WASHINGTON STATE DEPARTMENT OF ECOLOGY

Woodland Creek Water Quality Assessment Final Report Ecology Building Project

Abstract

Four sites along Woodland Creek were monitored before and during construction of the new Ecology Headquarters Building from January 1991 through September 1993. The primary objective was to assess water quality impacts from runoff resulting from construction activities. Monitoring results demonstrated that the construction project did not adversely impact the creek. A City of Lacey storm drain was found to be a primary loading source leading to Class AA fecal coliform excursions and increased total suspended solids during storm events. Metal and organics in sediment and depression of pollution intolerant macroinvertebrates at the upstream reference site were also likely a result of this storm drain. Natural conditions, namely intermittent and low flows, were the primary reason for water quality occasionally not meeting Class AA criteria for temperature, dissolved oxygen, pH, and characteristic uses (fish migration). The Woodland Creek monitoring project resulted in improved sediment BMPs at the construction site, identification of a serious loading impact from the Martin Village shopping center construction site, and identification of impacts associated with the Lacey storm drain discharge below Lake Lois.

Introduction

The new Department of Ecology (Ecology) Headquarters Building is located in Saint Martin's Park, Lacey (Figure 1). The building's eastern property line is located within 200 feet of Woodland Creek. Ecology's concern about protecting the creek during construction of the new building led the Watershed Assessments Section to conduct a study to monitor water quality.

Woodland Creek originates in the Long-Hicks-Pattison Lakes basin, flows north through residential, commercial, and agricultural areas, and eventually feeds into Henderson Inlet. Ecology has classified the stream as Class AA (Appendix A). Additionally, the City of Lacey has zoned the Woodland Creek drainage as an Environmentally Sensitive Area in recognition of the value and sensitivity of the resource (City of Lacey Zoning Ordinance, Chapter 16.54).

Ecology's water quality assessment focused on the portion of Woodland Creek adjacent to the new building site. The primary objective of this study was to assess water quality impacts from runoff resulting from construction activities. In-stream turbidity and total suspended solids (TSS) were the primary parameters chosen to monitor construction impacts.

This final report summarizes baseline data collected prior to construction (January 1991 - March 1992) and impact data collected during construction (April 1992 - July 1993).

