

*Willamette River Basin Studies:  
Human Health Technical Study*



**CHARACTERIZATION OF BACTERIA  
CONCENTRATIONS AT WATER RECREATIONAL SITES  
IN THE MIDDLE WILLAMETTE RIVER, JULY 1999**

**Prepared for**

**Oregon Department of Environmental Quality**  
Water Quality Division  
750 Front Street NE, Suite 120  
Salem, Oregon 97310

**Prepared by**

**EVS Environment Consultants, Inc.**  
200 West Mercer Street, Suite 403  
Seattle, WA 98119

EVS Project No. 2/839-01

**February 17, 2000**

*This report printed on recycled paper*

Willamette River Basin Studies:  
Human Health Technical Study

---

**CHARACTERIZATION OF  
BACTERIA CONCENTRATIONS  
AT WATER RECREATIONAL SITES IN THE  
MIDDLE WILLAMETTE RIVER, JULY 1999**

Julie Haddad  
Steven Ellis  
Lorraine Read

---

**Prepared for**

**Oregon Department of Environmental Quality  
Water Quality Division  
750 Front Street NE, Suite 120  
Salem, Oregon 97310**

---

**Prepared by**

**EVS Environment Consultants, Inc.  
200 West Mercer Street, Suite 403  
Seattle, WA 98119**

---

**EVS Project No.**

2/839-01

---

**February 17, 2000**

# TABLE OF CONTENTS

---

<b>LIST OF FIGURES</b>	iii
<b>LIST OF TABLES</b>	iii
<b>LIST OF ACRONYMS</b>	iv
<b>ACKNOWLEDGMENTS</b>	v
<hr/>	
<b>1.0 INTRODUCTION</b>	1
<hr/>	
<b>2.0 OBJECTIVES</b>	3
<hr/>	
<b>3.0 METHODS</b>	5
3.1 SAMPLE COLLECTION	5
3.2 LABORATORY ANALYSIS	6
<hr/>	
<b>4.0 DATA ANALYSIS</b>	7
4.1 COMPLIANCE WITH OREGON WATER QUALITY STANDARDS	7
4.2 COMPARE RESULTS AMONG STATIONS AND BETWEEN METHODS	7
<hr/>	
<b>5.0 RESULTS</b>	9
5.1 BACKGROUND CONDITIONS	9
5.1.1 Weather Conditions	9
5.1.2 Water Flow Conditions	9
5.2 <i>E. coli</i> CONCENTRATIONS AND COMPLIANCE WITH OREGON WATER QUALITY STANDARDS	9
5.2.1 Single Sample <i>E. coli</i> Compliance	12
5.2.2 Geometric Mean <i>E. coli</i> Compliance	12
5.3 FECAL COLIFORM BACTERIA CONCENTRATIONS AND COMPLIANCE WITH OREGON WATER QUALITY STANDARDS	12
5.4 COMPARISON OF RESULTS BETWEEN METHODS AND AMONG STATIONS	14
5.4.1 Comparison of Methods for Measuring <i>E. coli</i> Concentrations	14
5.4.2 Comparison of Bacteria Concentrations among Stations	16
<hr/>	
<b>6.0 CONCLUSIONS</b>	17
<hr/>	
<b>7.0 REFERENCES</b>	19

---

**APPENDIX A**

Results of 1998 Recreational Water Contact Survey of the Newberg Pool,  
Willamette River, Oregon

---

**APPENDIX B**

Laboratory Methods

---

**APPENDIX C**

Raw Data

---

**APPENDIX D**

Quality Assurance/Quality Control Review of July 1999 Bacterial Survey Data

---

## LIST OF FIGURES

---

Figure 1.	Bacteria sampling stations within the Wheatland-Willamette Falls reach of the Willamette River	2
Figure 2.	Mean daily streamflow for June 26-July 30, 1999	10
Figure 3a.	<i>E. coli</i> concentrations measured using Standard Method 9213D	13
Figure 3b.	Fecal coliform/ <i>E. coli</i> concentrations measured using Standard Method 9222D	13
Figure 4.	Mean <i>E. coli</i> concentrations measured at the four sampling stations during July 1999	15

---

## LIST OF TABLES

---

Table 1.	Locations and surface water temperatures of bacteria monitoring stations	5
Table 2.	Water quality standards for indicator bacteria	7
Table 3.	Mean <i>E. coli</i> concentrations measured using Standard Method 9213D	11
Table 4.	Mean fecal coliform/ <i>E. coli</i> concentrations measured using Standard Method 9222D	11

## **LIST OF ACRONYMS**

---

<b>ANOVA</b>	analysis of variation
<b>APHA</b>	American Public Health Association
<b>cfs</b>	cubic feet per second
<b>DEQ</b>	Oregon Department of Environmental Quality
<b>GPS</b>	global positioning system
<b>QA</b>	quality assurance
<b>RM</b>	river mile
<b>SM</b>	standard method
<b>USGS</b>	U.S. Geological Survey
<b>WRBTF</b>	Willamette River Basin Task Force

## **ACKNOWLEDGMENTS**

---

This report was prepared by EVS Environment Consultants (EVS) under contract No. 004-99 to the Oregon Department of Environmental Quality (DEQ). Dr. Gene Foster served as DEQ's Project Coordinator for this project and Dr. Steve Ellis served as EVS's project manager. Statistical analyses were provided by Ms. Lorraine Read. Report graphics were prepared by Mr. Rick Dailey and Ms. Kimberly Galimanis. Technical editing was performed by Ms. Sarah Moulton. Word processing was conducted by Ms. Kay Hessemer and Ms. Carol Pearsall.

