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ROSLYN POST-UPGRADE WASTEWATER TREATMENT PLANT LIMITED CLASS II INSPECTION AND RECEIVING WATER STUDY ON CRYSTAL CREEK

by
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ABSTRACT

A Limited Class II Inspection and receiving water survey were conducted at Roslyn Wastewater Treatment Plant (WTP) on September 10-12, 1990. The purpose of the study was to determine WTP efficiency and assess impacts of effluent discharge on Crystal Creek. Biochemical oxygen demand (BOD_5), total suspended solids (TSS), and fecal coliform were well within permit limits. Infiltration and inflow (I&I) continues to be a problem at Roslyn, particularly during the wet season. The creek to effluent dilution was 6:1 during the survey. The Class A water quality criterion for fecal coliform was exceeded at two sites near Roslyn. Chlorine and temperature criteria were exceeded below the WTP outfall. Surveys of stream fauna showed very little impact from effluent discharge 300 feet below the outfall. A statistical comparison of 1985 and 1990 data indicated significant improvement for several water quality parameters. Worst-case modeling predicted water quality violations for chlorine, ammonia, fecal coliform, and dissolved oxygen under critical design conditions. Recommendations include correcting I&I problems, adding effluent dechlorination or an alternative means of disinfection at the WTP, and implementing water quality-based permit limits.

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INTRODUCTION

The Town of Roslyn is located approximately 25 miles northwest of Ellensburg in Kittitas County. Roslyn's wastewater treatment plant (WTP) serves about 970 people and discharges to Crystal Creek at river mile (RM) 1.55. WTP effluent quality is regulated by National Pollutant Discharge Elimination System (NPDES) permit No. WA-002233-1, issued July 1, 1982.

Roslyn's WTP facilities have been improved several times over the last two decades. The existing plant was originally built in 1973. Prior to that, domestic wastes were processed through a small treatment plant at RM 3.0 or discharged directly into Crystal Creek. Water quality at that time was undoubtedly very poor. A 1978 Ecology study (Anderson and Egbers, 1978) documented several problems in Crystal Creek, including a low receiving water to effluent dilution ratio, infiltration and inflow (I&I), and high fecal coliform levels from unidentified sources in the town of Roslyn. Following this study, Roslyn received an Ecology grant to correct I&I and other general collection system problems.

In 1985, Ecology conducted an abbreviated Class II inspection and receiving water survey to assess water quality and evaluate improvements in the collection system (Joy, 1985). Major findings from the study included a creek to effluent dilution ratio of 5:1, Class A water quality violations for chlorine and pH as a result of WTP effluent, and continued high fecal coliform levels from unidentified sources within Roslyn. Following this study, additional improvements in the WTP and collection system were made with assistance from Ecology grant funds. Presently, the WTP consists of three 5-acre lagoons, an aeration basin, and a chlorine contact chamber (Figure 1). Effluent enters the stream by means of a pipe outfall on the bank.

Crystal Creek drains 7.7 square miles of forested foothills around Roslyn and Cle Elum before eventually discharging into the Yakima River (Figure 1). The stream is small, averaging 2-6 feet in width and 0.5 feet in depth, with a total length of about three miles. Two major tributaries to Crystal Creek enter the Roslyn stormwater collection system along the western and northern edges of town. Overflow from the Roslyn water reservoir and springs make up the larger tributary on the west side. Springs are the primary source of the middle tributary. The tributaries emerge as a single channel at RM 3.0 to form Crystal Creek.

Chapter 173-201-070 of the Washington Administrative Code (WAC) classifies Crystal Creek a Class A (Excellent) waterbody. Characteristic uses for Class A waters include water supply (domestic, industrial, and agricultural), fish and wildlife habitat, and recreation (primary contact, sport fishing, and aesthetic enjoyment).

The Water Quality Financial Assistance Program (WQFAP) and Central Regional Office (CRO) of Ecology were interested in determining if improvements made at Roslyn WTP facilities since 1985 have helped bring Crystal Creek into compliance with Class A Water Quality Standards.

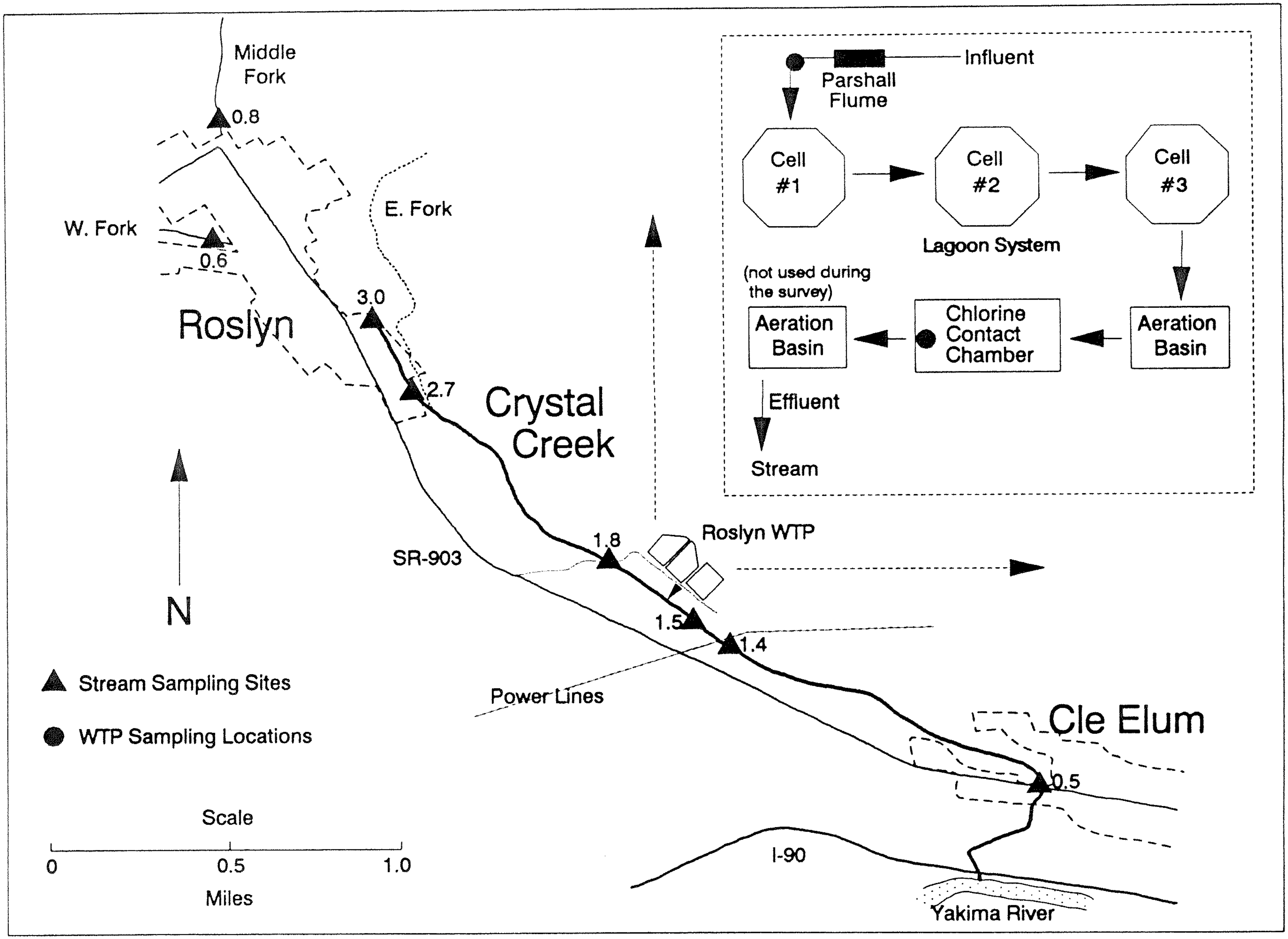

Figure 1. Map of study area with locations of sampling sites and Roslyn WTP diagram.

Therefore, the Watershed Assessments Section (WAS) of Ecology was asked to conduct a post-upgrade Limited Class II Inspection and receiving water study at Roslyn. Study objectives were as follows:

1. assess water quality impacts from wastewater discharge, including a Total Maximum Daily Load (TMDL) analysis to determine effects under critical design conditions;

2. evaluate WTP removal efficiency and NPDES permit compliance; and

3. recommend activities to improve the effectiveness of Roslyn WTP and protect the quality of Crystal Creek.

METHODS

Intensive surveys were conducted at Roslyn on September 10-12, 1990. Sampling stations included 6 mainstem sites, 2 tributaries, and WTP influent and effluent. Weather during the survey was dry and warm, and low streamflow conditions were observed. The WTP operator reported a moderate rainstorm three days prior to the survey. Sampling parameters and frequency are listed in Table 1.

Influent and effluent composite, and effluent grab samples were collected on September 11-12 at the Roslyn WTP. Influent samples were collected directly downstream of the Parshall flume and effluent samples were collected at the end of the chlorine contact chamber (Figure 1). Approximately 200 mL of sample was composited at half-hour intervals over a 24-hour period using ISCO sampling compositors. Samples from Ecology compositors were split with the WTP operator and analyzed for BOD_5 and TSS to assess Roslyn WTP laboratory results.

Samples for lab analysis were stored on ice and shipped to arrive at the Ecology/Environmental Protection Agency (EPA) Laboratory in Manchester, Washington, within 24 hours. Laboratory analyses were performed in accordance with EPA (1983), APHA *et al.* (1989), and Huntamer and Smith (1989). Field measurements included temperature (mercury thermometer), pH and conductivity (Beckman meters), dissolved oxygen (azide-modified Winkler titration), and total residual chlorine (LaMotte-Palin DPD kit). WTP flows were measured as head heights at the Parshall flume.

Eight surface water sites were sampled along Crystal Creek on September 11-12. Five of these sites were upstream of the WTP outfall and three sites were located downstream (Figure 1). Samples were taken at mid-channel. Approximately 15 percent of all samples were quality assurance related. Replicates were taken to assess field and laboratory variability and blanks were used to evaluate detection limits. Streamflow was measured by taking cross-channel velocity measurements with a Swoffer® current meter. Methods for remaining field measurements and lab analyses were as described above.

Table 1. Sampling design for Roslyn receiving water survey and limited Class II inspection conducted September 10-12, 1990.