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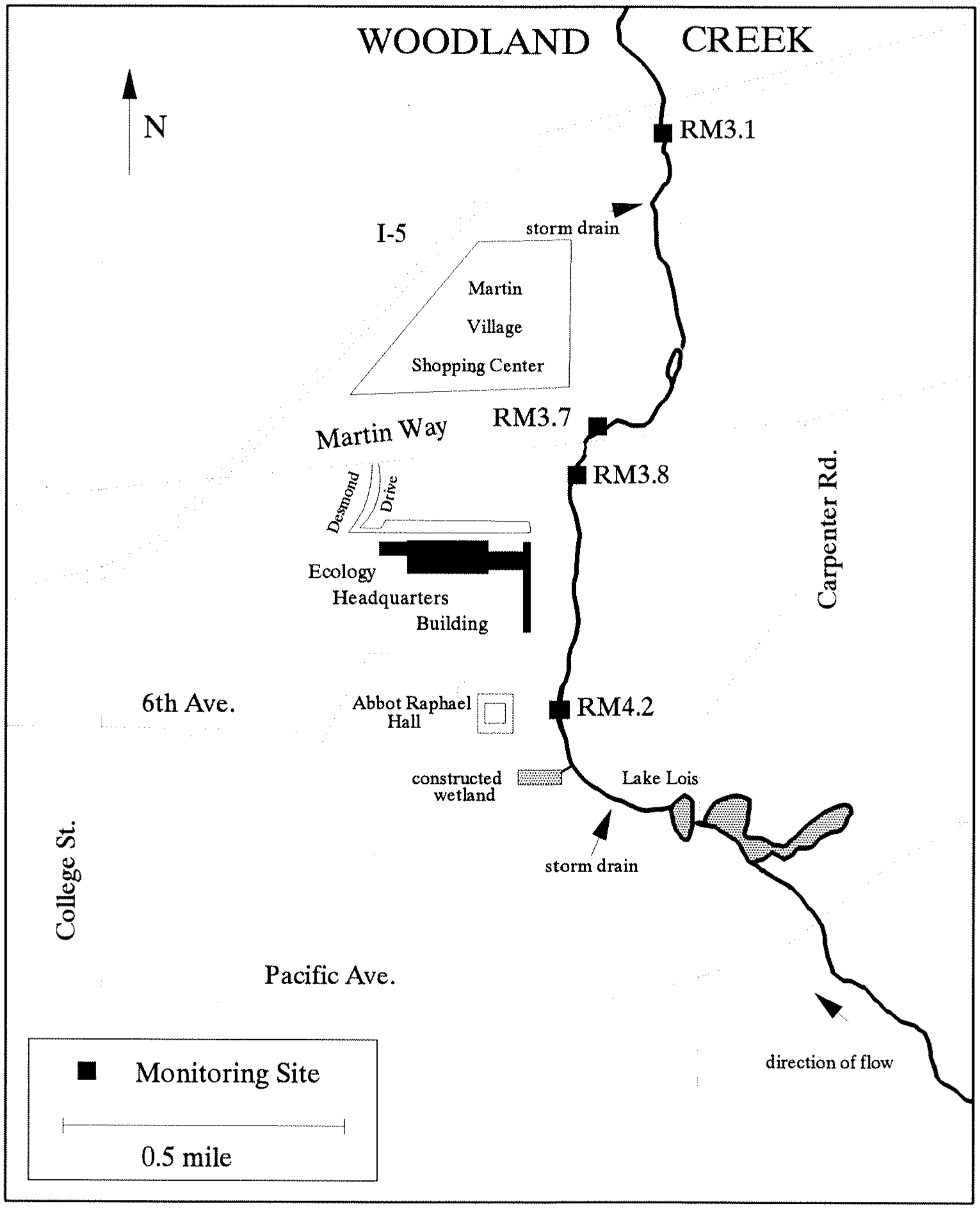

Figure 1. Monitoring sites for the Woodland Creek water quality assessment, January 1991 - September 1993.

Methods

Monitoring Sites

Four water quality monitoring sites were sampled on Woodland Creek from January 1991 - July 1993 (Figure 1). Sites at river mile (RM) 4.2 and RM 3.8 bracket the construction site. RM 4.2 is the upstream reference site. RM 3.8 is downstream of the construction area but upstream of Martin Way. RM 3.7, located just downstream of Martin Way, was monitored to help determine impacts from the construction of Desmond Drive, which was the new road designed to intersect with Martin Way. RM 3.1 is downstream from a large City of Lacey stormwater discharge. The site was originally chosen in the event that construction site runoff water was diverted into this stormwater drainage system. After monitoring began, it was determined that stormwater from the new building would be managed entirely on-site. Despite this change, monitoring at RM 3.1 was continued.

Sampling Strategy

The study design included two parts: 1) pre-construction baseline monitoring from January 1991 through March 1992; and 2) impact monitoring during construction activity from April 1992 through September 1993. The sampling strategy during the baseline phase included monthly water quality sampling, storm event sampling, a sediment survey, and two benthic macroinvertebrate surveys. During the impact phase, in addition to the above, the creek and construction site were visually inspected daily (twice daily during rain events).

Detailed sampling methods, QA/QC, and considerations in data analysis are summarized in Appendix B.

Results and Discussion

All data collected during the study are compiled in Appendices C through H. Data from RM 3.1 were analyzed separately and are described briefly at the end of this section.

Visual Observations

Sediment runoff was never observed entering the creek from the Ecology building construction site.