Ms. Julie Haddad, Dr. Ellis, and Ms. Lorraine Read were the authors of this report. Dr. Robert Dexter provided technical review. Field sampling was provided by Ms. Julie Haddad and Ms. Cynthia Wagener of EVS and Ms. Jessica Wilcox of Adolfson Associates Inc.

Laboratory analyses of bacteria concentrations were conducted by North Creek Analytical Laboratory (NCA) in Beaverton, Oregon. Ms. Lisa Domenighini served as NCA's project coordinator.

The following individuals provided comments on an earlier draft of this report:

Mr. James Bloom	Oregon Department of Environmental Quality
Dr. Gene Foster	Oregon Department of Environmental Quality
Mr. Dick Pederson	Oregon Department of Environmental Quality
Mr. Greg Pettit	Oregon Department of Environmental Quality
Mr. Don Yon	Oregon Department of Environmental Quality
Dr. Duncan Gilroy	Oregon Health Division
Mr. Ken Kauffman	Oregon Health Division

## 1.0 INTRODUCTION

---

The Willamette River and its tributaries are used for drinking and irrigation water, recreation, and commerce. Although many aspects of the health of the river are well understood, more information is needed regarding potential human health concerns related to the use of the river. The Willamette River Basin Task Force (WRBTF) assessed the status of the waters of the Willamette River Basin and issued a report of their recommendations to Governor Kitzhaber and the Oregon Legislature in December 1997 (WRBTF 1997). The WRBTF identified three areas where more information is needed regarding human health concerns in the Willamette River Basin: fish consumption, water contact recreation, and drinking water.

One of the primary concerns associated with water contact recreation is exposure to bacteria in the water. In July 1999, EVS conducted a survey to evaluate the concentrations of fecal coliform bacteria and *Escherichia coli* at several sites along the Lower Willamette River. The survey was conducted along a 45-mile stretch of the Willamette River extending from Wheatland Ferry, at river mile (RM) 72, to Willamette Falls near Oregon City, at RM 26.5 (the Wheatland-Willamette Falls Reach; Figure 1). This reach was chosen as the area of interest by the Oregon Department of Environmental Quality (DEQ) in part because it includes the Newberg Pool (RM 26.5 to RM 52), which has historically been identified as an area of poor water quality based on monitoring of trace metals, organic contaminants, and impaired biota. Newberg Pool is also an area of high recreational use (Appendix A). Four sampling locations with high primary-contact use (e.g., swimming, water skiing, and jet skiing) were identified through a reconnaissance survey of this reach in September 1998 (EVS 1999a; included as Appendix A). Samples were collected in July, the month with the highest recreational use based on past recreational use surveys (Marine Board 1996; Stallman pers. comm. 1998; EVS 1999a).

This data report presents the results of the 1999 bacteria study. The objectives of the study are identified in Section 2.0, and the methods used for data collection and analysis are briefly described in Sections 3.0 and 4.0. The results of the study are presented in Section 5.0, including an evaluation of the compliance of bacteria concentrations with state water quality standards, comparisons between two laboratory methods used to measure *E. coli* concentrations, and comparisons of bacteria concentrations among the four sampling locations. Conclusions of the study are presented in Section 6.0, and Section 7.0 is a list of references cited.

Four appendices are also included. Results from the 1998 recreational survey are presented in Appendix A. A description of bacteria laboratory methods is presented in Appendix B. Raw data are provided in Appendix C, and a quality assurance/quality control review of the bacteria data is provided in Appendix D.