Sampling Site	Date	Time	Flow	Temp	pH	Cond	D.O.	TRC	FC	TSS	Turb	Alk	Hard	BOD-5	NUTS-5	MET-4	Invert	Fish
			Parameter*															
CLASS II																		
Influent Comp.	9/12	0910	-	-	-	-	-	-	-	X	X	X	-	X	X	-	-	-
Effluent Comp.	9/12	0940	-	-	-	-	-	-	-	X	X	X	X	X	X	-	-	-
Effluent Grab	9/11	0940	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-	-
	9/12	0945	X	X	X	X	X	X	X	-	-	-	-	-	-	-	-	-
	9/12	1430	X	X	X	X	X	X	X	X	X	X	-	X	X	-	-	-
RECEIVING WATER																		
WF 0.6	9/11	1030	X	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
	9/12	1050	X	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
MF 0.8	9/11	1100	X	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
	9/12	1115	X	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
RM 3.0	9/11	1120	X	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
	9/12	1135	X	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
RM 2.7	9/11	1145	-	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
	9/12	1200	-	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
RM 1.8	9/10	1400	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X+	X
	9/11	1205	X+	X	X	X	X	-	X	-	X	X	X	-	X	X	-	-
	9/12	1215	X+	X	X	X	X+	-	X+	X+	X+	X+	-	-	X+	-	-	-
RM 1.5	9/10	1805	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X+	X
	9/11	1245	X+	X	X	X	X+	X	X+	X+	X+	X+	X+	X	X+	X+	-	-
	9/12	1250	X	X	X	X	X	X	X	X	X	X	X	-	X	X	-	-
RM 1.4	9/10	1725	X	-	-	-	-	-	-	-	-	-	-	-	-	-	X+	-
	9/11	1320	X	X	X	X	X	X	X	X	X	X	-	X	X	-	-	-
	9/12	1315	X	X	X	X	X	X	X	X	X	X	-	X	X	-	-	-
RM 0.5	9/11	1335	X	X	X	X	X	-	X	X	X	X	-	-	X	-	-	-
	9/12	1400	X	X	X	X	X	-	-	X	X	X	-	-	X	-	-	-

* - = No sample
X = Sample collected
X+ = Replicate sample collected

Temp = Temperature
Cond = Conductivity
D.O. = Dissolved Oxygen
TRC = Total Residual Chlorine
FC = Fecal Coliform
TSS = Total Suspended Solids
Turb = Turbidity

Alk = Alkalinity
Hard = Hardness
BOD-5 = 5-day Biochemical Oxygen Demand
MET-4 = Cadmium, Copper, Lead, Zinc (total recoverable metals)

NUTS-5 = Nutrients: ammonia, nitrate+nitrite, total persulfate nitrogen total phosphorus, soluble reactive phosphorus
Invert = Benthic Macroinvertebrates
Fish = Electroshocking Surveys

Dissolved oxygen surveys were conducted on the afternoon of September 10, and at dawn the next day. The surveys were performed to measure daily high and low oxygen levels in the stream and assess the effects of WTP discharge. Temperature, pH, and dissolved oxygen were measured at eight sites within a one-hour period to minimize temporal variability.

Benthic macroinvertebrate communities were surveyed on September 10 at three sites. One site was chosen above the WTP outfall and two sites were selected downstream to help assess impacts from the discharge. Riffle areas with similar habitat types (i.e. depth, velocity, substrate, and shading) were selected so that comparisons between sites could be made. Depth and flow were measured and substrate type noted for each sample. An area of approximately ten square feet was sampled by disturbing the sediment with vigorous kicking for two minutes. Dislodged organisms were swept downstream into a D-shaped net (600-um mesh) positioned directly below the sampling area.

After collection, each macroinvertebrate kick sample was placed in a shallow pan of water. Approximately 100 live organisms were then picked with forceps and preserved in 70 percent ethanol. In the lab, organisms were sorted, counted, and identified to the family level using the taxonomic keys of Pennak (1978) and Merritt and Cummins (1984).

Electrofishing was conducted on September 10 at two sites along Crystal Creek. Sites were selected above (RM 1.8) and below (RM 1.4) the WTP outfall to assess impacts on fish communities. Sampling effort and conditions were kept constant at both sites. Stunned fish were identified, counted, and released. Fish were identified using taxonomic keys found in Wydoski and Whitney (1979).

RESULTS AND DISCUSSION

Limited Class II Inspection

A summary of data collected during the Limited Class II Inspection at Roslyn WTP is listed in Table 2. Flows measured at the Parshall flume were consistent on both mornings of the survey at 0.15 MGD, which is well below the plant design flow of 1.4 MGD. Flow measured in the afternoon of September 12 was slightly lower (0.12 MGD). The above measurements were in agreement with the WTP continuous flow recorder.

Several observations were made during the inspection. From June through August 1990, effluent was not discharged into Crystal Creek. In the preceding spring, the lagoons were slowly drawn down for weed control. Following this, it took several months to bring the lagoons back up to discharge level, largely due to evaporation loss during hot weather. The WTP started discharging to Crystal Creek on September 4, approximately seven days prior to the survey. The post-chlorination aeration system was not being used at the plant because of earlier problems with excessive foam reaching the stream. The first cell of the lagoon system had a dense algal bloom, cell 2 was choked with macrophytes, and cell 3 was relatively clear.

Table 2. Results from the limited Class II Inspection at Roslyn WTP, September 11–12, 1990.

Sample Type	Date	Time	Sampler	Lab	Flow (MGD)	Temp (C)	pH (S.U.)	Cond (umhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	TRC (mg/L)	Fecal Coliform (#/100 mL)	TSS (mg/L)
Influent Comp.	9/12	0910	Ecol.	Ecol.	–	–	–	–	–	–	–	–	223
	9/12	0910	Ecol.	WTP	–	–	–	–	–	–	–	–	150
Effluent Comp.	9/12	0940	Ecol.	Ecol.	–	–	–	–	–	–	–	–	2
	9/12	0940	Ecol.	WTP	–	–	–	–	–	–	–	–	5
Effluent Grab	9/11	0940	Ecol.	Ecol.	0.15	22.1	8.2	260	7.9	98	0.2	20	4
	9/12	0945	Ecol.	Ecol.	0.15	18.4	8.3	320	8.2	94	0.2	10	–
	9/12	0945	WTP	WTP	0.15	–	–	–	–	–	0.2	12	–
	9/12	1430	Ecol.	Ecol.	0.12	18.8	8.7	330	8.3	96	0.2	10	4

Sample Type	Date	Time	Sampler	Lab	Turb. (NTU)	Alk. (mg/L as CaCO3)	Hard. (mg/L as CaCO3)	BOD-5 (mg/L)		Nutrients: NH3-N (mg/L)	Nutrients: NO3-N + NO2-N (mg/L)	Nutrients: TN (mg/L)	Nutrients: TP (mg/L)	Nutrients: SRP (mg/L)
Influent Comp.	9/12	0910	Ecol.	Ecol.	30.0	118.1	–	>79.8	E	8.721	0.055	6.84	3.890	2.007
	9/12	0910	Ecol.	WTP	–	–	–	127.3		–	–	–	–	–
Effluent Comp.	9/12	0940	Ecol.	Ecol.	11.0	119.6	54.9	4.2	E	0.099	0.023	1.64	2.084	2.007
	9/12	0940	Ecol.	WTP	–	–	–	5.6		–	–	–	–	–
Effluent Grab	9/11	0940	Ecol.	Ecol.	8.9	129.7	74.7	2.8	E	0.193	0.023	1.95	2.150	2.189
	9/12	0945	Ecol.	Ecol.	–	–	–	–		–	–	–	–	–
	9/12	0945	WTP	WTP	–	–	–	–		–	–	–	–	–
	9/12	1430	Ecol.	Ecol.	12.0	123.4	–	2.9	E	0.177	0.030	1.89	2.064	2.070

E = Estimated value

The WTP hydraulic retention time during summer was estimated at about 64 days based on a WTP storage capacity of 10 million gallons and average influent flow of 0.15 MGD. Due to the fact that effluent was not discharged during much of the 1990 summer, effluent samples collected during the survey were probably somewhat biased. Because effluent was retained in the plant for a longer period of time than normal, it potentially received a higher level of treatment. However, the survey results do appear to be fairly consistent with Discharge Monitoring Reports (DMRs) for April and May 1990, and WTP results reported in the 1985 Ecology study, indicating that the September 1990 data was representative of summer effluent quality.

The lagoon system was efficient in removing a large portion of incoming nutrient loads, particularly nitrogen. The ratio of total nitrogen to total phosphorus in WTP samples was low (approximately 2:1 for influent samples), indicating that nitrogen may be the limiting nutrient for plant growth in the lagoons. Removal of ammonia was greater than 99 percent. Nitrification did not appear to be occurring in the WTP because the net loss of ammonia was not balanced by a net gain in nitrate-nitrite. In fact, a two-fold decrease in nitrate-nitrite was found. It appears that algal uptake and subsequent settling was effectively removing ammonia and nitrate-nitrite in the lagoon system. Macrophytes will also use water column nutrients if they are available in high concentrations; however, macrophytes derive most nutrients from sediment (Bole and Allan 1978). Ammonia is the preferred nitrogen source of aquatic plants and thus it is used more rapidly than nitrate (Welch 1980).

Results of effluent grab samples taken at the end of the chlorine contact chamber indicated dissolved oxygen levels near saturation (94-98 percent), stable TRC concentrations (0.2 mg/L), and low fecal coliform levels (geometric mean of 13 organisms/100 mL of sample) (Table 2). Effluent pH ranged from 8.3 in the morning to 8.7 in the afternoon. This range was probably a result of algal and macrophyte productivity in the lagoon system.

Split samples for BOD_5 could not be effectively compared due to QA/QC problems with Ecology data. For TSS, sample splits between Ecology's lab and the Roslyn WTP lab were not very comparable (Table 2). Split samples were compared by calculating the relative percent difference (RPD), defined as the difference of two samples divided by their mean. The RPDs for TSS were 39 percent for influent and 86 percent for effluent. Higher RPDs are not unusual for low levels like those found in the effluent. Ecology and operator grab samples for fecal coliform showed good agreement (Table 2).

Table 3 assesses NPDES permit compliance during the survey. Effluent composite samples indicated that BOD_5 and TSS were well below permitted limits. Removal efficiency for BOD_5 and TSS was 96 and 99 percent, respectively. Fecal coliform samples were also well below permit limits and pH was measured within the acceptable range.

A review of DMR flow data indicates that I&I continues to be a problem at Roslyn, particularly during winter months following periods of rapid snow-melt and/or heavy rain (Table 4). During

Table 3. Assessment of NPDES permit compliance during the limited Class II inspection at Roslyn WTP on September 11-12, 1990.

		NPDES Permit Limits		(Ecology) Effluent Quality	
		Monthly	Weekly		
Parameter	Units	Average	Average	Grab	Composite
BOD-5	mg/L	30	45	-	5.6**
	lbs/day	350	525	-	7
	% removal	85	85	-	96
TSS	mg/L	75	110	-	2
	lbs/day	875	1284	-	2.5
	% removal	-	-	-	99
Fecal Coliform	#/100 mL	200	400	13*	-
Total Residual Chlorine	mg/L	-	-	0.2	-
pH	S.U.	$6.0 \leq pH \leq 9.0$		$8.2 \leq pH \leq 8.7$	
Flow	MGD	1.4	-	0.15	-

* Geometric mean.

** Analysis performed by Roslyn WTP operator.

Table 4. Climatological data for Cle Elum and Roslyn WTP flow summary.

	Climatological Data*		Roslyn WTP 1990 Flow Statistics**		
	Mean Temp (°F)	Precip. (inches)	Monthly Max.	Monthly Min.	Monthly Ave.
January	26.3	4.14	1.590	0.176	0.419
February	32.9	2.46	1.880	0.238	0.644
March	37.3	1.91	0.623	0.233	0.415
April	44.6	1.27	0.325	0.159	0.219
May	52.5	0.77	0.329	0.149	0.201
June	59.3	0.70	0.178	0.116	0.152
July	66.0	0.27	0.211	0.117	0.157
August	64.6	0.59	0.352	0.124	0.162
September	56.9	0.81	0.174	0.099	0.133
October	46.6	1.63	0.306	0.092	0.180
November	35.7	3.51	1.940	0.127	0.518
December	29.9	4.59	1.130	0.262	0.394
ANNUAL	46.1	22.65	-	-	-

* NOAA climatology data for Cle Elum, Washington (1951-1980 record).
** Influent flows obtained from Roslyn DMRs.