Precipitation and Discharge

Local rainfall has been below normal for the last two years (Figure 2) (Olympia Weather Station). As a result, the three upstream sites were dry for 11 of the 18 months of impact monitoring. Low rainfall has likely reduced groundwater recharge of the lakes that feed Woodland Creek. Increased development and impervious surfaces in Lacey may also be contributing to lower groundwater recharge.

Monthly Routine Monitoring

Appendix C contains all monthly routine data. These data are summarized in Table 1.

Between site comparisons

During both phases of the study, there were no statistically significant differences among the sites for turbidity, TSS, total phosphorus (TP), fecal coliform (FC), or discharge (Q). Maximum values for turbidity, TSS, and FC were higher at the downstream sites and lower at the upstream site during

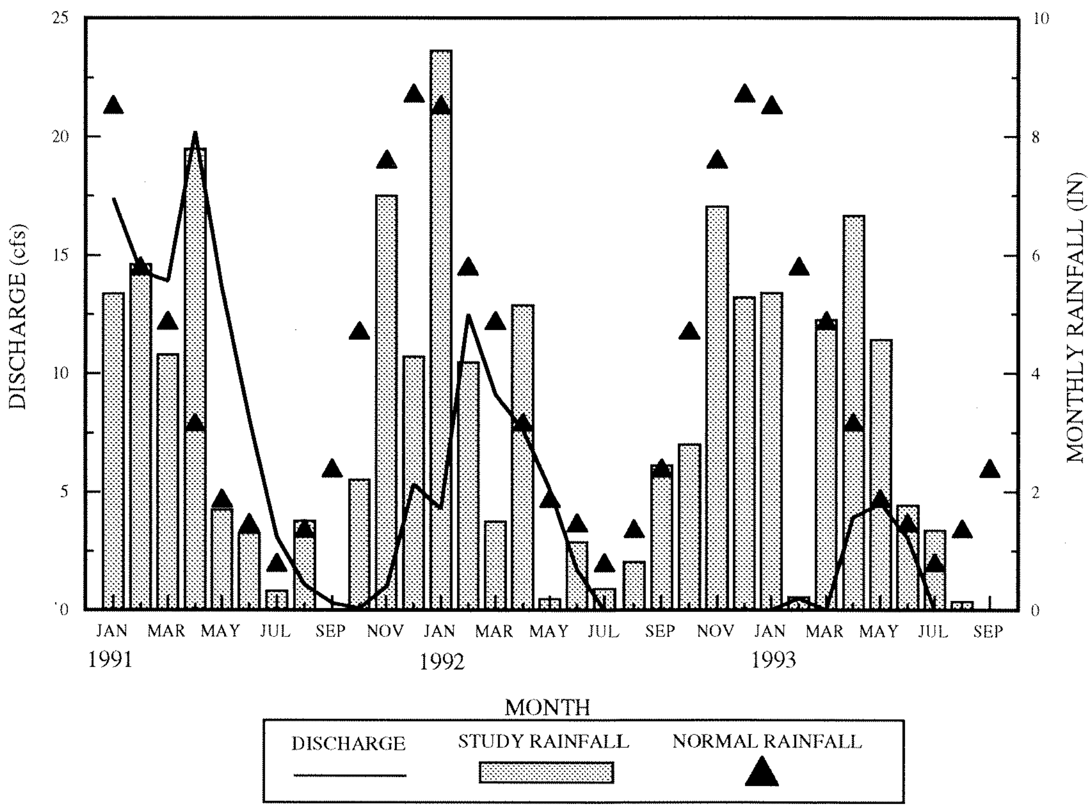

Figure 2. Woodland Creek discharge and rainfall, January 1991 - September 1993. Normal rainfall is average monthly rainfall for 1961-1990. Discharge is based on discharge measured monthly at RM 3.8.

Table 1. Woodland Creek summary statistics for monthly routine baseline and impact data, January 1991 - July 1993 (n = number of samples).