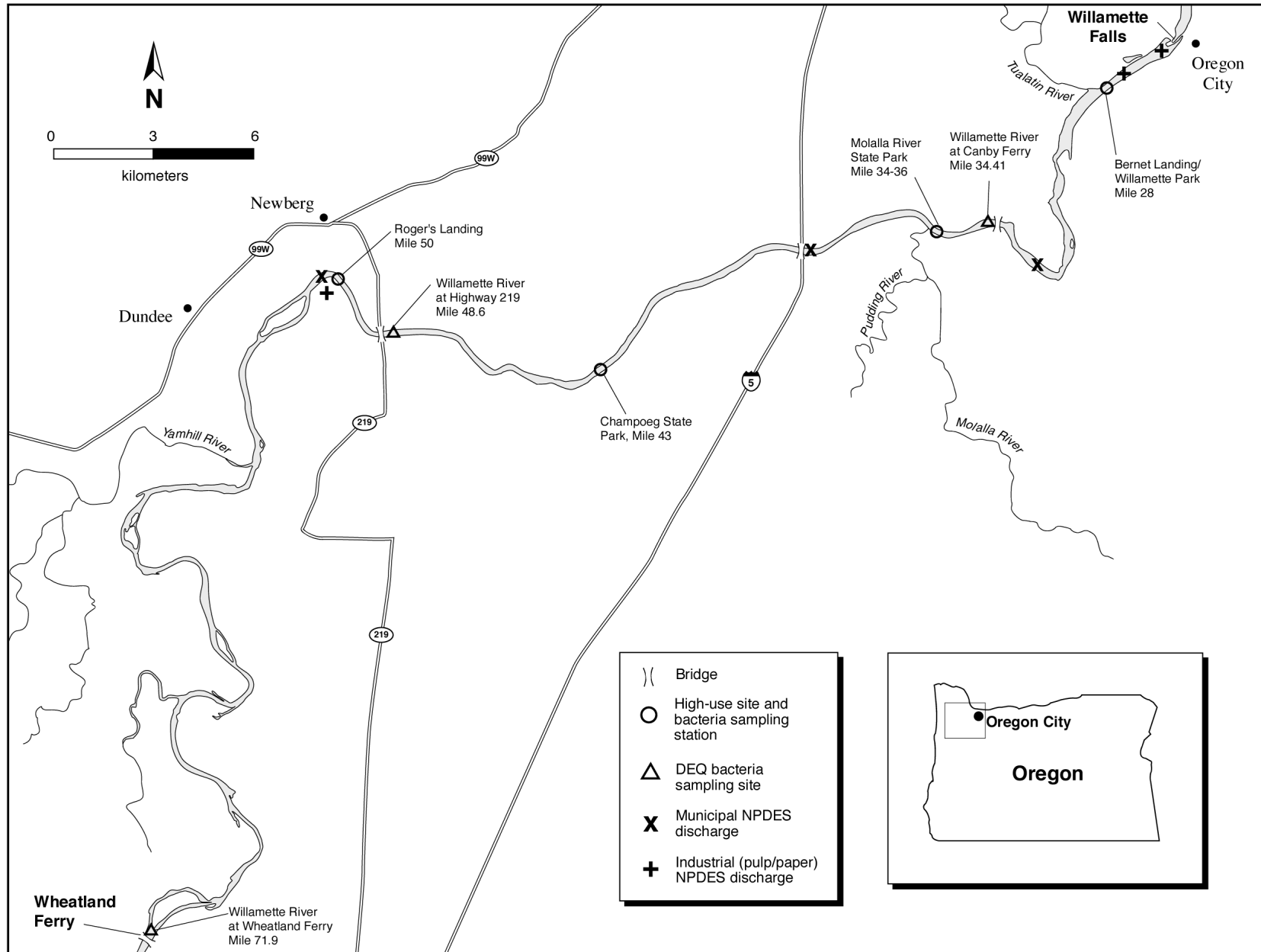


Figure 1. Bacteria sampling stations within the Wheatland-Willamette Falls reach of the Willamette River

## 2.0 OBJECTIVES

---

In this study, both fecal coliform bacteria and *E. coli* were monitored at locations and times of greatest recreational use. The primary objectives of the study were as follows:

- Determine compliance with state regulations for *E. coli* in the Willamette River basin at several high-use water contact recreation areas during a seasonal high-use period (July 1999)
- Report fecal coliform bacteria concentrations measured at high-use recreation sites in the study area (Figure 1) in summer 1999

In addition to the primary objectives identified above, the study design for this investigation allowed the evaluation of the following secondary objectives:

- Compare results of different laboratory methods commonly used to estimate *E. coli* bacteria concentrations within the Columbia River basin. The two methods commonly used are Standard Method (SM) 9213D and SM 9222D, from the American Public Health Association (APHA 1992)
- Determine whether bacteria concentrations varied significantly among sample stations

## 3.0 METHODS

### 3.1 SAMPLE COLLECTION

Three replicate water samples were collected at each of the four locations along the Willamette River over five sampling events in July, 1999; sampling dates were July 1, 8, 15, 22, and 29. Sampling locations were identified using a global positioning system (GPS) to ensure that actual sampling locations were replicated during each sampling event (Table 1). Samples were collected by wading into water 1 meter deep, waiting until any obvious sediment resuspension had moved downstream, immersing a pre-cleaned, sterilized 120 mL vial to 0.3 meters below the water surface and opening the vial (procedures detailed in APHA [1992] and EVS [1999b]). The vial's opening was directed upstream and toward the middle of the river with respect to the collector to avoid contaminating the sample with sediment and bacteria resuspended by the operator's movements. Three replicate water samples were collected for bacterial analysis at each site, and one additional sample was collected for use as a quality assurance (QA) measure for temperature during transport to the laboratory. Samples were stored on ice until they were delivered to the laboratory for analysis. On arrival at the laboratory, the temperature of the QA sample was measured to ensure that temperatures were not outside the QA limits. Surface water temperature and GPS coordinates were recorded at each sampling location (Table 1). Stations were consistently sampled in sequence from Station 4 to Station 1.

**Table 1. Locations and surface water temperatures of bacteria monitoring stations**

STATION	STATION NO.	RIVER MILE	LATITUDE	LONGITUDE	SURFACE WATER TEMPERATURE (°C)				
					7/1/99	7/8/99	7/15/99	7/22/99	7/29/99
Bernet Landing	1	28	45°20.334	122°38.978	18.5	20.5	na	22.0	22.2
Molalla River State Park	2	35	45°17.817	122°42.130	18.5	17.5	na	20.1	20.3
Champoeg State Park	3	43	45°15.228	122°53.040	17.0	18.0	20.0 <sup>a</sup>	20.1	20.8
Roger's Landing	4	50	45°17.160	122°57.965	17.0	16.5	19.0	20.1	21.2

NOTE: na – data not available; see Appendix D

<sup>a</sup> On this day, this sample location had to be relocated; see Appendix D.

## 3.2 LABORATORY ANALYSIS

A total of 60 samples were submitted for laboratory analysis of *E. coli* and fecal coliform bacteria concentrations. Both SM 9213D and SM 9222D (APHA 1992) have been used to estimate *E. coli* concentrations in the Willamette and Columbia River basins. The Oregon Health Division, which analyzes water samples for DEQ, uses SM 9213D to measure *E. coli* concentrations, and SM 9222D to measure fecal coliform bacteria concentrations, in natural waters. Both methods were used in this study. Brief descriptions of these methods are provided in Appendix B.