1990, two such events occurred, causing the plant to reach its design capacity (Joe Peck, WTP operator, personal communication). Several storm drains in Roslyn are probably still connected to the sanitary collection system. Infiltration also appears to be occurring to some degree at Roslyn in the summer. Influent BOD_5 and ammonia concentrations were weak at 127 mg/L and 8.7 mg/L, respectively (Table 2) (Metcalf and Eddy 1972).

Receiving Water Survey

Results of the receiving water survey on Crystal Creek are summarized in Table 5. In general, replicate samples and measurements showed good laboratory and field precision. Laboratory results for metals were the exception (Appendix A). Most metals data failed laboratory quality assurance criteria and were flagged as estimated values. For this reason, metals data were not analyzed further.

Streamflow was estimated immediately upstream of the outfall by subtracting the measured WTP discharge from the measured stream discharge below the outfall (RM 1.5). Using that value (1.4 cfs) and a WTP flow of 0.23 cfs, the receiving water to effluent dilution ratio was about 6:1. This is well below the Ecology recommended dilution of 100:1 for new facilities (Ecology 1985).

Receiving water quality was generally good at the time of the survey. Variability between sampling days was low in most cases. Violations of Class A water quality criteria were found for temperature and chlorine as a result of WTP discharge. Approximately 18 percent of all receiving water samples exceeded the fecal coliform criterion of 100 organisms/100 mL of sample. Exceedances occurred at RM 2.7 on both days and the W.F. tributary (RM 0.6) on September 11. Both of these sites were upstream of the WTP outfall and in close proximity to Roslyn.

Cross-channel conductivity measurements were taken at several sites downstream of the WTP outfall to assess effluent mixing (Figure 2). Mixing was complete at approximately 40 feet below the WTP outfall. Based on an average stream velocity of 1.5 feet per second (fps), total mixing probably occurs within 30 seconds.

Instream chlorine concentrations were below the test kit detection limit (0.1 mg/L). Acute and chronic toxicity criteria for TRC are 0.019 and 0.011 mg/L, respectively (Chapter 173-201 WAC). Figure 2 depicts predicted concentrations of TRC across the stream at various distances below the outfall. At 10 feet below the outfall, acute and chronic toxicity would occur across 75 percent of the stream width. Mixing was complete at 40 feet; based on conservative calculations, TRC would exceed acute and chronic toxicity across the entire stream. This could potentially create a barrier to fish passage in the vicinity of the outfall.

Nutrient concentrations and loads for Crystal Creek are presented in Figure 3 and Appendix B. All nutrients, with the exception of nitrate-nitrite showed increased concentrations and loads as a result of WTP discharge. Effluent nitrate-nitrite was three times lower than background

Table 5. Results of water quality surveys conducted on Crystal Creek, September 11-12, 1990. (WTP effluent grab results are included for comparison.)

Sampling Site	River Mile	Date	Time	Flow (cfs)	Temp (C)	pH (S.U.)	Cond. (umhos/cm)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	TRC (mg/L)	Fecal Coliform (#/100 mL)	TSS (mg/L)
W.F. Tributary at	0.6	9/11	1030	0.7	10.7	7.9	84	10.20	100	-	136	1
S.E. Corner of Pioneer Park		9/12	1050	0.7	11.8	8.6	85	10.25	102	-	74	2
N.F. Tributary at	0.8	9/11	1100	0.1	13.1	8.0	210	9.65	99	-	3	2
Nevada Ave. alleyway		9/12	1115	0.1	12.4	8.3	225	9.70	98	-	44	4
Crystal Creek at	3.0	9/11	1120	1.0	11.7	7.9	105	10.20	102	-	89	3
junkyard off S. "A" St.		9/12	1135	1.2	12.5	8.3	110	10.05	102	-	92	2
Crystal Creek below	2.7	9/11	1145	-	11.7	7.7	100	9.70	97	-	152	4
Hoffmanville Ave. culvert		9/12	1200	-	11.7	8.1	110	9.70	97	-	185	3
Crystal Creek below	1.8	9/11	1205	1.8	12.9	8.1	120	9.80	100	-	39	-
dirt road leading to		Repl.	1210	2.0	-	-	-	-	-	-	-	-
Roslyn WTP		9/12	1215	1.8	12.9	8.3	115	9.65	99	-	89	10
		Repl.	1215	2.0	-	-	-	9.70	99	-	79	9
Roslyn WTP	1.55	9/11	0940	0.23	22.1	8.2	260	7.90	98	0.2	20	4
effluent		9/12	0945	0.23	18.4	8.3	320	8.20	94	0.2	10	-
		9/12	1430	0.19	18.8	8.7	330	8.30	96	0.2	10	4
Crystal Creek	1.5	9/11	1245	1.6	16.0	7.9	180	9.30	102	<0.1	48	5
300 ft below WTP outfall		Repl.	1245	1.7	-	-	-	9.50	104	-	43	4
		9/12	1250	1.6	14.7	8.4	190	9.50	101	<0.1	55	5
Crystal Creek	1.4	9/11	1320	1.6	15.1	7.9	180	9.40	101	<0.1	32	9
900 ft below WTP outfall		9/12	1315	1.5	14.5	8.1	190	9.40	100	<0.1	60	7
Crystal Creek at	0.5	9/11	1335	1.6	16.0	8.0	200	9.55	104	-	16	7
HWY 903 Brdg in Cle Elum		9/12	1400	1.3	14.4	8.3	200	9.60	102	-	-	7
Field Blank	-	9/11	1600	-	-	-	-	-	-	-	2	<1
Field Blank	-	9/12	1620	-	-	-	-	-	-	-	2	<1

Repl. = Replicate sample
E = Estimated value due to QA/QC failure

Table 5. (Continued).

Sampling Site	River Mile	Date	Time	Turb. (NTU)	Alk. (mg/L as CaCO3)	Hard. (mg/L as CaCO3)	BOD-5 (mg/L)	Nutrients NH3-N (mg/L)	NO3-N + NO2-N (mg/L)	TN (mg/L)	TP (mg/L)	SRP (mg/L)
W.F. Tributary at	0.6	9/11	1030	<1.0	38.9	-	-	0.020	<0.010	0.571	0.020	0.012
S.E. Corner of Pioneer Park		9/12	1050	1.2	36.6	-	-	<0.010	<0.010	0.560	0.020	0.019
N.F. Tributary at	0.8	9/11	1100	<1.0	118.3	-	-	0.018	0.029	0.612	0.020	0.014
Nevada Ave. alleyway		9/12	1115	1.9	112.3	-	-	0.010	0.028	0.627	0.034	0.025
Crystal Creek at	3.0	9/11	1120	2.2	51.4	-	-	0.028	0.063	0.663	0.024	0.015
junkyard off S. "A" St.		9/12	1135	2.7	47.4	-	-	0.012	0.076	0.638	0.040	0.022
Crystal Creek below	2.7	9/11	1145	1.6	51.4	-	-	0.030	0.075	0.664	0.033	0.021
Hoffmanville Ave. culvert		9/12	1200	1.9	48.0	-	-	<0.010	0.081	0.657	0.039	0.025
Crystal Creek below	1.8	9/11	1205	3.8	56.8	46.1	-	0.022	0.085	0.676	0.058	0.031
dirt road leading to		Repl.	1210	-	-	-	-	-	-	-	-	-
Roslyn WTP		9/12	1215	4.1	51.3	-	-	0.013	0.081	0.677	0.074	0.036
		Repl.	1215	3.8	52.0	-	-	0.012	0.085	0.707	0.070	0.035
Roslyn WTP	1.55	9/11	0940	8.9	129.7	74.7	2.8 E	0.193	0.023	1.950	2.150	2.189
effluent		9/12	0945	-	-	-	-	-	-	-	-	-
		9/12	1430	12.0	123.4	-	2.9 E	0.177	0.030	1.890	2.064	2.070
Crystal Creek	1.5	9/11	1245	3.4	84.5	53.9	<2.0 E	0.049	0.071	0.889	0.430	0.387
300 ft below WTP outfall		Repl.	1245	3.4	86.1	52.4	-	0.046	0.072	0.834	0.440	0.379
		9/12	1250	4.5	78.6	53.2	-	0.040	0.072	0.969	0.460	0.401
Crystal Creek	1.4	9/11	1320	4.3	83.8	-	-	0.045	0.070	0.839	0.460	0.371
900 ft below WTP outfall		9/12	1315	4.7	78.5	-	-	0.037	0.075	0.894	0.460	0.378
Crystal Creek at	0.5	9/11	1335	3.9	91.6	-	-	0.017	0.085	0.808	0.380	0.348
HWY 903 Brdg in Cle Elum		9/12	1400	4.4	84.4	-	-	0.017	0.076	0.849	0.400	0.354
Field Blank	-	9/11	1600	<1.0	-	-	-	-	<0.010	-	-	<0.010
Field Blank	-	9/12	1620	<1.0	<1.0	-	-	-	<0.010	-	<0.010	<0.010

