.4	92	7.4
M8	14.8	94–08–23	1548	16.0	750	47.5	10.4	107	8.0
M11	14.3	94–08–24	0722	14.0	750	62.6	9.3	92	7.5
M11	14.3	94–08–23	1555	16.5	750	57.8	10.4	108	8.0
M13	13.8	94–08–24	0734	14.0	750	57.3	9.4	92	7.5
M13	13.8	94–08–23	1607	16.5	750	57.1	10.5	109	8.1
M15	13.4	94–08–24	0741	14.0	750	59.0	9.3	92	7.4
M15	13.4	94–08–23	1615	16.5	750	55.8	10.4	108	8.0
M16	13.0	94–08–24	0759	14.0	750	57.8	9.4	92	7.4
M19	10.4	94–08–24	0815	14.0	750	58.6	9.4	93	7.4
M19	10.4	94–08–23	1646	17.0	750	56.8	10.5	110	8.2
M20	9.5	94–08–24	0827	14.0	750	58.8	9.5	93	7.4
M20	9.5	94–08–23	1700	17.0	750	56.6	10.5	111	8.2
P2	151.0	94–08–25	0648	17.5	757	62.0	7.9	84	7.3
P2	151.0	94–08–24	1558	19.0	757	59.0	11.1	120	8.7
P4	149.4	94–08–25	0704	17.5	757	61.0	8.0	84	7.3
P4	149.4	94–08–24	1611	19.0	757	59.0	11.1	120	8.5
P5	147.6	94–08–25	0719	17.5	757	60.0	8.0	84	7.2
P5	147.6	94–08–24	1626	19.0	757	58.0	11.1	121	8.5
P7	147.4	94–08–25	0733	17.5	757	69.0	8.0	84	7.3
P7	147.4	94–08–24	1641	19.0	757	64.0	11.0	119	8.5
P9	146.6	94–08–25	0744	17.5	757	71.0	8.0	85	7.3
P9	146.6	94–08–24	1648	19.0	757	64.0	11.0	120	8.5
P10	146.0	94–08–25	0756	17.5	757	71.0	8.0	85	7.3
P10	146.0	94–08–24	1658	19.0	757	69.0	11.0	120	8.5
P12	145.8	94–08–24	1707	19.0	757	72.0	10.9	119	8.5

Table 9. Field-parameter measurements in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
August Field Data									
P15	142.5	94–08–25	0820	17.5	757	73.0	8.1	86	7.2
P15	142.5	94–08–24	1727	19.5	757	64.0	10.9	119	8.5
P16	141.6	94–08–25	0841	17.5	757	74.0	8.1	86	7.2
P16	141.6	94–08–24	1745	19.5	757	71.0	10.7	118	8.5
W5	132.3	94–08–26	0702	17.5	755	74.4	8.5	90	7.5
W5	132.3	94–08–25	1549	19.5	760	83.4	10.3	112	8.1
W8	131.9	94–08–26	0715	17.5	755	73.4	8.5	90	7.5
W8	131.9	94–08–25	1602	19.5	760	76.0	10.4	113	8.2
W9	131.7	94–08–25	1611	19.5	760	75.6	10.3	112	8.1
W10	131.4	94–08–26	0724	17.5	755	73.4	8.5	90	7.6
W11	131.1	94–08–25	1617	19.5	760	75.0	10.0	109	8.0
W13	130.7	94–08–26	0733	17.5	755	73.5	8.6	91	7.5
W13	130.7	94–08–25	1623	19.5	760	75.7	10.2	111	8.1
W14	129.5	94–08–26	0745	17.5	755	73.5	8.6	91	7.5
W14	129.5	94–08–25	1645	19.5	760	76.2	10.1	110	8.0
W16	128.0	94–08–26	0758	17.5	755	73.2	8.6	91	7.5
W16	128.0	94–08–25	1657	19.5	760	76.4	10.0	110	8.0
W18	127.1	94–08–26	0811	17.5	755	73.0	8.7	92	7.5
W18	127.1	94–08–25	1713	19.5	760	76.7	10.0	110	8.0
W19	126.7	94–08–26	0825	17.5	755	72.9	8.7	92	7.5
W19	126.7	94–08–25	1721	19.5	760	76.0	10.0	109	8.0

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994

[^{o}C, degrees Celsius; Min., minimum; Max., maximum; µS/cm, microsiemens per centimeter; mg/L, milligrams per liter; --, no data; DO, dissolved oxygen; mm Hg, millimeters of mercury; Site code, code defining each study site, where A, Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P, Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork Willamette River reach from RM 21.7 to RM 12.5 (see table 2 for additional site information)]

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (µS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
C1	21.7	94–07–24	1600	18.0	749	67.0	9.5	101	7.6
C1	21.7	94–07–24	1700	18.0	749	67.0	9.5	102	7.7
C1	21.7	94–07–24	1800	18.0	749	67.0	9.6	103	7.7
C1	21.7	94–07–24	1900	17.5	749	67.0	9.6	102	7.7
C1	21.7	94–07–24	2000	17.5	749	67.0	9.5	100	7.6
C1	21.7	94–07–24	2100	17.0	749	67.0	9.4	99	7.6
C1	21.7	94–07–24	2200	17.0	749	67.0	9.3	98	7.6
C1	21.7	94–07–24	2300	17.0	749	67.0	9.2	96	7.5
C1	21.7	94–07–24	2400	16.5	749	67.0	9.1	95	7.5
C1	21.7	94–07–25	100	16.5	749	68.0	9.0	94	7.5
C1	21.7	94–07–25	200	16.5	749	68.0	9.0	93	7.5
C1	21.7	94–07–25	300	16.0	749	68.0	9.0	93	7.5
C1	21.7	94–07–25	400	16.0	749	68.0	9.0	92	7.5
C1	21.7	94–07–25	500	16.0	749	68.0	9.0	92	7.5
C1	21.7	94–07–25	600	15.5	749	68.0	9.0	92	7.5
C1	21.7	94–07–25	700	15.5	749	68.0	9.0	92	7.4
C1	21.7	94–07–25	800	15.5	749	68.0	9.1	93	7.5
C1	21.7	94–07–25	900	15.5	749	68.0	9.2	94	7.5
C1	21.7	94–08–22	1300	17.0	747	78.0	9.5	100	7.4
C1	21.7	94–08–22	1330	17.0	747	78.0	9.6	101	7.5
C1	21.7	94–08–22	1400	17.5	747	78.0	9.6	102	7.5
C1	21.7	94–08–22	1430	17.5	747	78.0	9.6	103	7.5
C1	21.7	94–08–22	1500	18.0	747	78.0	9.7	104	7.5
C1	21.7	94–08–22	1530	18.0	747	78.0	9.7	105	7.6
C1	21.7	94–08–22	1600	18.0	747	78.0	9.8	105	7.6
C1	21.7	94–08–22	1630	18.0	747	78.0	9.8	106	7.6