PARAMETER		SITE							
		RM 4.2		RM 3.8		RM 3.7		RM 3.1	
		Baseline	Impact	Baseline	Impact	Baseline	Impact	Baseline	Impact
TURBIDITY (NTU)									
	n	16	9	15	7	13	7	15	15
	min	0.5	0.4	0.8	0.5	0.8	0.6	0.9	0.5
	max	4.6	2.0	4.5	4.9	4.0	5.5	5.0	8.5
	mean	1.9	1.2	1.9	1.8	1.8	1.8	2.0	2.4
	median	2.0	1.2	1.9	1.2	1.9	1.2	1.9	1.5
TSS (mg/L)									
	n	16	9	15	7	13	7	15	15
	min	1	1	1	1	1	1	1	1
	max	20	5	6	9	7	18	10	14
	mean	4	3	3	5	4	5	4	5
	median	3	3	3	4	3	4	3	5
TP (mg/L)									
	n	12	9	12	7	12	7	12	15
	min	0.01	0.02	0.02	0.01	0.02	0.01	0.04	0.05
	max	0.15	0.05	0.16	0.04	0.15	0.05	0.13	0.13
	mean	0.04	0.03	0.05	0.03	0.05	0.03	0.07	0.09
	median	0.03	0.02	0.04	0.02	0.04	0.02	0.06	0.09
TEMP (°C)									
	n	15	9	14	7	12	7	14	15
	min	4.8	5.5	4.4	5.5	4.3	5.3	7.6	7.5
	max	22.1	19.6	21.1	18.4	20.4	18.1	13.3	12.3
	mean	11.7	13.3	11.3	13.2	11.9	13	10.2	10.3
	median	10.4	14.3	10.1	13.9	11.0	13.8	9.8	10.1
DISCHARGE (cfs)									
	n	16	8	15	7	12	7	14	15
	min	0.1	0.1	<.1	0.5	<.1	0.3	5.3	6.2
	max	27.2	8.3	20.2	7.6	24.1	7.3	43.9	17.5
	mean	8.5	3.5	8.3	3.8	7.4	3.5	19.4	10.4
	median	5.5	3.5	8.1	3.9	4.9	3.7	18.2	9.6
pH (S.U.)									
	n	15	9	14	7	12	7	14	15
	min	7.2	6.1	7.3	6.3	7.3	6.1	6.9	5.7
	max	7.8	7.9	8.0	7.7	8.0	7.9	7.5	7.9
	median	7.4	7.2	7.6	7.2	7.7	7.2	7.1	6.9
FC (cfu/100mL)									
	n	16	8	15	7	13	7	15	14
	min	4	1	7	1	5	1	2	6
	max	630	210	260	550	160	670	130	320
	G. mean	28	14	28	23	32	18	15	33
	median	26	16	28	18	27	13	14	26
D.O. (%saturation)									
	n	15	9	14	7	12	7	14	14
	min	78	56	91	92	90	91	62	57
	max	96	99	104	106	108	105	86	81
	mean	88	87	95	98	95	99	74	66
	median	88	91	94	97	94	98	74	65
D.O. (mg/L)									
	n	16	9	15	7	13	7	15	14
	min	7.2	7.1	8.6	8.8	8.7	8.8	7.0	6.4
	max	11.7	11.6	12.8	12.2	12.3	13.1	10.2	9.3
	mean	9.7	9.2	10.5	10.4	10.4	10.6	8.2	7.4
	median	9.5	9.3	10.6	9.9	10.3	10.2	8.1	7.4
COND (umhos/cm)									
	n	15	9	14	7	12	7	14	15
	min	88	96	95	82	80	88	80	108
	max	135	109	130	109	132	114	150	171
	mean	109	101	109	97	107	100	124	130
	median	110	100	110	98	108	99	125	131

impact monitoring. These maximum values all occurred on June 9, 1993. Concentrations were likely higher at downstream sites due to 0.5 inches of rain that fell between 2:00 a.m. and 10:00 a.m., shortly before samples were collected (10:25 at RM 3.7 and 11:05 at RM 3.8). Rainfall and runoff had subsided by the time samples were collected at RM 4.2 (12:00 p.m.), resulting in lower concentrations.