## 4.0 DATA ANALYSIS

---

### 4.1 COMPLIANCE WITH OREGON WATER QUALITY STANDARDS

The current Oregon water quality standards for indicator bacteria are based solely on *E. coli* concentrations. In 1996, following a triennial review of its water quality standards, Oregon changed its standards from fecal coliform and enterococcus standards to the current *E. coli* standards. The new standards were deemed to provide the same level of protection as the past standards (DEQ 1995). The State of Oregon's current and former water quality standards for indicator bacteria are shown in Table 2.

**Table 2. Water quality standards for indicator bacteria**

TYPE OF STANDARD	PREVIOUS STANDARD <sup>a</sup> FECAL COLIFORM BACTERIA (colonies/100 mL)	CURRENT STANDARD <i>E. COLI</i> (colonies/100 mL)
Single Sample	—	406
Geometric Mean	200	126
Percent Limit	10% of samples > 400	—

NOTE: — - no standard for this metric

<sup>a</sup> Standards were rescinded in 1996.

The arithmetic mean of three replicate samples taken in one day at a given location was used to estimate a daily mean. These daily means were used to determine compliance with the single sample *E. coli* standard, and with the percent limit for the former fecal coliform standard. The geometric mean of the five daily means was used to determine compliance with the 30-day geometric mean standard. Values reported as not detected were included in the calculation of these mean values at one-half the reported detection limit.

### 4.2 COMPARE RESULTS AMONG STATIONS AND BETWEEN METHODS

A single analysis of variance (ANOVA) model was used to evaluate differences among stations and methods. Three factors were suspected to have an influence on the mean response—station, date, and method—so a three-factor ANOVA was evaluated, including all 2- and 3-way interactions. An initial step of this analysis involved checking that the required assumptions of normally distributed data and equal variances were met. These assumptions were sufficiently met when the bacterial concentration data were log-transformed. Data reported as not detected were included in this statistical analysis using one-half the reported detection limit.

## 5.0 RESULTS

---

### 5.1 BACKGROUND CONDITIONS

Weather and water flow conditions can have a substantial impact on bacteria concentrations, with higher bacteria concentrations usually following rain events and high river discharge (Niemi and Niemi 1990). The following paragraphs summarize relevant information regarding these conditions during the month of July 1999, when sampling occurred.

#### 5.1.1 Weather Conditions

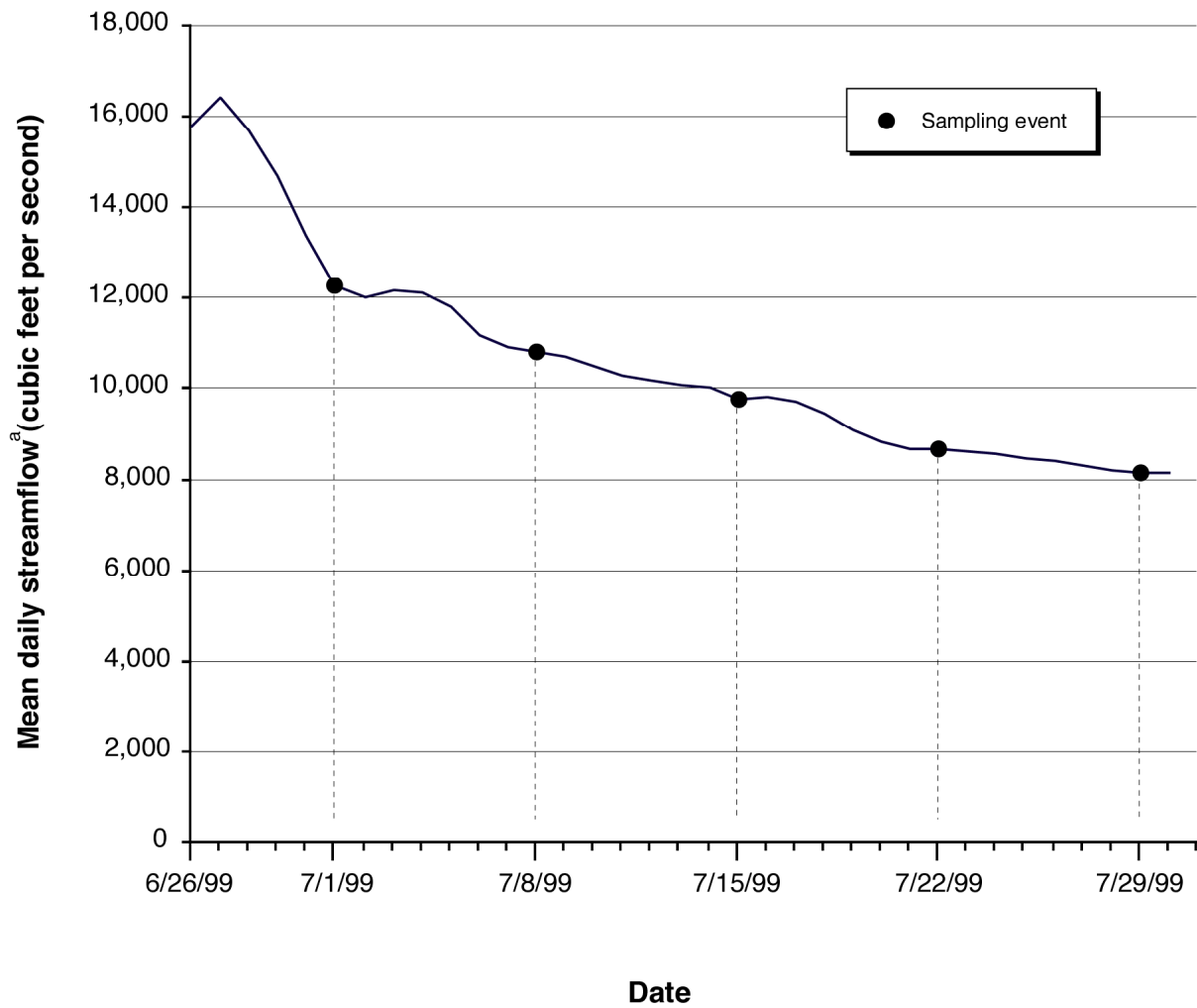
The National Weather Service database from the Salem, Oregon station provided climatological data for the study area. No measurable rainfall was recorded for 5 days prior to the first sampling event, July 1, 1999. Overall, the month of July was drier than normal, deviating from historical conditions for the month by 0.41 inches. Rainfall occurred on only two days: July 2 received 0.10 inches of rainfall and July 4 received 0.05 inches of rainfall. Weather during July was generally clear, with a mean high temperature of 80.4°F, and a mean low temperature of 51.7°F.