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance ($\mu S/cm$)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
C1	21.7	94–08–22	1700	18.0	747	78.0	9.8	106	7.6
C1	21.7	94–08–22	1730	18.0	747	78.0	9.8	105	7.7
C1	21.7	94–08–22	1800	18.0	747	78.0	9.7	105	7.7
C1	21.7	94–08–22	1830	18.0	747	78.0	9.5	103	7.6
C1	21.7	94–08–22	1900	18.0	747	78.0	9.4	101	7.6
C1	21.7	94–08–22	1930	18.0	747	78.0	9.3	100	7.6
C1	21.7	94–08–22	2000	18.0	747	78.0	9.1	99	7.5
C1	21.7	94–08–22	2030	18.0	747	78.0	9.0	98	7.5
C1	21.7	94–08–22	2100	18.0	747	78.0	9.0	97	7.5
C1	21.7	94–08–22	2130	18.0	747	78.0	8.9	96	7.5
C1	21.7	94–08–22	2200	18.0	747	78.0	8.8	95	7.5
C1	21.7	94–08–22	2230	18.0	747	78.0	8.7	94	7.5
C1	21.7	94–08–22	2300	18.0	747	78.0	8.7	94	7.4
C1	21.7	94–08–22	2330	18.0	747	78.0	—	--	7.4
C1	21.7	94–08–22	2400	18.0	747	78.0	--	--	7.4
C1	21.7	94–08–23	30	18.0	747	78.0	--	--	7.4
C1	21.7	94–08–23	100	17.5	747	78.0	--	--	7.4
C1	21.7	94–08–23	130	17.5	747	78.0	--	--	7.4
C1	21.7	94–08–23	200	17.5	747	78.0	--	--	7.4
C1	21.7	94–08–23	230	17.5	747	78.0	--	--	7.4
C1	21.7	94–08–23	300	17.0	747	78.0	--	--	7.4
C6	16.9	94–07–24	1700	20.0	749	64.4	10.1	113	8.1
C6	16.9	94–07–24	1800	20.0	749	64.8	10.0	111	8.0
C6	16.9	94–07–24	1900	19.5	749	65.3	9.8	108	7.9
C6	16.9	94–07–24	2000	19.5	749	64.8	9.5	105	7.8
C6	16.9	94–07–24	2100	19.0	749	65.7	9.1	100	7.6
C6	16.9	94–07–24	2200	18.5	749	66.3	8.9	97	7.5
C6	16.9	94–07–24	2300	18.5	749	67.0	8.7	95	7.4

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

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Site code	River mile	Sampling date	Sampling time	Water temperature (°C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
C6	16.9	94–07–24	2400	18.5	749	67.4	8.6	94	7.4
C6	16.9	94–07–25	100	18.5	749	67.9	8.5	92	7.3
C6	16.9	94–07–25	200	18.0	749	68.0	8.5	92	7.3
C6	16.9	94–07–25	300	18.0	749	68.5	8.4	91	7.3
C6	16.9	94–07–25	400	18.0	749	68.4	8.4	90	7.3
C6	16.9	94–07–25	500	18.0	749	68.9	8.4	90	7.2
C6	16.9	94–07–25	600	17.5	749	68.9	8.4	89	7.2
C6	16.9	94–07–25	700	17.5	749	69.1	8.4	90	7.2
C6	16.9	94–07–25	800	17.5	749	69.1	8.7	93	7.3
C6	16.9	94–07–25	900	17.5	749	68.1	9.2	98	7.4
C6	16.9	94–08–22	1530	20.0	747	68.0	10.0	112	8.5
C6	16.9	94–08–22	1600	20.0	747	66.8	10.0	113	8.5
C6	16.9	94–08–22	1630	20.0	747	67.3	9.9	111	8.5
C6	16.9	94–08–22	1700	20.0	747	67.3	9.9	111	8.5
C6	16.9	94–08–22	1730	20.0	747	66.1	9.8	110	8.6
C6	16.9	94–08–22	1800	20.0	747	66.8	9.7	109	8.5
C6	16.9	94–08–22	1830	20.0	747	65.8	9.7	108	8.5
C6	16.9	94–08–22	1900	19.5	747	66.3	9.4	105	8.4
C6	16.9	94–08–22	1930	19.5	747	65.3	9.3	103	8.3
C6	16.9	94–08–22	2000	19.0	747	66.5	9.0	100	8.2
C6	16.9	94–08–22	2030	19.0	747	67.0	8.8	97	8.0
C6	16.9	94–08–22	2100	19.0	747	65.4	8.7	95	7.9
C6	16.9	94–08–22	2130	18.5	747	66.6	8.4	92	7.8
C6	16.9	94–08–22	2200	18.5	747	67.3	8.4	91	7.8
C6	16.9	94–08–22	2230	18.5	747	65.4	8.2	89	7.7
C6	16.9	94–08–22	2300	18.5	747	65.9	8.3	90	7.7
C6	16.9	94–08–22	2330	18.5	747	67.1	8.1	88	7.6
C6	16.9	94–08–22	2400	18.5	747	67.4	8.1	88	7.6

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
C6	16.9	94–08–23	30	18.5	747	67.6	8.0	87	7.6
C6	16.9	94–08–23	100	18.5	747	68.1	8.0	87	7.5
C6	16.9	94–08–23	130	18.5	747	67.9	7.9	85	7.5
C6	16.9	94–08–23	200	18.5	747	68.5	7.8	85	7.5
C6	16.9	94–08–23	230	18.5	747	69.0	7.8	84	7.5
C6	16.9	94–08–23	300	18.0	747	67.8	7.8	84	7.4
C6	16.9	94–08–23	330	18.0	747	68.5	7.8	84	7.4
C6	16.9	94–08–23	400	18.0	747	67.8	7.7	83	7.4
C6	16.9	94–08–23	430	18.0	747	68.2	7.7	83	7.4
C6	16.9	94–08–23	500	18.0	747	69.2	7.7	82	7.4
C6	16.9	94–08–23	530	17.5	747	69.4	7.7	83	7.4
C6	16.9	94–08–23	600	17.5	747	68.7	7.6	82	7.4
C6	16.9	94–08–23	630	17.5	747	69.6	7.7	82	7.4
C6	16.9	94–08–23	700	17.5	747	69.5	7.7	82	7.3
C6	16.9	94–08–23	730	17.5	747	69.3	7.7	82	7.4
C6	16.9	94–08–23	800	17.5	747	67.7	7.9	84	7.4
C6	16.9	94–08–23	830	17.0	747	69.0	8.1	86	7.4
C6	16.9	94–08–23	900	17.0	747	68.9	8.3	88	7.5
C6	16.9	94–08–23	930	17.5	747	67.9	8.4	89	7.6
C6	16.9	94–08–23	1000	17.5	747	67.8	8.7	92	7.6
M1	19.3	94–07–25	1530	16.0	756	46.0	10.2	105	8.1
M1	19.3	94–07–25	1600	16.0	756	46.0	10.3	106	8.2
M1	19.3	94–07–25	1630	16.0	756	46.0	10.2	105	8.2
M1	19.3	94–07–25	1700	16.0	756	46.0	10.2	105	8.1
M1	19.3	94–07–25	1730	16.5	756	46.0	10.4	106	8.1
M1	19.3	94–07–25	1800	16.0	756	46.0	10.2	105	8.1
M1	19.3	94–07–25	1830	16.0	756	46.0	10.2	105	8.1
M1	19.3	94–07–25	1900	16.0	756	46.0	10.1	103	8.0

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
M1	19.3	94–07–25	1930	16.0	756	46.0	10.2	103	8.0
M1	19.3	94–07–25	2000	15.5	756	46.0	10.0	102	7.9
M1	19.3	94–07–25	2030	15.5	756	46.0	10.0	101	7.8
M1	19.3	94–07–25	2100	15.5	756	46.0	9.8	99	7.8
M1	19.3	94–07–25	2130	15.5	756	46.0	9.8	99	7.7
M1	19.3	94–07–25	2200	15.0	756	46.0	9.8	98	7.6
M1	19.3	94–07–25	2230	15.0	756	46.0	9.8	97	7.6
M1	19.3	94–07–25	2300	14.5	756	46.0	9.7	96	7.6
M1	19.3	94–07–25	2330	14.5	756	46.0	9.7	96	7.5
M1	19.3	94–07–25	2400	14.5	756	46.0	9.5	93	7.5
M1	19.3	94–07–26	30	14.0	756	46.0	9.6	94	7.4
M1	19.3	94–07–26	100	14.0	756	46.0	9.5	93	7.5
M1	19.3	94–07–26	130	14.0	756	46.0	9.5	93	7.4
M1	19.3	94–07–26	200	14.0	756	46.0	9.5	93	7.4
M1	19.3	94–07–26	230	14.0	756	46.0	9.5	92	7.4
M1	19.3	94–07–26	300	13.5	756	46.0	9.5	92	7.4
M1	19.3	94–07–26	330	13.5	756	46.0	9.4	91	7.4
M1	19.3	94–07–26	400	13.5	756	46.0	9.4	91	7.4
M1	19.3	94–07–26	430	13.5	756	45.0	9.4	91	7.4
M1	19.3	94–07–26	500	13.5	756	45.0	9.4	91	7.3
M1	19.3	94–07–26	530	13.5	756	45.0	9.5	92	7.4
M1	19.3	94–07–26	600	13.5	756	45.0	9.5	92	7.4
M1	19.3	94–07–26	630	13.5	756	45.0	9.4	91	7.3
M1	19.3	94–07–26	700	13.5	756	45.0	9.5	92	7.4
M19	10.4	94–07–25	1330	16.0	756	60.1	10.7	109	8.0
M19	10.4	94–07–25	1400	16.5	756	60.1	10.7	110	8.1
M19	10.4	94–07–25	1430	16.5	756	60.2	10.7	110	8.1
M19	10.4	94–07–25	1500	17.0	756	60.1	10.6	111	8.1