There were significant differences in temperature and dissolved oxygen (D.O.) between the upstream control site (RM 4.2) and downstream sites (Figure 3). Temperature was significantly higher at RM 4.2 than at the downstream sites during both phases of monitoring. The increase in temperature at the upstream site was most likely due to the sampling design which resulted in RM 4.2 being sampled latest in the day when air temperatures were higher. Dissolved oxygen concentrations and saturations at RM 4.2 were significantly lower than at the downstream sites, during both phases of the study. There was a significant negative linear relationship between D.O. concentrations and stream temperatures. As expected, when temperatures in the creek increased during the day, D.O. concentrations and saturations decreased.

During baseline monitoring, pH was consistently lower at RM 4.2. During impact monitoring, pH at RM 4.2 was consistently higher than the downstream sites (significant for RM 3.7 only). The magnitude of the pH differences between the sites was small, with only one difference greater than 0.5 standard units (S.U.). There were no significant or consistent relationships between pH and conductivity, temperature, discharge, or D.O. These differences, and the shift in the pH relationship between the sites from baseline to impact monitoring, can not be readily explained without more intensive monitoring. However, changes in pH are not believed to be related to construction of the Ecology building.

Baseline versus Impact data comparisons

Differences in water quality between baseline and impact monitoring were very difficult to explain because of the period of several months that the creek was dry. During impact monitoring, discharge never exceeded 10 cfs at any of the sites. Consequently, in comparing baseline and impact routine data, only baseline data with discharge values less than 10 cfs were used.

The only significant difference found between baseline and impact monitoring data was at RM 3.8 for conductivity. RM 3.8 conductivity was significantly lower during impact monitoring (mean 97 μmhos/cm) than during baseline monitoring (mean 112 μmhos/cm when $Q < 10$ cfs). Mean conductivity was also somewhat lower at RM 3.7 and RM 4.2 during impact monitoring, though not statistically significant. In addition, pH at all sites was lower during impact monitoring. We were unable to identify an environmental cause for these differences, but the nature of these changes is not consistent with impacts expected from construction activity. The conductivity and pH changes are probably natural, and may be related to the decreased precipitation trend.

State Water Quality Criteria

During both phases of the study, all sites met the Class AA criterion for turbidity, which limits turbidity increases to less than 5 nephelometric turbidity units (NTU) above background. Background turbidity was defined as the turbidity at RM 4.2, the upstream reference site.