Repl. = Replicate sample

E = Estimated value due to QA/QC failure

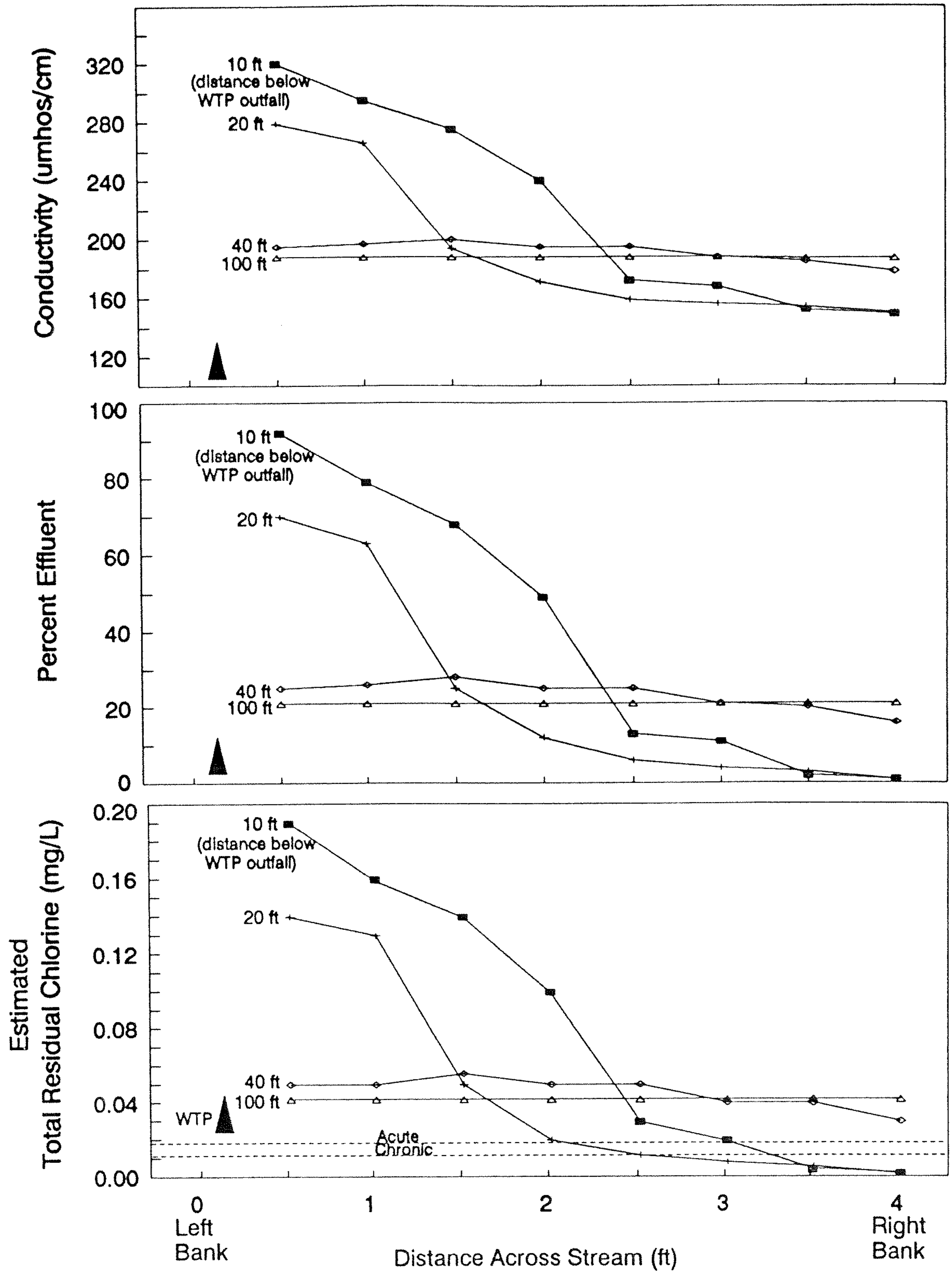

Figure 2. Cross-channel conductivity measurements, percent effluent, and estimated TRC in Crystal Creek immediately downstream from the Roslyn WTP outfall. Percent effluent was calculated using conductivity data.

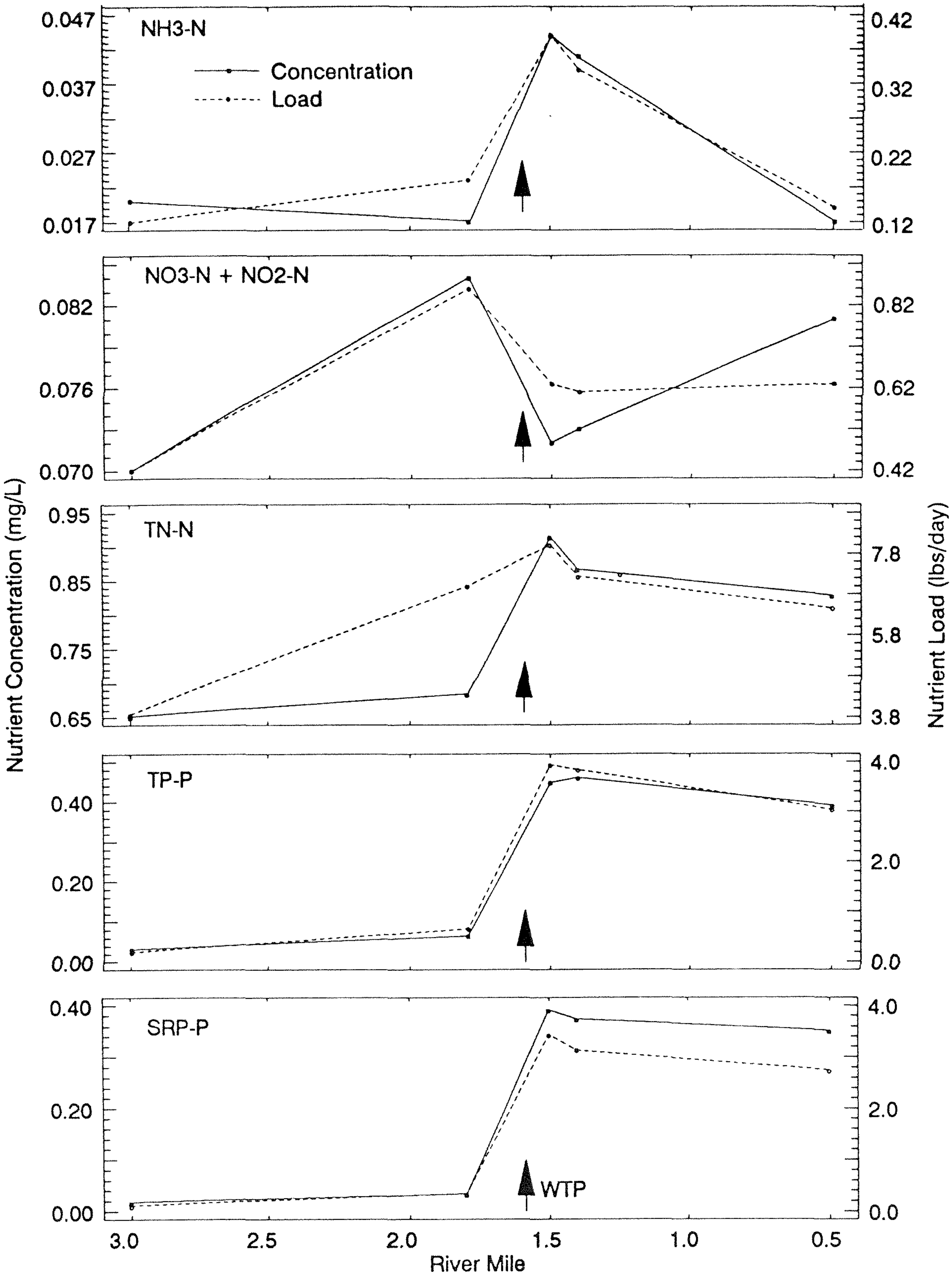

Figure 3. Nutrient concentrations and loads for Crystal Creek above and below the Roslyn WTP. Values represent the mean of samples collected on September 11-12, 1990.

conditions, which resulted in lower stream concentrations below the outfall. Ammonia concentrations at their highest were well below chronic toxicity standards at ambient temperature and pH (Chapter 173-201 WAC). The observed decrease in ammonia from RM 1.5 to 0.5 was probably a result of plant uptake and/or instream nitrification.

Instream ratios of N:P changed dramatically as a result of nutrient loading. Sites above the WTP had N:P ratios averaging 20:1, while sites below the outfall averaged only 2:1. Waterbodies are generally considered to be nitrogen-limited when the N:P ratio is less than 7:1 and phosphorus limited when the N:P ratio exceeds 17:1 (Forsberg 1980). In Crystal Creek, increased phosphorus loads from the WTP changed the potential limiting nutrient from phosphorus to nitrogen.

Dissolved oxygen (D.O.) surveys did not show a significant sag downstream of the WTP outfall (Figure 4; Appendix C). D.O. concentrations were well above the Class A criterion of 8.0 mg/L at all sites during the survey. Temperature increased 1.8°C as a result of effluent discharge, resulting in a violation of the Class A temperature criterion.

Fish populations showed little or no impact from WTP discharge. Electroshocking surveys above and below the outfall found good numbers of rainbow trout (*Oncorhynchus mykiss*) and brook trout (*Salvelinus fontinalis*). Trout were captured at a rate of 3 and 5 per minute at RM 1.8 and RM 1.5, respectively. The trout species encountered require good water quality and thus indicate a relatively healthy stream.

A summary of benthic macroinvertebrate data is presented in Table 6 and Appendix D. Monitoring of macroinvertebrates is useful in receiving water studies because wastewater effluents often eliminate sensitive species and enhance tolerant forms. In Crystal Creek, healthy invertebrate communities were found above and below the outfall. However, the percentage of Ephemeroptera, Plecoptera, and Trichoptera (EPT) did appear to decrease approximately ten percent at sites below the outfall. Conversely, Dipterans and Oligochaetes combined increased about ten percent at downstream sites. It appears waste loading is causing a slight decrease in pollutant intolerant species (EPT) and an increase in pollutant tolerant forms (Diptera + Oligochaeta) below the outfall.

As previously mentioned, effluent was not discharged into Crystal Creek for much of the summer in 1990. Effluent was discharged continuously for seven days prior to the study. Therefore, the resident biological community was only exposed to effluent for a short time. Exposure for longer periods may result in more severe impacts to stream fauna.

A statistical analysis was conducted to compare 1985 and 1990 Crystal Creek water quality data above and below the WTP outfall (Table 7). The Mann-Whitney test, a non-parametric analog to the two-sample t-test (Zar 1984), was employed to determine if median values were significantly different between the two years. Several parameters, including conductivity, nitrate-nitrite, and soluble reactive phosphorus, were found to be significantly lower in 1990,

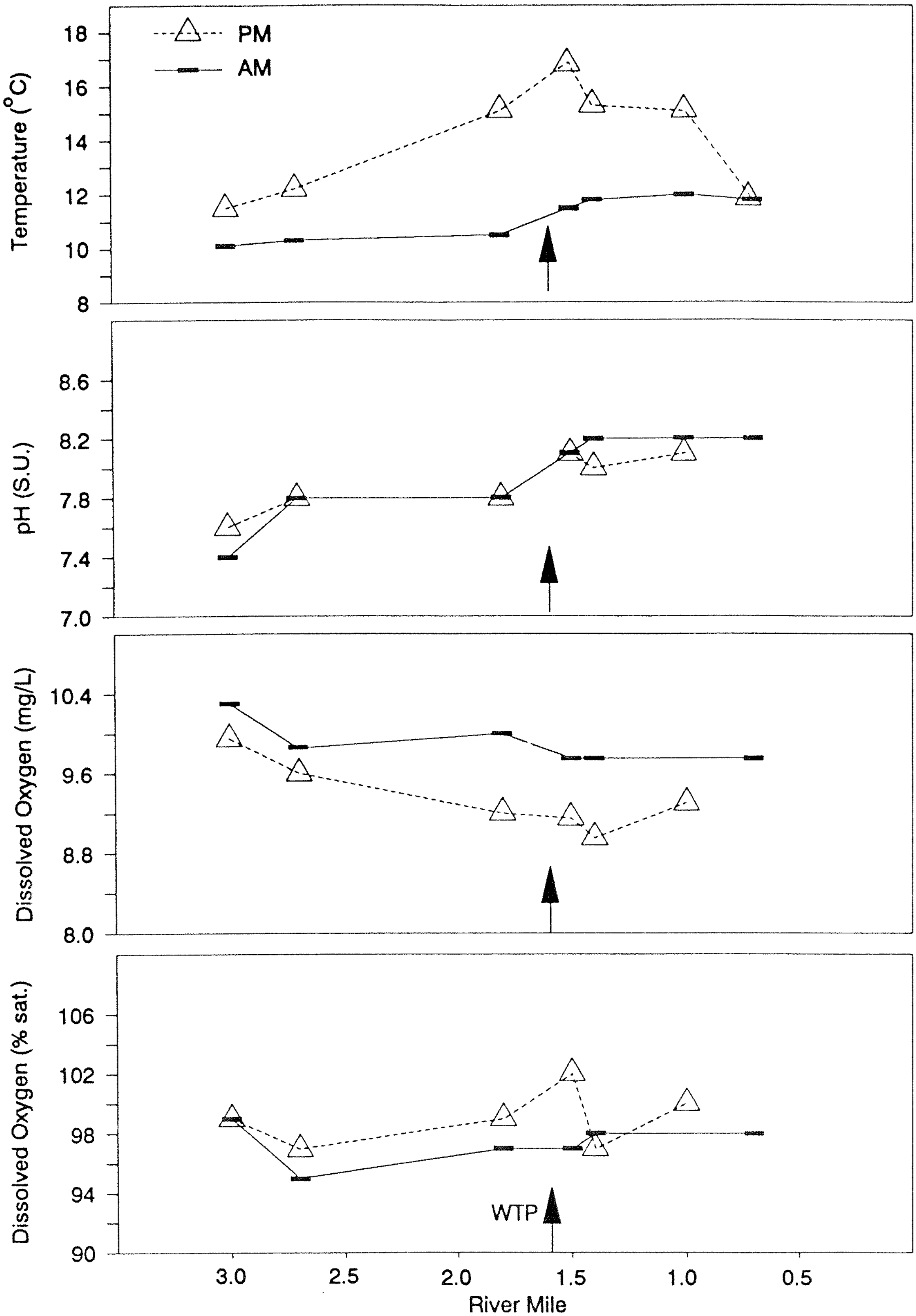

Figure 4. Results of early morning/late afternoon dissolved oxygen surveys on Crystal Creek, September 11-12, 1990.