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance ($\mu S/cm$)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
M19	10.4	94–07–25	1530	17.0	756	59.9	10.6	112	8.1
M19	10.4	94–07–25	1600	17.5	756	59.7	10.6	111	8.1
M19	10.4	94–07–25	1630	17.5	756	59.6	10.6	112	8.1
M19	10.4	94–07–25	1700	17.5	756	59.3	10.5	112	8.1
M19	10.4	94–07–25	1730	18.0	756	59.1	10.5	111	8.1
M19	10.4	94–07–25	1800	18.0	756	59.0	10.4	110	8.1
M19	10.4	94–07–25	1830	18.0	756	59.2	10.3	109	8.1
M19	10.4	94–07–25	1900	18.0	756	59.3	10.2	108	8.1
M19	10.4	94–07–25	1930	17.5	756	59.3	10.1	107	8.0
M19	10.4	94–07–25	2000	17.5	756	59.3	9.9	105	7.9
M19	10.4	94–07–25	2030	17.5	756	59.6	9.8	103	7.8
M19	10.4	94–07–25	2100	17.5	756	59.6	9.6	101	7.7
M19	10.4	94–07–25	2130	17.0	756	59.9	9.5	99	7.7
M19	10.4	94–07–25	2200	17.0	756	59.9	9.4	98	7.6
M19	10.4	94–07–25	2230	17.0	756	60.0	9.3	97	7.5
M19	10.4	94–07–25	2300	17.0	756	60.0	9.2	96	7.5
M19	10.4	94–07–25	2330	16.5	756	60.1	9.2	95	7.4
M19	10.4	94–07–25	2400	16.5	756	60.2	9.0	93	7.4
M19	10.4	94–07–26	30	16.5	756	60.2	9.1	93	7.4
M19	10.4	94–07–26	100	16.0	756	60.0	9.1	93	7.4
M19	10.4	94–07–26	130	16.0	756	59.9	9.1	93	7.3
M19	10.4	94–07–26	200	16.0	756	59.9	9.0	91	7.3
M19	10.4	94–07–26	230	15.5	756	59.9	9.1	92	7.3
M19	10.4	94–07–26	300	15.5	756	59.8	9.1	92	7.3
M19	10.4	94–07–26	330	15.5	756	59.6	9.1	91	7.3
M19	10.4	94–07–26	400	15.0	756	59.6	9.1	91	7.3
M19	10.4	94–07–26	430	15.0	756	59.6	9.1	91	7.3
M19	10.4	94–07–26	500	14.5	756	59.6	9.1	91	7.3

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
M19	10.4	94–07–26	530	14.5	756	59.6	9.2	91	7.3
M19	10.4	94–07–26	600	14.5	756	59.7	9.2	90	7.3
M19	10.4	94–07–26	630	14.5	756	59.9	9.2	91	7.3
M19	10.4	94–07–26	700	14.0	756	59.9	9.3	91	7.3
M19	10.4	94–07–26	730	14.0	756	59.9	9.4	92	7.3
M19	10.4	94–07–26	800	14.0	756	59.9	9.5	93	7.3
M19	10.4	94–07–26	830	14.0	756	59.8	9.6	94	7.3
M19	10.4	94–07–26	900	14.0	756	59.6	9.7	95	7.3
M19	10.4	94–07–26	930	14.5	756	59.6	9.9	97	7.4
M19	10.4	94–07–26	1000	14.5	756	59.5	10.0	98	7.4
M19	10.4	94–07–26	1030	14.5	756	59.7	10.1	100	7.5
M19	10.4	94–08–23	1400	16.0	750	55.0	10.5	109	8.0
M19	10.4	94–08–23	1430	16.5	750	55.0	10.5	109	8.0
M19	10.4	94–08–23	1500	16.5	750	55.0	10.5	109	8.1
M19	10.4	94–08–23	1530	16.5	750	55.0	10.5	109	8.1
M19	10.4	94–08–23	1600	17.0	750	55.0	10.4	109	8.1
M19	10.4	94–08–23	1630	17.0	750	56.0	10.5	110	8.2
M19	10.4	94–08–23	1700	17.0	750	56.0	10.4	109	8.2
M19	10.4	94–08–23	1730	17.0	750	57.0	10.3	108	8.1
M19	10.4	94–08–23	1800	17.0	750	56.0	10.3	108	8.1
M19	10.4	94–08–23	1830	17.0	750	56.0	10.2	106	8.1
M19	10.4	94–08–23	1900	16.5	750	57.0	10.1	105	8.1
M19	10.4	94–08–23	1930	16.5	750	58.0	9.9	103	8.0
M19	10.4	94–08–23	2000	16.5	750	58.0	9.7	101	7.9
M19	10.4	94–08–23	2030	16.5	750	57.0	9.6	100	7.8
M19	10.4	94–08–23	2100	16.5	750	57.0	9.5	98	7.7
M19	10.4	94–08–23	2130	16.0	750	58.0	9.3	97	7.6
M19	10.4	94–08–23	2200	16.0	750	58.0	9.3	96	7.6

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (⁰C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
M19	10.4	94–08–23	2230	16.0	750	58.0	9.2	95	7.5
M19	10.4	94–08–23	2300	16.0	750	58.0	9.1	94	7.5
M19	10.4	94–08–23	2330	15.5	750	57.0	9.1	93	7.4
M19	10.4	94–08–23	2400	15.5	750	58.0	9.1	93	7.4
M19	10.4	94–08–24	30	15.5	750	57.0	9.1	92	7.4
M19	10.4	94–08–24	100	15.5	750	56.0	9.0	92	7.4
M19	10.4	94–08–24	130	15.0	750	56.0	9.0	91	7.3
M19	10.4	94–08–24	200	15.0	750	57.0	9.0	91	7.3
M19	10.4	94–08–24	230	15.0	750	57.0	9.0	91	7.3
M19	10.4	94–08–24	300	14.5	750	58.0	9.0	90	7.3
M19	10.4	94–08–24	330	14.5	750	59.0	9.0	90	7.3
M19	10.4	94–08–24	400	14.5	750	59.0	9.1	90	7.3
M19	10.4	94–08–24	430	14.5	750	59.0	9.0	90	7.3
M19	10.4	94–08–24	500	14.0	750	59.0	9.1	90	7.3
M19	10.4	94–08–24	530	14.0	750	58.0	9.0	89	7.3
M19	10.4	94–08–24	600	14.0	750	58.0	9.0	89	7.3
M19	10.4	94–08–24	630	14.0	750	59.0	9.0	89	7.3
M19	10.4	94–08–24	700	14.0	750	59.0	9.1	89	7.2
M19	10.4	94–08–24	730	14.0	750	59.0	9.2	90	7.3
M19	10.4	94–08–24	800	14.0	750	59.0	9.2	91	7.3
M19	10.4	94–08–24	830	14.0	750	59.0	9.4	92	7.3
M19	10.4	94–08–24	900	14.0	750	60.0	9.5	93	7.4
M19	10.4	94–08–24	930	14.0	750	59.0	9.6	95	7.4
P1	151.4	94–08–24	1500	18.5	757	59.0	10.8	116	8.5
P1	151.4	94–08–24	1530	18.5	757	59.0	11.0	118	8.5
P1	151.4	94–08–24	1600	18.5	757	59.0	11.1	120	8.5
P1	151.4	94–08–24	1630	19.0	757	59.0	11.2	120	8.5
P1	151.4	94–08–24	1700	19.0	757	59.0	11.2	121	8.5