#### 5.1.2 Water Flow Conditions

The U.S. Geological Survey (USGS) data gage at Salem (Gage Number 14191000) provides streamflow data for the Willamette River. In 1999, daily mean streamflow declined from 12,300 cubic feet per second (cfs) on July 1 to 8,110 cfs on July 30 (Figure 2; Miller pers. comm. 1999). Data were qualified as provisional and subject to revision by USGS. Streamflow five days prior to the first sampling event was also included in order to characterize environmental conditions that may have impacted bacteria concentrations on the first sampling event.

### 5.2 *E. COLI* CONCENTRATIONS AND COMPLIANCE WITH OREGON WATER QUALITY STANDARDS

In 1996, Oregon rescinded its bacteria water quality standard for fecal coliform bacteria and replaced it with a standard based on *E. coli*. The Oregon water quality standard for *E. coli* concentrations consists of two parts: a single-sample standard of 406 colonies/100 mL, and a geometric mean standard of 126 colonies/mL, based on 5 samples collected within a 30-day period (see Section 4.1). In this study, *E. coli* concentrations were measured using two different methods. In this section, results are presented for both methods and compared to each type of standard. Results using SM 9213D are



<sup>a</sup> Data are from the U.S. Geological Survey (USGS) data gage (Gage Number 14191000) at Salem, Oregon. Data are provisional and subject to revision by USGS.

**Figure 2. Mean daily streamflow for June 26 - July 30, 1999**

summarized in Table 3; results using SM 9222D are summarized in Table 4. The comparison of methods is discussed in Section 5.4.1.

**Table 3. Mean *E. coli* concentrations measured using Standard Method 9213D**

STATION	STATION No.	DAILY MEAN <sup>a</sup> ± STANDARD DEVIATION (colonies/100 mL)					GEOMETRIC MEAN <sup>b</sup> (colonies/100 mL)
		7/1/99	7/8/99	7/15/99	7/22/99	7/29/99	
Bernet Landing	1	na	110 ± 85	23 ± 23	30 <sup>c</sup> ± 20	230 ± 38	85
Molalla River State Park	2	na	8 ± 6	40 ± 17	7 <sup>c</sup> ± 3	38 ± 33	18
Champoeg State Park	3	na	5 ± 4	8 ± 3	8 ± 3	17 ± 12	8
Roger's Landing	4	na	5 ± 3	5 ± 0	13 ± 6	7 ± 3	8

NOTE: na - data not available. Samples from this date were not submitted for *E. coli* analysis by method 9213D.

<sup>a</sup> Arithmetic mean of the three replicates.

<sup>b</sup> Geometric mean of the four daily means from this method plus the daily mean for 7/1/99 from SM 9222D.

<sup>c</sup> Holding time exceeded; see Appendix D.

**Table 4. Mean fecal coliform/*E. coli*<sup>a</sup> concentrations measured using Standard Method 9222D**

STATION	STATION No.	DAILY MEAN <sup>b</sup> ± STANDARD DEVIATION (colonies/100 mL)					GEOMETRIC MEAN <sup>c</sup> (colonies/100mL)
		7/1/99	7/8/99	7/15/99	7/22/99	7/29/99	
Bernet Landing	1	260 ± 300	120 ± 76	50 ± 0	43 <sup>d</sup> ± 32	330 ± 170	116
Molalla River State Park	2	23 ± 9	23 ± 15	50 ± 0	20 ± 10	33 ± 23	28
Champoeg State Park	3	5 ± 3	10 ± 0	50 ± 0	27 ± 29	23 ± 12	18
Roger's Landing	4	13 ± 15	17 ± 6	50 ± 0	43 ± 23	7 ± 3	20

<sup>a</sup> All fecal coliform colonies were found to be *E. coli*.

<sup>b</sup> Arithmetic mean of the three replicates.

<sup>c</sup> Geometric mean of the five daily means.

<sup>d</sup> Holding time exceeded; see Appendix D.