Table 6. Summary of benthic macroinvertebrate data from sites above and below the Roslyn WTP outfall, September 10, 1990. Note the WTP outfall is located at RM 1.55.

	Site (River mile)					
	1.8	1.8	1.5	1.5	1.4	1.4
Sample Depth (ft)	0.5	0.5	0.5	0.6	0.5	0.5
Sample Velocity (fps)	1.2	1.1	1.7	1.1	1.5	1.8
Diptera (flies, midges)	2	2	4	7	4	3
Ephemeroptera (mayflies)	32	30	47	58	44	53
Plecoptera (stoneflies)	14	19	11	15	1	22
Trichoptera (caddisflies)	20	20	14	2	5	7
Oligochaeta (worms)	1	2	8	4	7	12
Others*	5	4	12	3	0	5
Total Organisms	74	77	96	89	61	102
Number of Taxa	17	12	16	13	8	15
Percent EPT**	89	90	75	84	82	80
Percent Diptera + Oligochaeta	4	5	12	12	18	15

* See Appendix D for detailed list of families

Table 7. Comparison of 1985 and 1990 mainstem Crystal Creek water quality data above and below the Roslyn WTP outfall. Site locations were the same for both surveys. Data from sites above and below the WTP outfall were lumped into 2 data sets for comparison.

			1985			1990		
Parameter	Units	Upstream/ Downstream	N	Median		N	Median	
pH	mg/L	U	4	7.7		6	8.1	*
		D	4	8.0		6	8.1	
Cond.	umhos/cm	U	4	126	*	6	110	
		D	4	233	*	6	190	
TSS	mg/L	U	4	6		6	4	
		D	3	2		6	7	
Turb.	NTU	U	4	3		6	2	
		D	4	4		6	4	
NH3-N	mg/L	U	6	0.020		6	0.017	
		D	4	0.035		6	0.038	
NO3+NO2	mg/L	U	6	0.180	*	6	0.078	
		D	4	0.225	*	6	0.074	
TP	mg/L	U	6	0.060		6	0.040	
		D	4	0.380		6	0.448	
SRP	mg/L	U	6	0.040	*	6	0.024	
		D	4	0.365		6	0.374	

* Indicates the median value is significantly greater relative to the other year (Mann-Whitney statistic $p \leq 0.05$).

indicating some improvement in water quality since 1985. Since improvements occurred both upstream and down of the Roslyn WTP they were not necessarily related to facility improvements.

Figure 5 compares fecal coliform levels in Crystal Creek during 1985 and 1990 Ecology surveys. Highest bacteria levels were found upstream of the WTP discharge and within Roslyn during both surveys. Violations of the Class A criterion in 1985 were attributed to raw fecal wastes from illegal domestic discharges within Roslyn. Violations were much less severe in 1990, indicating that collection system work done at Roslyn after 1985 was somewhat successful. However, fecal coliform water quality violations were still found at RM 2.7 (above the WTP). Additional monitoring in this area should be conducted to identify sources within Roslyn.

Total Maximum Daily Load (TMDL) Analyses

A TMDL analysis determines a particular waterbody's loading capacity, or the amount of pollution it can naturally assimilate without impairing water quality and limiting beneficial uses. TMDLs are management tools to control the discharge of pollutants to surface waters to the level necessary to protect water quality standards. Once established, the TMDL for a given pollutant is apportioned between point sources as wasteload allocations (WLAs), and nonpoint sources as load allocations (LAs). The allocations are implemented through NPDES permits and nonpoint source controls. A reserve may be set aside to provide a margin of safety for a sensitive water body or to accommodate future growth. The following TMDL analyses for Crystal Creek recommend WLAs for chlorine, ammonia, fecal coliform, and BOD_5 to Roslyn WTP based on critical conditions during the low flow season. A wet-weather analysis was not done for this report due to a lack of high flow water quality data. Permit limits calculated based on the low flow design conditions are applicable year-round.

A preliminary analysis based on critical low flow design conditions was conducted to assess the potential impacts that Roslyn WTP discharge may have on Crystal Creek. Critical conditions include the following: design streamflow (7Q10 or 1Q10), WTP flow at design capacity, and effluent quality at current NPDES permit limits. Generally, TMDLs are based on these critical design conditions.

Because a continuous gage station was not located on Crystal Creek, the 7Q10 and 1Q10 design flows were estimated using data from a nearby gage on the Teanaway River. The following relationship was used to estimate design flows on Crystal Creek:

$$\frac{\text{survey flow at Teanaway gage}}{\text{design flow at Teanaway gage}} = \frac{\text{survey flow on Crystal Creek}}{\text{design flow for Crystal Creek}}$$

This analysis estimated 7Q10 and 1Q10 flows for Crystal Creek at 0.53 and 0.41 cfs, respectively. EPA recommends the use of 7Q10 as the critical design flow for chronic criteria and 1Q10 for acute criteria (EPA 1986a; EPA 1986b). The low flow season for the

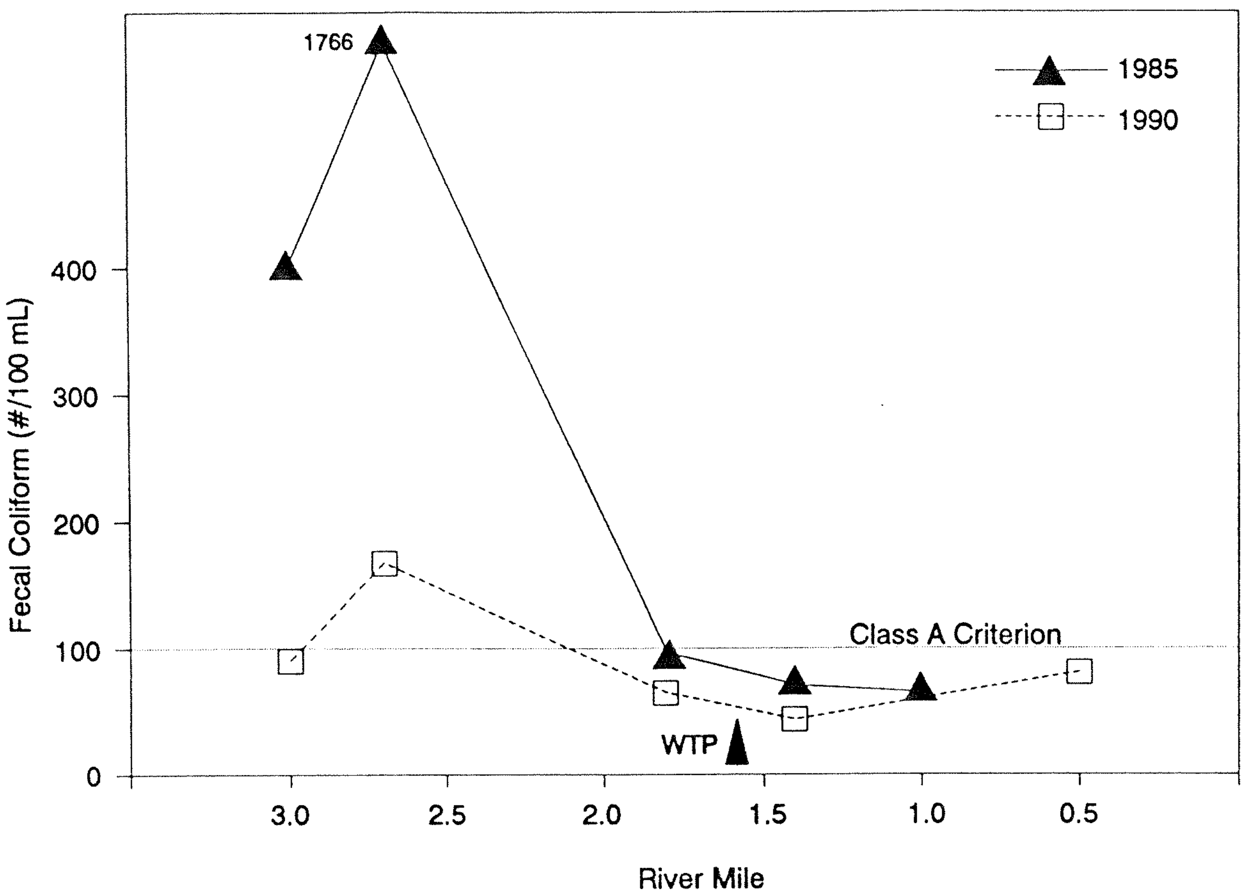

Figure 5. Fecal coliform levels in Crystal Creek during 1985 and 1990 surveys. Data points represent the geometric mean of 2 samples.

Teanaway River is typically from June through October based on historical discharge data (USGS 1985). This report assumes a similar low flow pattern for Crystal Creek.

Results of the preliminary analysis using critical summer low flow conditions found Class A water quality violations for TRC, ammonia, fecal coliform, and dissolved oxygen (Table 8). Proposed revisions to state water quality standards specify that water quality criteria not be violated outside of the boundary of a mixing zone resulting from a discharge. According to the draft regulation, the maximum size of a mixing zone cannot be greater than 25 percent of the streamflow and cannot extend more than 300 feet below the outfall. This proposed rule was incorporated into the worst-case analysis for TRC and ammonia which are both near-field toxicants. The receiving water to effluent dilution under these conditions was approximately 1:16 for 7Q10 flow and 1:21 for 1Q10 flow.

Under worst-case conditions (i.e., 1:21 and 1:16 dilution), mass-balance equations for TRC project instream concentrations which exceed acute and chronic toxicity limits for aquatic organisms (Table 8). Ammonia mass-balance equations project an exceedance of the chronic criterion based on an effluent ammonia concentration of 2.4 mg/L. A conservative mass-balance equation for fecal coliform based on a weekly permitted average of 400 cfu/100 mL and 7Q10 streamflow (0.53 cfs) predicted a downstream concentration of 332 cfu/100 mL. A Streeter-Phelps model was used to predict D.O. depletion under 7Q10 conditions (Mills *et al.*, 1985). The model was calibrated using conditions observed during the survey (Appendix E-1). The critical low D.O. predicted under calibration conditions was 9.5 mg/L, within 0.1 mg/L of measured D.O. (9.6 mg/L at RM 0.5). At design conditions, D.O. was predicted to drop 1.1 mg/L below the Class A standard (Appendix E-2). D.O. violations would be expected to occur under these WTP loading conditions until streamflow increased to 2.3 cfs.