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
P1	151.4	94–08–24	1730	19.0	757	59.0	11.2	121	8.6
P1	151.4	94–08–24	1800	19.0	757	59.0	11.2	121	8.6
P1	151.4	94–08–24	1830	19.0	757	59.0	11.1	120	8.6
P1	151.4	94–08–24	1900	19.0	757	59.0	11.0	119	8.6
P1	151.4	94–08–24	1930	19.0	757	59.0	10.8	117	8.6
P1	151.4	94–08–24	2000	18.5	757	59.0	10.6	115	8.5
P1	151.4	94–08–24	2030	18.5	757	60.0	10.4	113	8.5
P1	151.4	94–08–24	2100	18.5	757	60.0	10.2	110	8.5
P1	151.4	94–08–24	2130	18.5	757	60.0	10.0	107	8.4
P1	151.4	94–08–24	2200	18.5	757	60.0	9.8	105	8.3
P1	151.4	94–08–24	2230	18.5	757	60.0	9.5	102	8.2
P1	151.4	94–08–24	2300	18.5	757	60.0	9.3	100	8.0
P1	151.4	94–08–24	2330	18.5	757	60.0	9.1	98	7.9
P1	151.4	94–08–24	2400	18.5	757	61.0	9.0	96	7.7
P1	151.4	94–08–25	30	18.5	757	61.0	8.8	94	7.6
P1	151.4	94–08–25	100	18.5	757	61.0	8.7	93	7.5
P1	151.4	94–08–25	130	18.0	757	61.0	8.5	91	7.4
P1	151.4	94–08–25	200	18.0	757	61.0	8.4	90	7.3
P1	151.4	94–08–25	230	18.0	757	61.0	8.3	89	7.3
P1	151.4	94–08–25	300	18.0	757	61.0	8.2	87	7.2
P1	151.4	94–08–25	330	18.0	757	61.0	8.1	87	7.2
P1	151.4	94–08–25	400	18.0	757	61.0	8.1	86	7.2
P1	151.4	94–08–25	430	18.0	757	61.0	8.0	85	7.1
P1	151.4	94–08–25	500	18.0	757	61.0	8.0	84	7.1
P1	151.4	94–08–25	530	17.5	757	61.0	7.9	83	7.1
P1	151.4	94–08–25	600	17.5	757	61.0	7.9	83	7.0
P1	151.4	94–08–25	630	17.5	757	61.0	7.8	82	7.0
P1	151.4	94–08–25	700	17.5	757	61.0	7.8	82	7.0

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
P1	151.4	94–08–25	730	17.5	757	61.0	7.8	82	6.9
P1	151.4	94–08–25	800	17.5	757	61.0	7.9	83	7.0
P1	151.4	94–08–25	830	17.5	757	61.0	8.0	84	7.0
P1	151.4	94–08–25	900	17.5	757	61.0	8.1	85	7.0
P1	151.4	94–08–25	930	17.5	757	61.0	8.3	87	7.0
P1	151.4	94–08–25	1000	17.5	757	61.0	8.5	90	7.1
P16	141.6	94–07–26	1330	19.5	759	74.6	9.8	107	7.8
P16	141.6	94–07–26	1400	19.5	759	75.3	9.9	108	7.9
P16	141.6	94–07–26	1430	20.0	759	75.0	10.0	110	8.0
P16	141.6	94–07–26	1500	20.0	759	74.9	10.1	111	8.0
P16	141.6	94–07–26	1530	20.0	759	74.7	10.2	113	8.1
P16	141.6	94–07–26	1600	20.5	759	75.8	10.2	114	8.1
P16	141.6	94–07–26	1630	20.5	759	74.6	10.3	114	8.2
P16	141.6	94–07–26	1700	20.5	759	74.9	10.3	115	8.2
P16	141.6	94–07–26	1730	20.5	759	74.8	10.3	115	8.3
P16	141.6	94–07–26	1800	20.5	759	74.9	10.3	115	8.3
P16	141.6	94–07–26	1830	20.5	759	74.2	10.3	115	8.3
P16	141.6	94–07–26	1900	20.5	759	73.5	10.2	114	8.3
P16	141.6	94–07–26	1930	20.5	759	73.6	10.1	112	8.3
P16	141.6	94–07–26	2000	20.5	759	73.7	10.0	111	8.2
P16	141.6	94–07–26	2030	20.0	759	73.9	9.8	109	8.2
P16	141.6	94–07–26	2100	20.0	759	73.7	9.7	108	8.1
P16	141.6	94–07–26	2130	20.0	759	73.3	9.6	106	8.1
P16	141.6	94–07–26	2200	20.0	759	73.5	9.5	105	8.0
P16	141.6	94–07–26	2230	20.0	759	73.6	9.4	103	8.0
P16	141.6	94–07–26	2300	19.5	759	73.6	9.3	102	7.9
P16	141.6	94–07–26	2330	19.5	759	71.5	9.2	101	7.8
P16	141.6	94–07–26	2400	19.5	759	71.4	9.1	99	7.8

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
P16	141.6	94–07–27	30	19.5	759	70.3	9.0	98	7.7
P16	141.6	94–07–27	100	19.5	759	70.3	8.9	97	7.7
P16	141.6	94–07–27	130	19.5	759	69.8	8.8	96	7.6
P16	141.6	94–07–27	200	19.0	759	70.3	8.7	95	7.6
P16	141.6	94–07–27	230	19.0	759	69.6	8.7	94	7.6
P16	141.6	94–07–27	300	19.0	759	69.7	8.6	93	7.5
P16	141.6	94–07–27	330	19.0	759	70.1	8.5	92	7.5
P16	141.6	94–07–27	400	19.0	759	69.6	8.4	91	7.5
P16	141.6	94–07–27	430	19.0	759	69.8	8.4	90	7.4
P16	141.6	94–07–27	500	18.5	759	70.2	8.3	89	7.4
P16	141.6	94–07–27	530	18.5	759	69.4	8.2	88	7.4
P16	141.6	94–07–27	600	18.5	759	69.2	8.1	87	7.3
P16	141.6	94–07–27	630	18.5	759	69.9	8.1	87	7.3
P16	141.6	94–07–27	700	18.5	759	70.0	8.1	86	7.3
P16	141.6	94–07–27	730	18.5	759	69.7	8.0	86	7.3
P16	141.6	94–07–27	758	18.5	759	79.0	8.2	88	7.3
P16	141.6	94–07–27	800	18.5	759	69.9	8.1	87	7.3
P16	141.6	94–07–27	830	18.5	759	70.1	8.2	87	7.3
P16	141.6	94–08–24	1300	18.5	757	71.3	10.0	108	7.8
P16	141.6	94–08–24	1330	19.0	757	71.8	10.2	111	8.0
P16	141.6	94–08–24	1400	19.0	757	72.0	10.4	113	8.1
P16	141.6	94–08–24	1430	19.0	757	71.9	10.5	115	8.2
P16	141.6	94–08–24	1500	19.5	757	72.9	10.7	117	8.3
P16	141.6	94–08–24	1530	19.5	757	71.0	10.8	118	8.4
P16	141.6	94–08–24	1600	19.5	757	70.8	10.9	120	8.4
P16	141.6	94–08–24	1630	19.5	757	72.7	11.0	121	8.5
P16	141.6	94–08–24	1700	19.5	757	70.9	11.1	121	8.5
P16	141.6	94–08–24	1730	19.5	757	71.7	11.1	121	8.6