### **5.2.1 Single Sample *E. coli* Compliance**

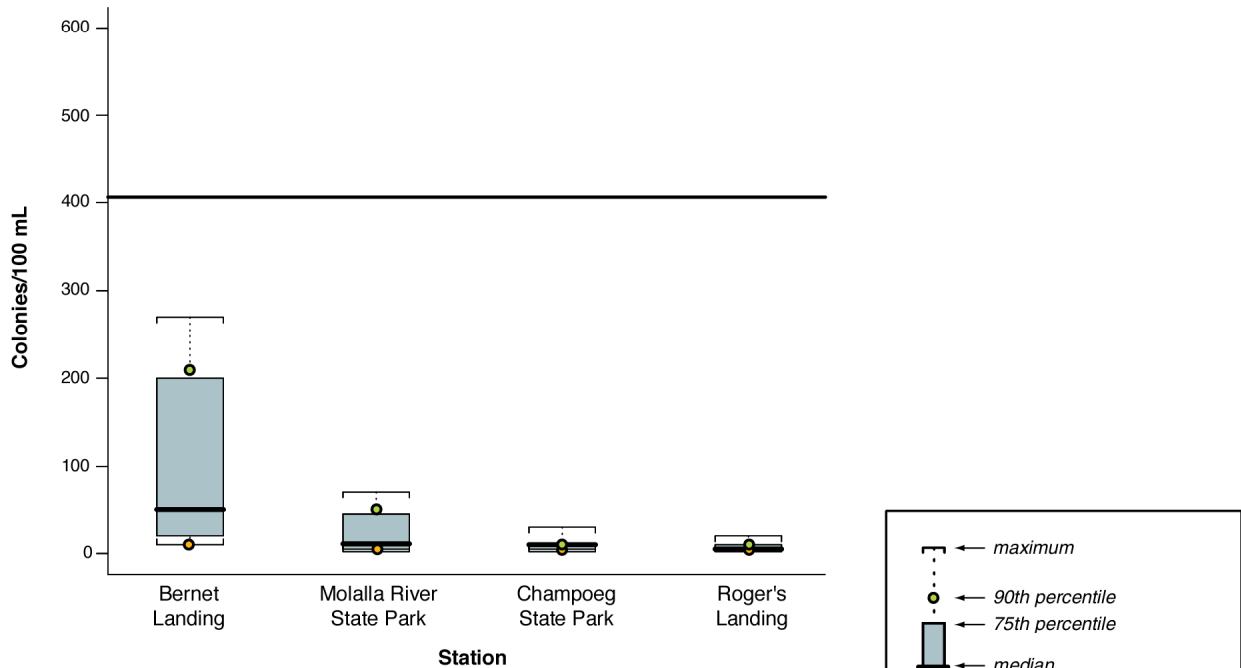
The daily mean *E. coli* concentrations for SM 9213D analysis ranged from 5 to 230 colonies/100 mL (Table 3). The daily mean *E. coli* concentrations for SM 9222D analysis ranged from 5 to 330 colonies/100 mL (Table 4). Box plots showing the distribution of *E. coli* concentrations measured using SM 9213D and SM 9222D are provided in Figures 3a and 3b. None of the estimated concentrations of *E. coli*, measured using either method, violated Oregon's single sample water quality standards (Table 2).

### **5.2.2 Geometric Mean *E. coli* Compliance**

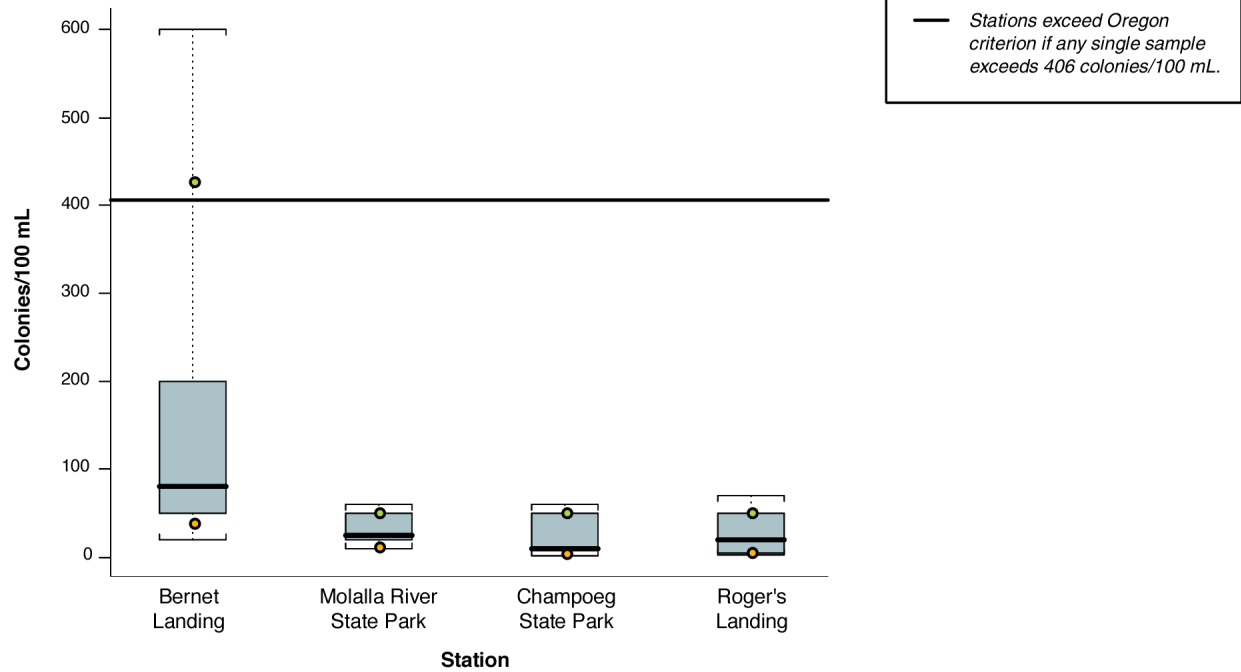
The state's geometric mean *E. coli* standards were not exceeded. Because results from the July 1, 1999 sampling event were not available for SM 9213D analysis, a 30-day geometric mean based on 5 sampling events could not be calculated. A geometric mean based on four sampling events over a 21-day period would not be acceptable for comparison to the Oregon water quality standards. For comparison purposes, a 30-day geometric mean estimate was calculated using the four daily means measured using SM 9213D, along with the daily mean for July 1, 1999 measured using SM 9222D. These results, shown in Table 3, are in compliance with Oregon water quality standards. For SM 9222D analysis, the 30-day geometric mean estimate calculated from the 5 daily means was also in compliance with Oregon water quality standards.