The above analysis indicates that if technology-based limits in Roslyn's present permit were approached during a low flow period, water quality problems would result. Therefore, the creek is water quality limited for these parameters and water quality-based permit limits are needed. Recommended TMDLs and WLAs are shown in Table 9. These limits are based on restricting the WTP flow to 0.80 MGD, and then adjusting effluent limits so that water quality standards in the stream are maintained.

A steady-state WLA procedure was used to derive water quality-based permit limits for chlorine and total ammonia (Appendices F-1 and F-2). The procedure addresses effluent variability when setting permit limits for toxics (EPA 1985). Dilution was so low under critical conditions that WLAs for these toxics were essentially set equal to water quality criteria. For chlorine, recommended permit limits could only be attained if dechlorination or another method of disinfection was employed at the WTP. If effluent ammonia concentrations measured in 1990 are representative of effluent ammonia at the plant, then recommended ammonia permit limits should be attainable under existing WTP operating conditions. Effluent ammonia should be monitored at Roslyn.

Streeter-Phelps analyses were used to determine the BOD_5 WLA of 113 lbs/day for the WTP (Table 9; Appendix G-1). This limit also appears to be attainable for the WTP at present and

Table 8. Results of preliminary worst–case TMDL analysis using design streamflow, WTP flow at design capacity, and effluent quality at permit limits. Oxygen model parameters are provided in Appendices E–1 and E–2.

	Acute (1Q10)		Chronic (7Q10)		
Parameters	WQ Criterion	Predicted	WQ Criterion/Class A		Predicted
Total Residual Chlorine (mg/L)	0.019	0.191 **	0.011	--	0.188 *
NH3–N (mg/L)	6.9	2.29 **	1.33	--	2.26 *
Fecal Coliform (cfu/100 mL)	--	--	--	100	332
Dissolved Oxygen (mg/L)	--	--	--	8	6.9

* Assumes 25% of the 7Q10 design flow is available for dilution.
** Assumes 25% of the 1Q10 design flow is available for dilution.

Critical Design Conditions

Effluent characteristics

Discharge = 1.4 MGD (2.17 cfs)
BOD–5 = 45 mg/L
Temperature = 20.2 C
Fecal coliform = 400 cfu/100 mL
TRC = 0.2 mg/L
D.O. = 8.1 mg/L
NH3–N = 2.4 mg/L

Background characteristics

7Q10 = 0.53 cfs
1Q10 = 0.41 cfs
BOD–5 = 1.0 mg/L
Temperature = 12.9 C
Fecal coliform = 57 cfu/100 mL
TRC = 0.0 mg/L
D.O. = 9.75 mg/L
NH3–N = 0.017 mg/L

Table 9. Recommended WLAs and water quality-based permit limits for Roslyn WTP during the low flow season (June - October). TMDLs for Crystal Creek are provided and apportioned as background LAs and Roslyn's WLAs. Calculations are based on the following design flows: WTP - 1.23 cfs; Crystal Creek - 0.53 cfs (7Q10); 0.41 cfs (1Q10); for TRC and NH3-N only 25% of the creek design flow is available for chronic dilution and 2.5% for acute. Calculations are detailed in Appendices F-1, F-2, and G-1.

	Total Residual Chlorine		Total NH3-N		Fecal Coliform		BOD-5		
	Conc. mg/L	Load lbs/day	Conc. mg/L	Load lbs/day	Conc. cfu/100 mL	Load cfu/sec	Conc. mg/L	Load lbs/day	Effluent Discharge (MGD)
Water Quality Criterion									
Acute toxicity (1Q10)	0.019	--	6.90	--	--	--	--	--	--
Chronic toxicity (7Q10)	0.011	--	1.33	--	--	--	--	--	--
Class A	--	--	--	--	100	--	8.0 *	--	--
Crystal Creek TMDL	0.011	0.08	1.330	9.75	100	49,900	12	116	--
Crystal Creek LA (background)	0.00	0.00	0.017	0.05	59	8,800	1	3	--
Roslyn WLA (WTP)	0.012	0.08	1.461	9.70	118	41,100	17	113	--
Recommended Roslyn WTP Permit Limits									
Daily	0.019	0.126	2.400	15.92	--	--	--	--	--
Weekly	--	--	--	--	118	--	17	113	--
Monthly	0.008	0.053	1.197	7.94	59 **	--	11 ***	75 ***	0.80

* Dissolved oxygen concentration (mg/L).

** Monthly fecal coliform permit limit based on 1/2 of the weekly limit.

*** Monthly BOD-5 permit limit based on 2/3 of the weekly limit.

would protect against D.O. violations during a critical low flow year. Appendix G-2 provides a flow-based range of BOD_5 effluent limits and WLAs which would also protect the stream during a 7Q10 year. Note that the water quality criterion can be attained by decreasing plant flow and increasing BOD_5 concentration limits, or by increasing plant flow and decreasing BOD_5 limits. The water quality-based permit limits recommended in this report for chlorine, ammonia, and fecal coliform were based on a WTP discharge of 0.8 MGD. If the WTP discharge limit were changed to something other than 0.8 MGD, then water quality-based permit limits for these parameters would also change.

TMDLs for Crystal Creek are included in Table 9. The TMDL for each parameter, expressed as a load, was determined by summing the background LA and Roslyn WLA. The TMDLs are also provided as concentrations; notice that these are equal to the most limiting water quality criterion. For Crystal Creek, the majority of the TMDL was apportioned to the Roslyn WTP as a WLA. For chlorine and ammonia, the TMDL is based on the most limiting design condition. For TRC acute conditions were most limiting and chronic conditions were most limiting for ammonia (Appendices F-1 and F-2). A LA set-aside for safety was not included because a safety margin was built into the TMDL calculations by using conservative critical design conditions.

By not discharging in the summer of 1990, the WTP operator demonstrated that it may be possible to avoid discharging to Crystal Creek during critical low flow periods. This would be ideal for a small receiving water such as Crystal Creek. Review of DMR data found WTP influent flows to be very stable and low during summer months. Lagoon storage capacity may be increased by discharging effluent at a higher rate than incoming flows in early spring, when receiving water flows are high enough to provide adequate dilution. Evaporation loss from lagoons during summer will provide additional storage for the low flow season.

A request was made by CRO staff to determine if diversion of the Ronald sewage into Roslyn WTP would adversely impact Crystal Creek. Ronald WTP currently serves a population of approximately 150 and has an I&I problem. If the I&I problems were eliminated, then the flows at Ronald would only add approximately 5% to the flows at the Roslyn WTP. If Roslyn accepted this added burden and could still meet the permit limits recommended in this report, then Ronald should be allowed to connect to Roslyns WTP.

SUMMARY AND CONCLUSIONS

Limited Class II Inspection

- From June through August 1990, Roslyn WTP did not discharge into Crystal Creek. However, effluent was discharged continuously for seven days prior to this survey.

- The WTP lagoon system was efficient in removing a large portion of incoming nitrogen loads. Removal of ammonia was greater than 99 percent.

- Sample splits between Ecology's lab and the Roslyn WTP lab were not very comparable for TSS.

- BOD_5, TSS, and fecal coliform were well below permit limits. Removal efficiency for BOD_5 and TSS was 96 and 99 percent, respectively.

- I&I continues to be a problem, particularly during wet weather. Several storm drains in Roslyn are probably still connected to the sanitary sewer system.

Receiving Water Survey

- Receiving water to effluent dilution was 6:1, based on an average upstream flow of 1.4 cfs and a morning WTP flow of 0.23 cfs.

- Approximately 18 percent of the fecal coliform samples exceeded the Class A criterion of 100 cfu/100 mL. All the violations were measured upstream of the WTP in close proximity to Roslyn.

- Cross-channel conductivity measurements in Crystal Creek indicated effluent mixing was complete about 40 feet downstream of the outfall.

- Total residual chlorine was predicted to exceed acute and chronic toxicity thresholds across much of the stream as a result of wastewater discharge. Temperature increases as a result of WTP discharge also violated the Class A criterion.

- Dawn and mid-afternoon D.O. surveys did not show a significant sag downstream of the WTP outfall.

- Stream fauna showed little or no impact from WTP discharge 300 feet below the outfall. Trout were found in good numbers both above and below the outfall. Macroinvertebrate communities were relatively healthy; however, a slight decrease in pollution-intolerant species and an increase of pollution-tolerant forms were seen downstream of discharge.

- A statistical analysis comparing 1985 and 1990 Crystal Creek data found several parameters, including conductivity, nitrate-nitrite, and soluble reactive phosphorus, to be significantly lower in 1990.

- Violations of fecal coliform criteria were much less severe in 1990 compared to 1985, indicating that collection system work done in Roslyn after 1985 was relatively successful. However, exceedances of the Class A criterion still occurred at RM 2.7, indicating that raw fecal wastes from Roslyn may still be entering Crystal Creek.

TMDL Analyses

- A worst-case analysis based on design streamflow (7Q10 or 1Q10), WTP flow at design capacity, and effluent quality at permit limits projected Class A water quality criteria violations for TRC, ammonia, fecal coliform, and dissolved oxygen.

- Because current technology-based permit limits do not provide adequate protection for Crystal Creek during the low flow season, water quality-based permit limits for effluent BOD_5, TRC, total ammonia, and fecal coliform were derived using the low flow period for design conditions.

- Due to a lack of water quality data for the rest of the year, an analysis for other seasons was not conducted. Since low flow conditions are probably critical for the Roslyn WTP, year round limits based on this season are expected to protect against water quality standards violations from this facility. However, it is unlikely that the water quality-based permit limits recommended in this report would be attainable for Roslyn WTP during winter until I&I problems are corrected.

RECOMMENDATIONS

The following recommendations are offered to improve the operation of Roslyn WTP and protect water quality in Crystal Creek.

- The WTP laboratory did not perform well on TSS split sample comparisons. A review of laboratory procedures is in order.

- I&I problems in Roslyn should be investigated and corrected. All storm drains should be disconnected from the sanitary collection system.

- Dechlorination, effluent diversion, or an alternative method of disinfection are needed to avoid chlorine toxicity in Crystal Creek during the low flow season.

- Instream monitoring for fecal coliform at RM 2.7 should be required as part of the Roslyn NPDES permit until sources within town are identified and eliminated.

- The WLAs and water quality-based permit limits suggested in this report should be incorporated into the Roslyn NPDES permit as soon as possible to afford maximum protection to Crystal Creek. The water quality-based permit limits should be used for the summer low flow season (June-October) until I&I problems are corrected. Following this, the water quality-based permit should be applied year round. If Roslyn still can't meet these limits during winter, then seasonal permit limits could be developed if additional wet season data are collected.

- Effluent ammonia monitoring should be incorporated into the NPDES permit at a rate of once weekly.

- A spring drawdown of WTP lagoons during a period of high flow should be considered to provide additional storage for the low flow season. This could lead to no discharge during summer months. This would address temperature and TRC violations which occur as a result of WTP discharge.

- The town of Ronald should be allowed to connect to the Roslyn WTP if they correct their current I&I problem and Roslyn can still meet the permit limits recommended in this report.

REFERENCES

Anderson, D. and E. Egbers. Ronald and Roslyn STP Inspections and Receiving Water Surveys. Memorandum to John Hodgson, WDOE Central Regional Office, 1978, 6 pp.