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
P16	141.6	94–08–24	1800	19.5	757	70.9	11.1	122	8.6
P16	141.6	94–08–24	1830	19.5	757	72.4	11.1	121	8.6
P16	141.6	94–08–24	1900	19.5	757	70.7	11.0	120	8.6
P16	141.6	94–08–24	1930	19.0	757	70.9	10.9	119	8.6
P16	141.6	94–08–24	2000	19.0	757	72.1	10.8	117	8.6
P16	141.6	94–08–24	2030	19.0	757	71.7	10.7	116	8.6
P16	141.6	94–08–24	2100	19.0	757	70.8	10.6	114	8.5
P16	141.6	94–08–24	2130	19.0	757	70.0	10.4	113	8.5
P16	141.6	94–08–24	2200	18.5	757	70.1	10.3	111	8.5
P16	141.6	94–08–24	2230	18.5	757	70.9	10.2	110	8.5
P16	141.6	94–08–24	2300	18.5	757	71.2	10.1	109	8.4
P16	141.6	94–08–24	2330	18.5	757	69.4	10.0	107	8.4
P16	141.6	94–08–24	2400	18.5	757	71.7	9.8	105	8.4
P16	141.6	94–08–25	30	18.5	757	72.4	9.8	105	8.3
P16	141.6	94–08–25	100	18.5	757	74.5	9.6	103	8.3
P16	141.6	94–08–25	130	18.5	757	72.3	9.5	102	8.2
P16	141.6	94–08–25	200	18.0	757	72.9	9.4	100	8.1
P16	141.6	94–08–25	230	18.0	757	73.0	9.2	98	8.0
P16	141.6	94–08–25	300	18.0	757	75.5	9.1	97	7.9
P16	141.6	94–08–25	330	18.0	757	75.1	9.0	96	7.8
P16	141.6	94–08–25	400	18.0	757	74.2	8.9	94	7.7
P16	141.6	94–08–25	430	18.0	757	76.3	8.8	93	7.6
P16	141.6	94–08–25	500	18.0	757	75.0	8.6	92	7.5
P16	141.6	94–08–25	530	18.0	757	74.9	8.5	90	7.5
P16	141.6	94–08–25	600	18.0	757	75.0	8.4	89	7.4
P16	141.6	94–08–25	630	18.0	757	75.5	8.4	88	7.4
P16	141.6	94–08–25	700	18.0	757	75.4	8.3	87	7.4
P16	141.6	94–08–25	730	17.5	757	75.7	8.2	87	7.4

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
P16	141.6	94–08–25	800	17.5	757	77.4	8.2	87	7.3
P16	141.6	94–08–25	830	17.5	757	75.9	8.3	87	7.3
W19	126.7	94–07–27	1530	21.0	762	80.0	9.3	105	7.9
W19	126.7	94–07–27	1600	21.0	762	80.0	9.5	106	7.9
W19	126.7	94–07–27	1630	21.0	762	80.0	9.5	107	7.9
W19	126.7	94–07–27	1700	21.5	762	80.0	9.5	108	8.0
W19	126.7	94–07–27	1730	21.5	762	80.0	9.6	109	8.0
W19	126.7	94–07–27	1800	21.5	762	80.0	9.6	109	8.0
W19	126.7	94–07–27	1830	21.5	762	80.0	9.7	110	8.1
W19	126.7	94–07–27	1900	21.5	762	80.0	9.6	109	8.1
W19	126.7	94–07–27	1930	21.5	762	80.0	9.5	108	8.1
W19	126.7	94–07–27	2000	21.5	762	80.0	9.4	106	8.0
W19	126.7	94–07–27	2030	21.5	762	80.0	9.3	105	8.0
W19	126.7	94–07–27	2100	21.5	762	79.0	9.2	104	8.0
W19	126.7	94–07–27	2130	21.0	762	79.0	9.2	103	7.9
W19	126.7	94–07–27	2200	21.0	762	78.0	9.2	103	7.9
W19	126.7	94–07–27	2230	21.0	762	77.0	9.1	103	7.9
W19	126.7	94–07–27	2300	21.0	762	77.0	9.1	102	7.9
W19	126.7	94–07–27	2330	21.0	762	76.0	9.0	101	7.9
W19	126.7	94–07–27	2400	21.0	762	76.0	9.0	100	7.9
W19	126.7	94–07–28	30	21.0	762	75.0	8.9	99	7.9
W19	126.7	94–07–28	100	20.5	762	75.0	8.9	99	7.9
W19	126.7	94–07–28	130	20.5	762	75.0	8.7	97	7.8
W19	126.7	94–07–28	200	20.5	762	75.0	8.7	96	7.8
W19	126.7	94–07–28	230	20.5	762	75.0	8.6	95	7.7
W19	126.7	94–07–28	300	20.5	762	75.0	8.5	94	7.7
W19	126.7	94–07–28	330	20.0	762	75.0	8.5	93	7.7
W19	126.7	94–07–28	400	20.0	762	75.0	8.4	92	7.6

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance ($\mu S/cm$)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
W19	126.7	94–07–28	430	20.0	762	74.0	8.3	91	7.6
W19	126.7	94–07–28	500	20.0	762	74.0	8.3	91	7.6
W19	126.7	94–07–28	530	19.5	762	74.0	8.2	90	7.5
W19	126.7	94–07–28	600	19.5	762	74.0	8.2	89	7.5
W19	126.7	94–07–28	630	19.5	762	74.0	8.1	88	7.5
W19	126.7	94–07–28	700	19.5	762	74.0	8.1	88	7.5
W19	126.7	94–07–28	730	19.0	762	74.0	8.2	88	7.5
W19	126.7	94–07–28	800	19.0	762	74.0	8.3	90	7.5
W19	126.7	94–07–28	830	19.0	762	74.0	8.4	91	7.5
W19	126.7	94–08–25	1500	19.5	760	76.0	9.6	105	8.0
W19	126.7	94–08–25	1530	19.5	760	76.0	9.6	105	8.0
W19	126.7	94–08–25	1600	19.5	760	76.0	9.8	107	8.1
W19	126.7	94–08–25	1630	19.5	760	76.0	9.9	108	8.1
W19	126.7	94–08–25	1700	20.0	759	76.0	9.9	109	8.2
W19	126.7	94–08–25	1730	20.0	759	76.0	10.1	111	8.2
W19	126.7	94–08–25	1800	20.0	759	76.0	10.0	110	8.2
W19	126.7	94–08–25	1830	20.0	759	76.0	10.0	110	8.2
W19	126.7	94–08–25	1900	19.5	759	76.0	9.9	109	8.2
W19	126.7	94–08–25	1930	19.5	759	76.0	9.9	108	8.2
W19	126.7	94–08–25	2000	19.5	759	76.0	9.8	107	8.2
W19	126.7	94–08–25	2030	19.5	758	76.0	9.7	106	8.2
W19	126.7	94–08–25	2100	19.5	758	76.0	9.5	104	8.1
W19	126.7	94–08–25	2130	19.5	758	76.0	9.6	105	8.2
W19	126.7	94–08–25	2200	19.5	758	76.0	9.5	104	8.1
W19	126.7	94–08–25	2230	19.5	758	76.0	9.2	100	8.1
W19	126.7	94–08–25	2300	19.5	758	76.0	9.4	102	8.1
W19	126.7	94–08–25	2330	19.0	758	76.0	9.3	101	8.1
W19	126.7	94–08–25	2400	19.0	758	76.0	9.2	100	8.0