## **5.3 FECAL COLIFORM BACTERIA CONCENTRATIONS AND COMPLIANCE WITH OREGON WATER QUALITY STANDARDS**

As noted in Section 4.1, in 1996 Oregon rescinded its bacteria water quality standard for fecal coliform bacteria and replaced it with a standard based on *E. coli*. However, because SM 9222D was used in this study, concentrations of fecal coliform bacteria were measured, and these concentrations were compared with the former standard (Table 2). This standard consists of two parts: a percent limit standard of no more than 10 percent of samples to exceed 400 colonies/100 mL, and a geometric mean standard of 200 colonies/100 mL. The observed fecal coliform concentrations (Table 4) did not exceed either the percent limit or the geometric mean fecal coliform standard (Table 2). Using SM 9222D, all fecal coliform colonies were subsequently identified as *E. coli* colonies (Section 5.4.1).



**Figure 3a. E.coli concentrations measured using Standard Method 9213D**



**Figure 3b. Fecal coliform/E.coli concentrations measured using Standard Method 9222D**

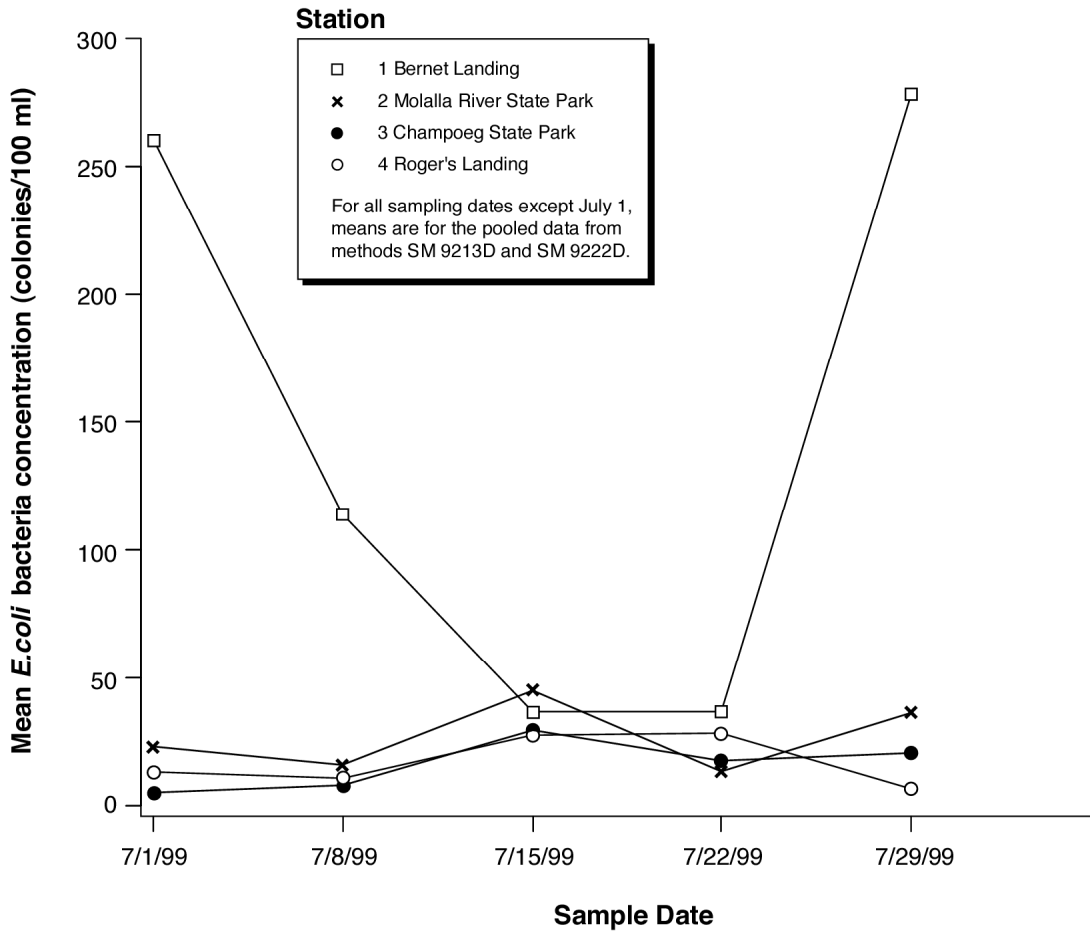
## 5.4 COMPARISON OF RESULTS BETWEEN METHODS AND AMONG STATIONS

Both methods, SM 9213D and SM 9222D, were used to analyze samples collected on four of the five sampling dates. A 3-factor ANOVA model was used to test for differences between the two methods used to determine *E. coli* concentrations in the Willamette River, and among the four stations at which samples were collected. The results of this statistical analysis were indeterminate because differences between methods and among stations were not consistent through time (Figure 4). For example, *E. coli* concentrations at Bernet Landing were higher than at the other stations on four of the sampling dates, and lower than another station on one sampling date. This could be the result of random variation, rather than of particular characteristics at the Bernet Landing station. In statistical terms, there were significant two-way interactions between station and date, and between method and date. In the following sections, sources of variability in *E. coli* concentrations are discussed in greater detail.