APHA (American Public Health Association, American Water Works Association, and Water Pollution Control Federation). Standard Methods for the Examination of Water and Wastewater, 17th ed., Washington DC, 1989.

Bole, J.B. and J.R. Allan. Uptake of Phosphorus from Sediment by Aquatic *Myriophyllum spicatum* and *Hydrilla verticillata*, Water Resource. Vol. 12, 1978. pp. 353-358.

Ecology. Criteria for Sewage Works Design. Washington State Department of Ecology Report 78-5, Olympia, WA, 1985. 276 pp.

EPA (United States Environmental Protection Agency). Methods for Chemical Analysis of Water and Wastes. EPA 600\4-79-020, Cincinnati, 1983.

------. Technical Support Document for Water Quality-Based Toxics Control. EPA Report 440/4-85-032. Washington, DC, 1985.

------. Quality Criteria for Water. EPA Report 440/5-86-001. Washington DC, 1986a.

------. Technical Guidance Manual for Performing Waste Load Allocations. EPA Report 440/4-87-004. Cincinnati, 1986b.

Forsberg, C. Present Knowledge on Limiting Nutrients. In: Restoration of Lakes and Inland Waters. EPA Report 440/5-81-010. Washington, DC, 1980, 37 pp.

Huntamer, D. and C. Smith. Laboratory User's Manual. Washington State Department of Ecology, Manchester, WA, 1986, 139 pp.

Joy, J. Roslyn Wastewater Lagoons and Crystal Creek Receiving Water Study--Findings. Washinigton State Department of Ecology, Memorandum to Chris Haynes and Harold Porath, 1985, 27 pp.

Merritt, R.W., and K.W. Cummins. An Introduction to the Aquatic Insects of North America. 2nd ed., Kendall-Hunt Publishing Company, Dubuque, IA, 1984, 722 pp.

Metcalf and Eddy. Wastewater Engineering. McGraw-Hill Book Co., New York, 1972, 782 pp.

Mills, W.B., D.B. Percella, M.J. Ungs, S.A. Gherini, K.V. Summers, Lingfung Mok, G.L. Rupp, and G.L. Bowie. A Screening Procedure for Toxic and Conventional Pollutants in Surface and Ground Water. EPA 600/6-85-022a, 1985.

Peck, J. Personal Communication. Wastewater Treatment Plant Operator, Roslyn, WA, 1990.

Pennak, R.W. Fresh-water Invertebrates of the United States. 2nd ed. John Wiley and Sons, New York, 1978, 803 pp.

USGS (United States Geological Survey). Streamflow Statistics and Drainage-Basin Characteristics for the Southwestern and Eastern Regions, Washington. USGS Open-file Report 84-145-B, Tacoma, WA, 1985, 662 pp.

Welch, E.B. Ecological Effects of Waste Water. Cambridge University Press, Cambridge, U.K., 1985, 337 pp.

Wydoski, R.S., and R.R. Whitney. Inland Fishes of Washington. University of Washington Press, Seattle, 1979, 220 pp.

Zar, J.H. Biostatistical Analysis. Prentice-Hall, Inc., 2nd ed., Englewood Cliffs, NJ, 1984, 718 pp.

APPENDICES

Appendix A. Total recoverable metals data for Crystal Creek and Roslyn WTP effluent.

Sampling Site	River Mile	Date	Time	Total Hardness (mg/L)	Total Recoverable Metals (ug/l)			
					Cadmium	Copper	Lead	Zinc
Crystal Creek below dirt road leading to Roslyn WTP	1.8	9/11	1205	46.1	<0.10	<2.0	1.3 J	4.6 BJ
Effluent Grab	1.55	9/11	0940	74.7	<0.10	3.8 J	1.1 J	10.1 BJ
Crystal Creek	1.5	9/11	1245	53.9	<0.10	<2.0	3.8 J	7.9 BJ
300 feet below		Repl.	1245	52.4	<0.10	<2.0	<1.0	5.0 BJ
WTP outfall		9/12	1250	53.2	<0.10		1.1 J	
Lab Blank 1	–	9/12	–	–	<0.10	<2.0	<1.0	6.3 J
Lab Blank 2	–	9/12	–	–	<0.10	<2.0	<1.0	3.3 J

B = Analyte is found in the blank as well as the sample, indicating probable blank contamination.

J = Estimated value; not accurate.

Appendix B. Constituent loads in Crystal Creek, September 11–12, 1990.

Sampling Site	River Mile	Date	Time	Flow (cfs)	Fecal Coliform (#/sec)	TSS (lbs/day)	NH3–N (lbs/day)	NO3–N+ NO2–N (lbs/day)	TN (lbs/day)	TP (lbs/day)	SRP (lbs/day)
W.F. tributary at S.E. Corner of Pioneer Park	0.6	9/11	1030	0.7	27000	4	0.08	0.02	2.16	0.08	0.05
		9/12	1050	0.7	15000	8	0.02	0.02	2.11	0.08	0.07
N.F. tributary at Nevada Ave. alleyway	0.8	9/11	1100	0.1	85	1	0.01	0.02	0.33	0.01	0.01
		9/12	1115	0.1	1200	2	0.01	0.02	0.34	0.02	0.01
Crystal Creek at junkyard at S. "A" St	3.0	9/11	1120	1.0	25000	16	0.15	0.34	3.58	0.13	0.08
		9/12	1135	1.2	31000	13	0.08	0.49	4.13	0.26	0.14
Crystal Creek at dirt road leading to Roslyn WTP	1.8	9/11	1205	1.9	21000	--	0.23	0.87	6.93	0.59	0.32
		9/12	1215	1.9	45000	97	0.13	0.85	7.09	0.74	0.37
Endicott WTP effluent	1.55	9/12	0940	0.21	750	2	0.11	0.03	1.86	2.36	2.27
Crystal Creek 300 ft below WTP outfall	1.5	9/11	1245	1.6	21000	40	0.43	0.64	7.67	3.92	3.41
		9/12	1250	1.6	25000	43	0.35	0.62	8.36	3.97	3.46
Crystal Creek 900 ft below WTP outfall	1.4	9/11	1320	1.6	14000	78	0.39	0.60	7.24	3.97	3.20
		9/12	1315	1.5	25000	57	0.30	0.61	7.23	3.72	3.06
Crystal Creek at Hwy 903 bridge in Cle Elum	0.5	9/11	1335	1.6	7200	60	0.15	0.73	6.97	3.28	3.00
		9/12	1400	1.3	150000	49	0.12	0.53	5.95	2.80	2.48

Appendix C. Results of dawn/mid-afternoon dissolved oxygen surveys conducted on Crystal Creek, September 10-11, 1990.

Sampling Site	River Mile	Date	Time	Temp (C)	pH (S.U.)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)
W.F. tributary at S.E. corner of Pioneer Park	0.6	9/10	1510	11.1	7.9	9.90	97
		9/11	0530	9.3	7.2	10.35	98
Crystal Creek at junkyard off S. "A" Street	3.0	9/10	1530	11.5	7.6	9.95	99
		9/11	0545	10.1	7.4	10.30	99
Crystal Creek below Hoffmanville Ave. culvert	2.7	9/10	1535	12.2	7.8	9.60	97
		Repl.	-	-	-	9.55	96
		9/11	0550	10.3	7.8	9.85	95
		Repl.	-	-	-	9.80	95
Crystal Creek below dirt road leading to Roslyn WTP	1.8	9/10	1540	15.1	7.8	9.20	99
		9/11	0600	10.5	7.8	10.00	97
Crystal Creek 300 ft below WTP outfall	1.5	9/10	1550	16.9	8.1	9.15	102
		9/11	0611	11.5	8.1	9.75	97
Crystal Creek 900 ft below WTP outfall	1.4	9/10	1605	15.3	8.0	8.95	97
		Repl.	-	-	-	8.90	96
		9/11	0614	11.8	8.2	9.75	98
Crystal Creek adjacent to Mile 3 marker on Hwy 903	1.0	9/10	1625	15.1	8.1	9.30	100
		9/11	0633	12	8.2	9.75	98
Crystal Creek at Hwy 903 bridge in Cle Elum	0.7	9/11	0649	11.8	8.2	9.75	98

Appendix D. Benthic macroinvertebrate data for Crystal Creek (9/10/90).

	Site (River mile)					
	1.8	1.8	1.5	1.5	1.4	1.4
Sample Depth (ft)	0.5	0.5	0.5	0.6	0.5	0.5
Velocity (fps)	1.2	1.1	1.7	1.1	1.5	1.8
Diptera (flies, midges)						
Chironomidae	1		1	5	1	
Simuliidae		2	2	2	3	3
Tipulidae	1		1			
Ephemeroptera (mayflies)						
Baetidae	21	10	14	25	39	15
Ephemerellidae	3	2	1		1	2
Heptageniidae	7	18	31	32	4	36
Leptophlebiidae	1		1	1		
Plecoptera (stoneflies)						
Perlodidae	3	16	3	12		19
Nemouridae	11	3	8	3	1	3
Trichoptera (caddisflies)						
Brachycentridae				1		1
Glossosomatidae	3		11			
Hydropsychidae	13	18	3		5	1
Hydroptilidae	1					
Limnephilidae						3
Rhyacophilidae	3	2		1		2
Coleoptera (beetles)						
Elmidae larvae	1		1			
Others (adults)	2		8			1
Gastropoda (snails)						
Planorbidae				1		
Hydracarina (water mites)	1					1
Megaloptera						
Sialidae (alderflies)				1		
Oligochaeta (worms)						
Lumbriculidae			4			1
Naididae	1	2	4	4	7	11
Decapoda (crayfish)						
Astacidae		2				
Pelecypoda (clams)						
Sphaeriidae		1		1		3
Terrestrial Insects	1	1	3			
Total Organisms	74	77	96	89	61	102

Appendix E-1. Streeter-Phelps analysis of critical dissolved oxygen sag downstream of the Roslyn WTP outfall. Model calibration.

INPUT***

1. EFFLUENT CHARACTERISTICS
   - Discharge (cfs) 0.23
   - CBOD5 (mg/L) 2.9
   - NBOD (mg/L) 0.845
   - Dissolved Oxygen (mg/L) 8.1
   - Temperature (deg C) 20.2
2. RECEIVING WATER CHARACTERISTICS
   - Discharge (cfs) 1.9
   - Upstream CBOD5 (mg/L) 1.0
   - Upstream NBOD (mg/L) 0.08
   - Upstream Dissolved Oxygen (mg/L) 9.75
   - Upstream Temperature (deg C) 12.9
   - Elevation (ft NGVD) 2200
   - Downstream Average Channel Slope (ft/ft) 0.0126
   - Downstream Average Channel Depth (ft) 0.4
   - Downstream Average Channel Velocity (fps) 1.3
3. REAERATION RATE (Base e) AT 20 deg C (day^-1) 113.13

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggest Value
Churchill	1.5 - 6	2 - 50	69.28
O'Connor and Dobbins	.1 - 1.5	2 - 50	58.41
Owens	.1 - 6	1 - 2	140.28
Tsivoglou-Wallace	.1 - 6	.1 - 2	113.13

4. BOD DECAY RATE (Base e) AT 20 deg C (day^-1)3.33

Reference	Suggest Value
Wright and McDonnell, 1979	3.33

OUTPUT**

1. INITIAL MIXED RIVER CONDITION
   - CBOD5 (mg/L) 1.2
   - NBOD (mg/L) 0.2
   - Dissolved Oxygen (mg/L) 9.6
   - Temperature (deg C) 13.7

Appendix E-1. Continued.