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
W19	126.7	94–08–26	30	19.0	757	76.0	9.1	99	8.0
W19	126.7	94–08–26	100	19.0	757	76.0	9.0	98	7.9
W19	126.7	94–08–26	130	19.0	757	76.0	8.9	96	7.9
W19	126.7	94–08–26	200	18.5	757	75.0	8.8	95	7.9
W19	126.7	94–08–26	230	18.5	757	75.0	8.7	94	7.8
W19	126.7	94–08–26	300	18.5	757	75.0	8.6	93	7.8
W19	126.7	94–08–26	330	18.5	757	75.0	8.5	92	7.8
W19	126.7	94–08–26	400	18.5	756	75.0	8.6	92	7.7
W19	126.7	94–08–26	430	18.0	756	74.0	8.4	90	7.7
W19	126.7	94–08–26	500	18.0	756	74.0	8.4	89	7.7
W19	126.7	94–08–26	530	18.0	756	74.0	8.2	88	7.7
W19	126.7	94–08–26	600	18.0	756	73.0	8.1	86	7.6
W19	126.7	94–08–26	630	18.0	756	73.0	--	--	7.6
W19	126.7	94–08–26	700	17.5	756	73.0	--	--	7.6
W19	126.7	94–08–26	730	17.5	755	73.0	--	--	7.6
W19	126.7	94–08–26	800	17.5	755	73.0	--	--	7.6
W19	126.7	94–08–26	830	17.5	755	73.0	--	--	7.6
W19	126.7	94–08–26	900	18.0	755	73.0	8.8	93	7.6
A1	121.5	94–07–28	1300	20.0	758	75.0	9.1	101	7.6
A1	121.5	94–07–28	1330	20.0	758	76.0	9.0	99	7.6
A1	121.5	94–07–28	1400	20.5	758	76.0	9.0	100	7.6
A1	121.5	94–07–28	1430	20.5	758	77.0	9.1	101	7.7
A1	121.5	94–07–28	1500	20.5	758	77.0	9.2	103	7.7
A1	121.5	94–07–28	1530	20.5	758	76.0	9.2	103	7.7
A1	121.5	94–07–28	1600	21.0	758	77.0	9.2	104	7.8
A1	121.5	94–07–28	1630	21.0	758	76.0	9.3	104	7.8
A1	121.5	94–07–28	1700	21.0	758	77.0	9.3	105	7.8
A1	121.5	94–07–28	1730	21.0	758	77.0	9.3	105	7.8

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
A1	121.5	94–07–28	1800	21.0	758	77.0	9.4	106	7.9
A1	121.5	94–07–28	1830	21.0	758	76.0	9.4	106	7.9
A1	121.5	94–07–28	1900	21.0	758	77.0	9.3	105	7.9
A1	121.5	94–07–28	1930	21.0	758	76.0	9.3	105	7.9
A1	121.5	94–07–28	2000	21.0	758	77.0	9.3	105	7.9
A1	121.5	94–07–28	2030	21.0	758	76.0	9.3	105	7.9
A1	121.5	94–07–28	2100	21.0	758	75.0	9.3	105	7.9
A1	121.5	94–07–28	2130	21.0	758	76.0	9.2	103	7.9
A1	121.5	94–07–28	2200	21.0	758	75.0	9.1	103	7.9
A1	121.5	94–07–28	2230	21.0	758	76.0	9.1	102	7.9
A1	121.5	94–07–28	2300	21.0	758	75.0	9.0	101	7.8
A1	121.5	94–07–28	2330	21.0	758	75.0	9.0	101	7.8
A1	121.5	94–07–28	2400	21.0	758	76.0	9.0	101	7.8
A1	121.5	94–07–29	30	20.5	758	75.0	8.8	99	7.8
A1	121.5	94–07–29	100	20.5	758	75.0	8.8	99	7.8
A1	121.5	94–07–29	130	20.5	758	75.0	8.8	99	7.8
A1	121.5	94–07–29	200	20.5	758	75.0	8.8	98	7.8
A1	121.5	94–07–29	230	20.5	758	74.0	8.7	97	7.7
A1	121.5	94–07–29	300	20.5	758	74.0	8.6	96	7.7
A1	121.5	94–07–29	330	20.0	758	74.0	8.5	95	7.7
A1	121.5	94–07–29	400	20.0	758	75.0	8.5	94	7.6
A1	121.5	94–07–29	430	20.0	758	75.0	8.4	93	7.6
A1	121.5	94–07–29	500	20.0	758	75.0	8.4	92	7.5
A1	121.5	94–07–29	530	20.0	758	75.0	8.3	91	7.5
A1	121.5	94–07–29	600	19.5	758	75.0	8.2	90	7.5
A1	121.5	94–07–29	630	19.5	758	75.0	8.2	90	7.4
A1	121.5	94–07–29	700	19.5	758	75.0	8.2	90	7.4
A1	121.5	94–07–29	730	19.5	758	75.0	8.1	89	7.4

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^0C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
A1	121.5	94–07–29	800	19.5	758	75.0	8.2	89	7.4
A1	121.5	94–07–29	830	19.5	758	76.0	8.2	89	7.4
A1	121.5	94–07–29	900	19.0	758	76.0	8.2	89	7.4
A1	121.5	94–07–29	930	19.0	758	76.0	8.3	90	7.4
A14	114.5	94–07–28	1330	20.5	758	83.8	8.8	98	7.5
A14	114.5	94–07–28	1400	21.0	758	83.3	8.9	99	7.5
A14	114.5	94–07–28	1430	21.0	758	82.9	8.9	100	7.5
A14	114.5	94–07–28	1500	21.0	758	82.2	9.0	101	7.5
A14	114.5	94–07–28	1530	21.0	758	81.8	9.0	102	7.5
A14	114.5	94–07–28	1600	21.0	758	81.9	9.1	103	7.5
A14	114.5	94–07–28	1630	21.0	758	82.8	9.1	103	7.6
A14	114.5	94–07–28	1700	21.5	758	82.5	9.2	104	7.6
A14	114.5	94–07–28	1730	21.5	758	82.1	9.2	104	7.6
A14	114.5	94–07–28	1800	21.5	758	81.8	9.2	105	7.6
A14	114.5	94–07–28	1830	21.5	758	81.5	9.2	105	7.6
A14	114.5	94–07–28	1900	21.5	758	83.0	9.2	105	7.6
A14	114.5	94–07–28	1930	21.5	758	82.0	9.2	105	7.6
A14	114.5	94–07–28	2000	21.5	758	81.7	9.2	105	7.6
A14	114.5	94–07–28	2030	21.5	758	82.1	9.2	104	7.6
A14	114.5	94–07–28	2100	21.5	758	82.3	9.2	104	7.6
A14	114.5	94–07–28	2130	21.0	758	82.6	9.1	103	7.6
A14	114.5	94–07–28	2200	21.0	758	82.5	9.0	101	7.6
A14	114.5	94–07–28	2230	21.0	758	82.0	9.0	102	7.6
A14	114.5	94–07–28	2300	21.0	758	82.4	9.1	103	7.6
A14	114.5	94–07–28	2330	21.0	758	81.3	8.9	101	7.6
A14	114.5	94–07–28	2400	21.0	758	82.6	9.0	101	7.5
A14	114.5	94–07–29	30	21.0	758	81.9	9.0	102	7.5
A14	114.5	94–07–29	100	21.0	758	82.4	9.0	101	7.5

Table 10. Field-parameter measures from the reach monitors in the upper Willamette River Basin, July 24–29 and August 22–26, 1994—Continued

Site code	River mile	Sampling date	Sampling time	Water temperature (^{0}C)	Barometric pressure (mm Hg)	Specific conductance (μS/cm)	DO concentration (mg/L as O_2)	DO saturation (percent)	pH (standard units)
A14	114.5	94–07–29	130	21.0	758	82.4	9.0	101	7.5
A14	114.5	94–07–29	200	20.5	758	83.2	9.0	100	7.5
A14	114.5	94–07–29	230	20.5	758	82.2	8.9	100	7.5
A14	114.5	94–07–29	300	20.5	758	82.2	8.9	100	7.5
A14	114.5	94–07–29	330	20.5	758	82.6	8.9	99	7.5
A14	114.5	94–07–29	400	20.5	758	83.3	8.8	98	7.5
A14	114.5	94–07–29	430	20.5	758	83.4	8.8	98	7.5
A14	114.5	94–07–29	500	20.5	758	83.5	8.7	97	7.5
A14	114.5	94–07–29	530	20.5	758	83.0	8.7	97	7.5
A14	114.5	94–07–29	600	20.5	758	83.7	8.7	97	7.5
A14	114.5	94–07–29	630	20.5	758	83.2	8.6	96	7.5
A14	114.5	94–07–29	700	20.0	758	83.1	8.6	96	7.5
A14	114.5	94–07–29	730	20.0	758	83.3	8.3	92	7.5
A14	114.5	94–07–29	800	20.0	758	83.4	8.2	91	7.4
A14	114.5	94–07–29	830	20.0	758	84.0	8.2	91	7.4
A14	114.5	94–07–29	900	20.0	758	84.3	8.2	90	7.4