### 5.4.1 Comparison of Methods for Measuring *E. coli* Concentrations

*E. coli* was measured using two different methods, SM 9213D and SM 9222D. SM 9213D requires that water samples be added directly to media that will only support the growth of *E. coli* colonies. SM 9222D is designed to quantify all types of fecal coliform colonies, with secondary steps designed to determine whether those colonies are *E. coli* or one of several other fecal bacteria. The *E. coli* results and the fecal coliform results reported using SM 9222D were identical, suggesting that all fecal coliform colonies were subsequently identified as *E. coli* colonies.

For all but four of the 60 replicates evaluated, higher concentrations were reported in SM 9222D results than in SM 9213D results (Appendix C). These differences, however, appear to be primarily driven by differences in the detection limits. More values were reported below the detection limit in SM 9222D results (n=18) than in SM 9213D results (n=14). Twelve of the 18 values (67 percent) reported as not detected using SM 9222D had detection limits of 100 colonies/mL. In contrast, only 1 of the 14 values (7 percent) reported as not detected using SM 9213D had a reported detection limit as high as 100 colonies/mL. Unlike SM 9222D, SM 9213D is specifically designed to measure only *E. coli* colonies. With SM 9213D, other fecal coliform bacteria are not likely to grow and interfere with the laboratory colony counts. This may explain the lower concentrations and lower detection limits for SM 9213D results.



**Figure 4. Mean *E.coli* concentrations measured at the four sampling stations during July 1999**

Results for SM 9222D analysis had greater variability among replicate samples than did results from SM 9213D analysis. The coefficient of variation was calculated only for samples in which bacteria were detected in all three replicates. The coefficients of variation ranged from 17 to 78 percent for SM 9213D and from 38 to 119 percent for SM 9222D. The generally high coefficients of variation for both methods reflect the variability inherent in measuring bacteria concentrations in aquatic environments and highlight the importance of having an adequate number of replicates to characterize a waterbody.

#### **5.4.2 Comparison of Bacteria Concentrations among Stations**

The Bernet Landing station tended to have higher concentrations of bacteria than the other stations, except on July 8, 1999, when concentrations at the Molalla River State Park station were higher. The Bernet Landing station was exposed to more wind and was consistently more turbid than the other stations (from field observations); the higher turbidity at this site may have been caused by wind or by the high recreational use of the site, particularly boating activity. The fluctuations in bacteria concentrations over the sampling period at Bernet Landing suggest a potential for bacteria concentrations to exceed Oregon water quality standards at this station.

## 6.0 CONCLUSIONS

---

The results of this study have allowed us to evaluate the water quality at four stations for comparison to Oregon's bacterial standards for human health. The study design also allowed us to make comparisons between two different methods currently used to estimate *E. coli* concentrations.

- The Willamette River water quality did not exceed current or previous Oregon state standards for *E. coli* or fecal coliform bacteria during July 1999.
- From the data produced in this study, it appears that SM 9213D—the method currently used by Oregon State Department of Health—is preferable to SM 9222D for determining *E. coli* concentrations. SM 9213D results had fewer values reported below the detection limit, and much lower detection limits for those samples reported as not detected. In addition, SM 9213D results were less variable than SM 9222 results.
- The Bernet Landing station, at RM 28, tended to have higher *E. coli* concentrations than the other stations and data show a potential for violations at this site. Higher *E. coli* concentrations may be attributed to the higher turbidity observed at this station relative to the other stations.
- Bacteria concentrations were measured in July during dry-weather conditions. Concentrations may not be representative of wetter months or river conditions after storms.

## 7.0 REFERENCES

---

- APHA. 1992. Standard methods for the examination of water and wastewater, 18<sup>th</sup> edition. American Public Health Association, Washington, DC.
- DEQ. 1995. 1992–1994 water quality standards review: Fall issue papers. Standards and Assessment Section, Oregon Department of Environmental Quality, Portland, OR.
- EVS. 1999a. Technical memorandum 1: results of 1998 recreational water contact survey of the Newburg Pool, Willamette River, Oregon. Prepared for Oregon Department of Environmental Quality, Portland, OR. EVS Environment Consultants, Inc., Seattle, WA.
- EVS. 1999b. Field sampling and analysis plan for contaminant concentrations in fish tissues. Prepared for Oregon Department of Environmental Quality, Portland, OR. EVS Environment Consultants, Inc., Seattle, WA.
- Marine Board. 1996. Oregon recreational boating survey 1996: a report to the Oregon State Marine Board. Prepared by Wayne Schuyler. Oregon State Marine Board, Salem, OR.
- Miller, S.J. 1999. Personal communication (e-mail to J. Haddad, EVS Environment Consultants, Inc., Seattle, WA, on November 29, 1999). Technical Information Specialist, U.S. Geological Survey, Portland, OR.
- Niemi, R.M. and J.S. Niemi. 1990. Monitoring of fecal indicators in rivers on the basis of random sampling and percentiles. *Water Air Soil Pollut.* 50(3-4):331-342.
- Stallman, K. 1998. Personal communication (facsimile to Lisa Mill, EVS Environment Consultants, Seattle, WA, dated September 11, 1998 regarding park use at Willamette River parks). Oregon Parks and Recreation Department, Portland, OR.
- WRBTF. 1997. Willamette River Basin Task Force recommendations to Governor John Kitzhaber. Willamette River Basin Task Force.