2. TEMPERATURE ADJUSTED RATE CONSTANTS (Base e)
   - Reaeration (day^-1) 97.40
   - BOD Decay (day^-1) 2.49
3. CALCULATED INITIAL ULTIMATE CBODU AND TOTAL BODU
   - Initial Mixed CBODU (mg/L) 1.8
   - Initial Mixed Total BODU (CBODU + NBOD, mg/L) 1.9
4. INITIAL DISSOLVED OXYGEN DEFICIT
   - Saturation Dissolved Oxygen (mg/L) 9.53
   - Initial Deficit (mg/L) . . . .-0.04
5. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days) 0.05
6. DISTANCE TO CRITICAL DO CONCENTRATION (miles) 0.96
7. CRITICAL DO DEFICIT (mg/L) 0.04
8. CRITICAL DO CONCENTRATION (mg/L) 9.48

****

Appendix E-2. Streeter-Phelps analysis of critical dissolved oxygen sag downstream of the Roslyn WTP outfall. Model calibration. Worst-case analysis.

INPUT***

1. EFFLUENT CHARACTERISTICS
   - Discharge (cfs) 2.17
   - CBOD5 (mg/L) 45
   - NBOD (mg/L) 10.95
   - Dissolved Oxygen (mg/L) 8.1
   - Temperature (deg C) 20.2
2. RECEIVING WATER CHARACTERISTICS
   - Upstream Discharge (cfs) 0.53
   - Upstream CBOD5 (mg/L) 1.0
   - Upstream NBOD (mg/L) 0.08
   - Upstream Dissolved Oxygen (mg/L) 9.75
   - Upstream Temperature (deg C) 12.9
   - Elevation (ft NGVD) 2200
   - Downstream Average Channel Slope (ft/ft) 0.0126
   - Downstream Average Channel Depth (ft) 0.4
   - Downstream Average Channel Velocity (fps) 1.3
3. REAERATION RATE (Base e) AT 20 deg C (day^-1) 113.13

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggest Value
Churchill	1.5 - 6	2 - 50	69.28
O'Connor and Dobbins	.1 - 1.5	2 - 50	58.41
Owens	.1 - 6	1 - 2	140.28
Tsivoglou-Wallace	.1 - 6	.1 - 2	113.13

4. BOD DECAY RATE (Base e) AT 20 deg C (day^-1) 3.33

Reference	Suggest Value
Wright and McDonnell, 1979	3.33

OUTPUT**

1. INITIAL MIXED RIVER CONDITION
   - CBOD5 (mg/L) 36.4
   - NBOD (mg/L) 8.8

Appendix E-2. Continued.

Oxygen (mg/L) 8.4
Temperature (deg C) 18.8

2. TEMPERATURE ADJUSTED RATE CONSTANTS (Base e)
   Reaeration (day^-1) 109.87
   BOD Decay (day^-1) 3.15
3. CALCULATED INITIAL ULTIMATE CBODU AND TOTAL BODU
   Initial Mixed CBODU (mg/L) 53.5
   Initial Mixed Total BODU (CBODU + NBOD, mg/L) 62.3
4. INITIAL DISSOLVED OXYGEN DEFICIT
   Saturation Dissolved Oxygen (mg/L) 8.53
   Initial Deficit (mg/L) 0.11
5. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days) 0.03
6. DISTANCE TO CRITICAL DO CONCENTRATION (miles) 0.70
7. CRITICAL DO DEFICIT (mg/L) 1.61
8. CRITICAL DO CONCENTRATION (mg/L) 6.92

****

Appendix F-1. WLAs and permit limits for total residual chlorine. Based on EPA WLA procedure for setting water quality-based permit limits.

INPUT**

1. Water Quality Standards/Criteria (Concentration)
   Acute (one-hour) Criteria 0.019
   Chronic (n-day) Criteria 0.011

2. Upstream Receiving Water Concentration
   Upstream Concentration for Acute Condition (1Q10) 0.000
   Upstream Concentration for Chronic Condition (7Q10) 0.000

3. Dilution Factors (1/{Effluent Volume Fraction})
   Acute Receiving Water Dilution Factor at 1Q10 . . . . 1.000
   Chronic Receiving Water Dilution Factor at 7Q10 . . . . 1.100

4. Coefficient of Variation for Effluent Concentration
   (use 0.6 if data are not available) 0.600

5. Number of days (n1) for chronic average
   (usually four or seven; four is recommended) 4

6. Number of samples (n2) per month to base permit on 20

OUTPUT**

1. Z Statistics
   LTA Derivation (99%tile) 2.326
   Daily Maximum Permit Limit (99%tile) 2.326
   Monthly Average Permit Limit (95%tile) 1.645

2. Calculated Waste Load Allocations (WLA's)
   Acute (one-hour) WLA 0.019
   Chronic (n1-day) WLA 0.012

3. Back-Calculation of Long Term Averages (LTA's)
   Sigma (same for acute and chronic) 0.5545
   Mu for Acute WLA . . . . -5.2531
   Mu-n1 for Chronic WLA . . . . -5.0974
   Mu for Chronic WLA . . . . -5.2080
   LTA for Acute (one-hour) WLA 0.0061
   LTA for Chronic (n1-day) WLA 0.0064
   Most Limiting LTA (minimum of acute and chronic) 0.0061

Appendix F-1. Continued.

4. Derivation of Permit Limits From Limiting LTA

Mu for daily maximum permit limit	-5.2531
Mu-n2 for monthly average permit limit	-5.1083
Sigma^2-n for monthly avg permit limit	0.0178
Daily Maximum Permit Limit	0.019
Monthly Average Permit Limit	0.008

****

Appendix F-2. WLAs and permit limits for total ammonia. Based on EPA WLA procedure for setting water quality-based permit limits.

INPUT**

1. Water Quality Standards/Criteria (Concentration)
   Acute (one-hour) Criteria 6.900
   Chronic (n-day) Criteria 1.330

2. Upstream Receiving Water Concentration
   Upstream Concentration for Acute Condition (1Q10) 0.017
   Upstream Concentration for Chronic Condition (7Q10) 0.017

3. Dilution Factors (1/{Effluent Volume Fraction})
   Acute Receiving Water Dilution Factor at 1Q10 . . . . 1.000
   Chronic Receiving Water Dilution Factor at 7Q10 . . . . 1.100

4. Coefficient of Variation for Effluent Concentration
   (use 0.6 if data are not available) 0.600

5. Number of days (n1) for chronic average
   (usually four or seven; four is recommended) 4

6. Number of samples (n2) per month to base permit on 4

OUTPUT**

1. Z Statistics
   LTA Derivation (99%tile) 2.326
   Daily Maximum Permit Limit (99%tile) 2.326
   Monthly Average Permit Limit (95%tile) 1.645

2. Calculated Waste Load Allocations (WLA's)
   Acute (one-hour) WLA 6.900
   Chronic (n1-day) WLA 1.461

3. Back-Calculation of Long Term Averages (LTA's)
   Sigma (same for acute and chronic) 0.5545
   Mu for Acute WLA 0.6417
   Mu-n1 for Chronic WLA . . . . -0.3035
   Mu for Chronic WLA . . . . -0.4141
   LTA for Acute (one-hour) WLA 2.2155
   LTA for Chronic (n1-day) WLA 0.7707
   Most Limiting LTA (minimum of acute and chronic) 0.7707

Appendix F-2. Continued.

4. Derivation of Permit Limits From Limiting LTA

Mu for daily maximum permit limit	-0.4141
Mu-n2 for monthly average permit limit	-0.3035
Sigma^2-n for monthly avg permit limit	0.0862
Daily Maximum Permit Limit	2.400
Monthly Average Permit Limit	1.197

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Appendix G-1. Streeter-Phelps analysis of critical dissolved oxygen sag downstream of the Roslyn WTP outfall. Model calibration. Recommended BOD-5 and effluent discharge permit limits which don't violate the Class A standard.

INPUT**

1. EFFLUENT CHARACTERISTICS
   - Discharge (cfs) 1.23
   - CBOD5 (mg/L) 17
   - NBOD (mg/L) 10.95
   - Dissolved Oxygen (mg/L) 8.1
   - Temperature (deg C) 20.2
2. RECEIVING WATER CHARACTERISTICS
   - Upstream Discharge (cfs) 0.53
   - Upstream CBOD5 (mg/L) 1.0
   - Upstream NBOD (mg/L) 0.08
   - Upstream Dissolved Oxygen (mg/L) 9.75
   - Upstream Temperature (deg C) 12.9
   - Elevation (ft NGVD) 2200
   - Downstream Average Channel Slope (ft/ft) 0.0126
   - Downstream Average Channel Depth (ft) 0.4
   - Downstream Average Channel Velocity (fps) 1.3
3. REAERATION RATE (Base e) AT 20 deg C (day^-1) 113.13

Reference	Applic. Vel (fps)	Applic. Dep (ft)	Suggest Value
Churchill	1.5 - 6	2 - 50	69.28
O'Connor and Dobbins	.1 - 1.5	2 - 50	58.41
Owens	.1 - 6	1 - 2	140.28
Tsivoglou-Wallace	.1 - 6	.1 - 2	113.13

4. BOD DECAY RATE (Base e) AT 20 deg C (day^-1) 3.33

Reference	Suggest Value
Wright and McDonnell, 1979	3.33

OUTPUT***

1. INITIAL MIXED RIVER CONDITION
   - CBOD5 (mg/L) 12.2
   - NBOD (mg/L) 7.7

Dissolved Oxygen (mg/L) 8.6
Temperature (deg C) 18.0 . . . .

2. TEMPERATURE ADJUSTED RATE CONSTANTS (Base e)
   Reaeration (day^-1) 107.89
   BOD Decay (day^-1) 3.04
3. CALCULATED INITIAL ULTIMATE CBODU AND TOTAL BODU
   Initial Mixed CBODU (mg/L) 17.9
   Initial Mixed Total BODU (CBODU + NBOD, mg/L) 25.6
4. INITIAL DISSOLVED OXYGEN DEFICIT
   Saturation Dissolved Oxygen (mg/L) 8.67
   Initial Deficit (mg/L) 0.07
5. TRAVEL TIME TO CRITICAL DO CONCENTRATION (days) 0.03
6. DISTANCE TO CRITICAL DO CONCENTRATION (miles) 0.70
7. CRITICAL DO DEFICIT (mg/L) 0.65
8. CRITICAL DO CONCENTRATION (mg/L) 8.02

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Appendix G–2. Alternative BOD–5 WLAs for Roslyn WTP, based on Streeter–Phelps oxygen sag predictions.

Plant Flow (MGD)	BOD–5 Concentration Weekly (mg/L)	BOD–5 Concentration Monthly (mg/L)	WLA BOD–5 Load Weekly (lbs/day)	WLA BOD–5 Load Monthly** (lbs/day)
0.32	45 *	30 *	121	81
0.60	23	15	115	75
0.80	17	11	114	74
1.00	13	9	109	75
1.20	11	7	110	70
1.40	9	6	105	70

* Indicates the current NPDES permit limit.

** Monthly BOD–5 permit limit based on 2/3 the weekly limit.