Table 11. Nutrient analyses for the upper Willamette River Basin, August 22–26, 1994

[TDP, total dissolved phosphorus; SRP, soluble reactive phosphorus; mg/L, milligrams per liter; N, nitrogen; P, phosphorus; Site code, code defining each study site, where A, Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P, Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork Willamette River reach from RM 21.7 to RM 12.5 (see table 2 for additional site information); Filtered, passed through a 0.45 micrometer filter prior to analysis]

Site code	River mile	Sampling date	Sampling time	Filtered water samples						Unfiltered water samples	
				Ammonia nitrogen (mg/L as N)	Ammonia plus organic nitrogen (mg/L as N)	Nitrite (mg/L as N)	Nitrite plus nitrate (mg/L as N)	TDP (mg/L as P)	SRP (mg/L as P)	Ammonia plus organic nitrogen (mg/L as N)	Phosphorus (mg/L as P)
C1	21.7	94–08–22	1400	< 0.002	< 0.2	< 0.001	0.005	0.001	< 0.001	< 0.2	0.001
C4	20.7	94–08–23	0800	< .002	< .2	.005	.098	.043	.034	< .2	.051
C5	20.0	94–08–22	1845	.021	< .2	.009	.144	.042	.030	< .2	.046
C7	13.9	94–08–23	0700	< .002	< .2	.005	.122	.046	.030	< .2	.036
C8	12.5	94–08–22	1800	.002	< .2	.009	.056	.012	.006	< .2	.018
M8	14.8	94–08–24	0830	< .002	< .2	.001	.008	.023	.019	< .2	.027
M11	14.3	94–08–23	1800	.007	< .2	.001	.008	.029	.022	< .2	.030
M12	13.7	94–08–24	0900	.003	< .2	.001	.013	.010	.004	< .2	.018
M15	13.4	94–08–23	1620	< .002	< .2	.002	.008	.025	.020	< .2	.032
M20	9.5	94–08–23	1500	< .002	< .2	.001	.010	.026	.021	< .2	.028
P2	151.0	94–08–24	1340	< .002	< .2	.005	.041	.016	.011	< .2	.031
P5	147.6	94–08–24	1530	< .002	< .2	.003	032	.018	.011	< .2	.027
P10	146.0	94–08–24	1700	.011	< .2	.003	.032	.026	.017	< .2	.041
P11	145.9	94–08–24	1820	.016	.4	.015	.958	.050	.017	.4	.051
P14	144.6	94–08–24	1830	.013	< .2	.002	.037	.028	.019	< .2	.039
P16	141.6	94–08–25	0900	.003	< .2	.003	.054	.023	.015	< .2	.033
W2	132.6	94–08–25	1310	< .002	< .2	.003	.053	.023	.015	< .2	.033
W10	131.4	94–08–25	1530	< .002	< .2	.003	.055	.022	.015	< .2	.036
W13	130.7	94–08–25	1600	< .002	< .2	.005	.080	.038	.031	< .2	.049
W18	127.1	94–08–25	1740	.002	< .2	.006	.073	.038	.029	< .2	.053

Table 12. Biochemical oxygen demand measurements in the upper Willamette River Basin, August 22–26, 1994

[BOD, biochemical oxygen demand; D, day; mg/L, milligrams per liter; Site code, code defining each study site, where A , Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P, Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork Willamette River reach from RM 21.7 to RM 12.5 (see table 2 for additional site information); rates are log base 10]

Site code	River mile	Sampling date	Sampling time	BOD			Carbonaceous BOD			Nitrogenous BOD	
				Rate (D^{-1})	5 Day (mg/L)	Ultimate (mg/L)	Rate (D^{-1})	5 Day (mg/L)	Ultimate (mg/L)	5 Day (mg/L)	Ultimate (mg/L)
C1	21.7	94–08–22	1400	0.03	1.0	2.3	0.03	0.7	1.7	0.3	0.6
C3	21.4	94–08–22	1640	.04	1.1	3.1	.03	.6	2.1	.5	1.0
C4	20.7	94–08–23	0800	.02	.5	2.4	.03	.6	1.9	< .1	.5
C5	20.0	94–08–22	1845	.04	.8	2.3	.04	.6	1.5	.2	.8
C7	13.9	94–08–23	0700	.03	.5	1.8	.03	.5	1.8	< .1	< .1
C8	12.5	94–08–22	1800	.03	1.0	3.3	.03	.6	2.0	.4	1.3
M8	14.8	94–08–24	0830	.03	.3	.9	.03	.4	1.2	< .1	< .1
M11	14.3	94–08–23	1800	.03	.5	1.6	.04	.7	2.0	< .1	< .1
M12	13.7	94–08–24	0900	.02	.4	2.0	.02	.4	1.8	< .1	.2
M15	13.4	94–08–23	1620	.04	.6	1.6	.04	.6	1.5	.2	.1
M19	10.4	94–08–23	1500	.05	1.1	2.6	.03	.6	2.1	.5	.5
P2	151.0	94–08–24	1340	.03	.6	2.1	.03	.8	2.8	< .1	< .1
P5	147.6	94–08–24	1520	.04	1.1	3.1	.04	.6	1.7	.5	1.4
P10	146.0	94–08–24	1820	.03	.8	2.9	.03	.7	2.3	.1	.6
P12	145.8	94–08–24	1820	.03	1.0	3.5	.04	.9	2.4	.1	1.1
P14	144.6	94–08–24	1830	.02	.7	3.5	.04	1.0	2.7	< .1	.8
P16	141.6	94–08–25	0900	.03	.7	2.3	.03	.7	2.5	< .1	< .1
W3	132.6	94–08–25	1310	.04	.9	2.5	.02	.5	2.6	.4	< .1
W10	131.4	94–08–25	1530	.03	1.0	3.5	.04	.8	2.2	.2	1.3
W12	130.7	94–08–25	1600	.03	.9	3.1	.03	.7	2.3	.2	.8
W18	127.1	94–08–25	1740	.02	.7	3.3	.02	.5	2.6	.2	.7

Table 13. Estimated average streamflow for selected sites in the upper Willamette River Basin, August 22–26, 1994

[Site code, code defining each study site, where A, Albany reach of Willamette River from RM 121.5 to RM 114.5, M, McKenzie reach from RM 19.3 to RM 7.1, W, Corvallis reach of the Willamette River from RM 132.6 to RM 126.7, P , Peoria reach of the Willamette River from RM 151.4 to RM 141.6, C, Coast Fork Willamette River reach from RM 21.7 to RM 12.5 (see table 2 for further clarification); cfs ,cubic feet per second]

Site code	River mile	July synoptic		August synoptic	
		Date	Estimated discharge (cfs)	Date	Estimated discharge (cfs)
Coast Fork reach					
C6	16.9	94–07–20	121	94–08–20	135
C6	16.9	94–07–21	121	94–08–21	136
C6	16.9	94–07–22	120	94–08–22	135
C6	16.9	94–07–23	116	94–08–23	131
C6	16.9	94–07–24	118	94–08–24	127
C6	16.9	94–07–25	121	94–08–25	126
C6	16.9	94–07–26	120	94–08–26	124
C6	16.9	94–07–27	116	94–08–27	120
C6	16.9	94–07–28	115	94–08–28	120
C6	16.9	94–07–29	115	94–08–29	118
C6	16.9	94–07–30	116	94–08–30	114
McKenzie reach					
M1	19.3	94–07–20	2,690	94–08–20	3,000
M1	19.3	94–07–21	2,660	94–08–21	3,000
M1	19.3	94–07–22	2,650	94–08–22	3,000
M1	19.3	94–07–23	2,660	94–08–23	3,000
M1	19.3	94–07–24	2,670	94–08–24	3,000
M1	19.3	94–07–25	2,660	94–08–25	3,000
M1	19.3	94–07–26	2,620	94–08–26	3,010
M1	19.3	94–07–27	2,630	94–08–27	3,010
M1	19.3	94–07–28	2,670	94–08–28	3,010
M1	19.3	94–07–29	2,720	94–08–29	3,010
M1	19.3	94–07–30	2,780	94–08–30	3,010
M12	13.7	94–07–20	46	94–08–20	26
M12	13.7	94–07–21	44	94–08–21	26
M12	13.7	94–07–22	42	94–08–22	26
M12	13.7	94–07–23	42	94–08–23	24
M12	13.7	94–07–24	41	94–08–24	22
M12	13.7	94–07–25	43	94–08–25	21
M12	13.7	94–07–26	43	94–08–26	22
M12	13.7	94–07–27	40	94–08–27	22
M12	13.7	94–07–28	37	94–08–28	22
M12	13.7	94–07–29	36	94–08–29	22
M12	13.7	94–07–30	38	94–08–30	22

Table 13. Estimated average streamflow for selected sites in the upper Willamette River Basin, August 22–26, 1994—Continued

Site code	River mile	July synoptic		August synoptic	
		Date	Estimated discharge (cfs)	Date	Estimated discharge (cfs)
McKenzie reach					
M18	11.8	94–07–20	2,740	94–08–20	3,030
M18	11.8	94–07–21	2,700	94–08–21	3,030
M18	11.8	94–07–22	2,690	94–08–22	3,030
M18	11.8	94–07–23	2,700	94–08–23	3,020
M18	11.8	94–07–24	2,710	94–08–24	3,020
M18	11.8	94–07–25	2,700	94–08–25	3,020
M18	11.8	94–07–26	2,660	94–08–26	3,030
M18	11.8	94–07–27	2,670	94–08–27	3,030
M18	11.8	94–07–28	2,710	94–08–28	3,030
M18	11.8	94–07–29	2,760	94–08–29	3,030
M18	11.8	94–07–30	2,820	94–08–30	3,030
Peoria reach					
P2	151	94–07–20	4,960	94–08–20	5,500
P2	151	94–07–21	4,920	94–08–21	5,530
P2	151	94–07–22	4,940	94–08–22	5,570
P2	151	94–07–23	4,890	94–08–23	5,570
P2	151	94–07–24	4,970	94–08–24	5,570
P2	151	94–07–25	5,120	94–08–25	5,590
P2	151	94–07–26	5,100	94–08–26	5,560
P2	151	94–07–27	5,020	94–08–27	5,540
P2	151	94–07–28	4,980	94–08–28	5,540
P2	151	94–07–29	5,010	94–08–29	5,530
P2	151	94–07–30	5,060	94–08–30	5,540
P16	141.6	94–07–20	4,980	94–08–20	5,520
P16	141.6	94–07–21	4,940	94–08–21	5,550
P16	141.6	94–07–22	4,960	94–08–22	5,590
P16	141.6	94–07–23	4,910	94–08–23	5,590
P16	141.6	94–07–24	4,990	94–08–24	5590
P16	141.6	94–07–25	5,140	94–08–25	5,610
P16	141.6	94–07–26	5,120	94–08–26	5,580
P16	141.6	94–07–27	5,040	94–08–27	5,560
P16	141.6	94–07–28	5,000	94–08–28	5,550
P16	141.6	94–07–29	5,030	94–08–29	5,550
P16	141.6	94–07–30	5,080	94–08–30	5,560

Table 13. Estimated average streamflow for selected sites in the upper Willamette River Basin, August 22–26, 1994—Continued

Site code	River mile	July synoptic		August synoptic	
		Date	Estimated discharge (cfs)	Date	Estimated discharge (cfs)
Corvallis reach					
W3	132.6	94–07–20	40	94–08–20	16
W3	132.6	94–07–21	38	94–08–21	16
W3	132.6	94–07–22	36	94–08–22	16
W3	132.6	94–07–23	36	94–08–23	16
W3	132.6	94–07–24	35	94–08–24	15
W3	132.6	94–07–25	37	94–08–25	14
W3	132.6	94–07–26	37	94–08–26	14
W3	132.6	94–07–27	34	94–08–27	14
W3	132.6	94–07–28	32	94–08–28	14
W3	132.6	94–07–29	31	94–08–29	14
W3	132.6	94–07–30	33	94–08–30	14
W7	132.1	94–07–20	16	94–08–20	9
W7	132.1	94–07–21	16	94–08–21	9
W7	132.1	94–07–22	15	94–08–22	9
W7	132.1	94–07–23	15	94–08–23	8
W7	132.1	94–07–24	15	94–08–24	7
W7	132.1	94–07–25	15	94–08–25	7
W7	132.1	94–07–26	15	94–08–26	7
W7	132.1	94–07–27	14	94–08–27	7
W7	132.1	94–07–28	13	94–08–28	7
W7	132.1	94–07–29	13	94–08–29	7
W7	132.1	94–07–30	13	94–08–30	7
W17	127.4	94–07–20	5,020	94–08–20	5,530
W17	127.4	94–07–21	4,980	94–08–21	5,560
W17	127.4	94–07–22	4,990	94–08–22	5,600
W17	127.4	94–07–23	4,950	94–08–23	5,600
W17	127.4	94–07–24	5,030	94–08–24	5,600
W17	127.4	94–07–25	5,180	94–08–25	5,620
W17	127.4	94–07–26	5,160	94–08–26	5,590
W17	127.4	94–07–27	5,080	94–08–27	5,570
W17	127.4	94–07–28	5,030	94–08–28	5,560
W17	127.4	94–07–29	5,060	94–08–29	5,560
W17	127.4	94–07–30	5,110	94–08–30	5,570

Table 13. Estimated average streamflow for selected sites in the upper Willamette River Basin, August 22–26, 1994—Continued

Site code	River mile	July synoptic		August synoptic	
		Date	Estimated discharge (cfs)	Date	Estimated discharge (cfs)
Albany reach					
A1	121.5	94–07–20	5,030	94–08–20	5,540
A1	121.5	94–07–21	4,990	94–08–21	5,570
A1	121.5	94–07–22	5,000	94–08–22	5,610
A1	121.5	94–07–23	4,960	94–08–23	5,610
A1	121.5	94–07–24	5,040	94–08–24	5,610
A1	121.5	94–07–25	5,190	94–08–25	5,630
A1	121.5	94–07–26	5,170	94–08–26	5,600
A1	121.5	94–07–27	5,090	94–08–27	5,580
A1	121.5	94–07–28	5,040	94–08–28	5,570
A1	121.5	94–07–29	5,070	94–08–29	5,570
A1	121.5	94–07–30	5,120	94–08–30	5,580
A4	119.5	94–07–20	110	94–08–20	76
A4	119.5	94–07–21	109	94–08–21	76
A4	119.5	94–07–22	105	94–08–22	76
A4	119.5	94–07–23	105	94–08–23	74
A4	119.5	94–07–24	103	94–08–24	72
A4	119.5	94–07–25	106	94–08–25	71
A4	119.5	94–07–26	106	94–08–26	72
A4	119.5	94–07–27	101	94–08–27	72
A4	119.5	94–07–28	95	94–08–28	72
A4	119.5	94–07–29	94	94–08–29	72
A4	119.5	94–07–30	96	94–08–30	72
A14	114.5	94–07–20	5,140	94–08–20	5,620
A14	114.5	94–07–21	5,100	94–08–21	5,650
A14	114.5	94–07–22	5,100	94–08–22	5,690
A14	114.5	94–07–23	5,070	94–08–23	5,680
A14	114.5	94–07–24	5,140	94–08–24	5,680
A14	114.5	94–07–25	5,300	94–08–25	5,700
A14	114.5	94–07–26	5,280	94–08–26	5,670
A14	114.5	94–07–27	5,190	94–08–27	5,650
A14	114.5	94–07–28	5,130	94–08–28	5,640
A14	114.5	94–07–29	5,160	94–08–29	5,690
A14	114.5	94–07–30	5,220	94–08–30	5,650