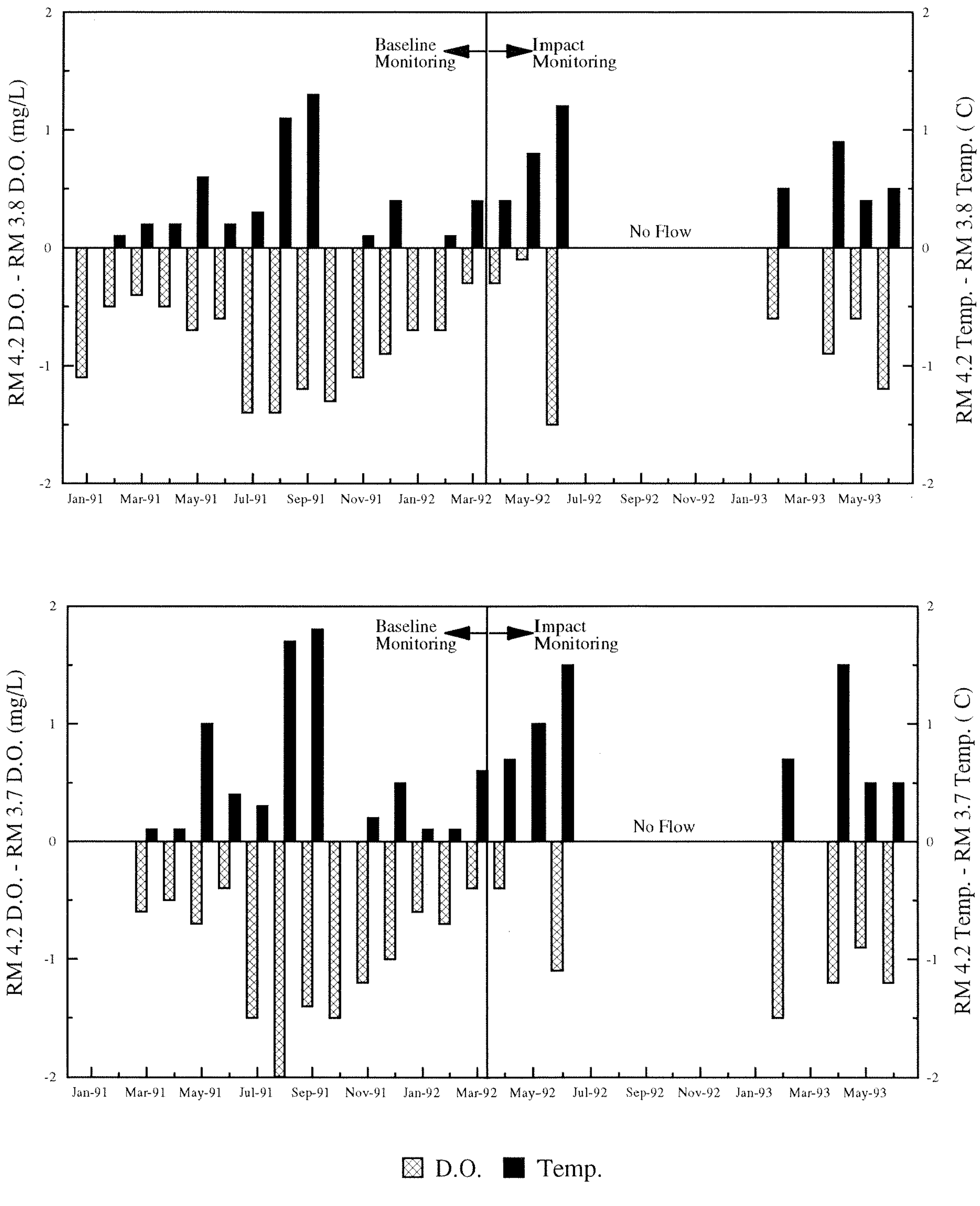

Figure 3. Differences in D.O. and temperature between RM 4.2 and the downstream sites.

The Class AA criterion for fecal coliform consists of two parts: 1) the geometric mean should not exceed 50 colony forming units (cfu) per 100 mL; and 2) not more than 10% of samples should exceed 100 cfu/100 mL. The first part of the criterion was met (Table 1). However, elevated levels during several months resulted in violations of the second part of the criterion at all three sites (Figure 4). Sources of bacteria may include septic system failures, wildlife, domestic animals, and the storm drain discharge below Lake Lois.

The Class AA criterion for temperature states that temperature should not exceed 16° C due to human activities. All sites exceeded 16° C several times during both phases of the study. These high values were likely due to solar warming and low flow conditions.

All sites fell below the dissolved oxygen Class AA standard of 9.5 mg/L several times during baseline and impact monitoring (Figure 5). As previously discussed, low D.O. concentrations are likely a result of warm stream temperatures.

During baseline monitoring, all sites were within the Class AA pH criterion range of 6.5 to 8.5 S.U. In April 1993, pH at all sites fell below 6.5 S.U. (Figure 5). Again, additional data would be necessary to explain the cause of this change.

Fish kills were observed in October 1991, March 1993, and July 1993 when portions of the creek went dry. The fish kills were due to low or no flow conditions and subsequent low D.O. As a result, characteristic uses (fish migration, spawning, and rearing) for Class AA waters were not met. The Washington State Department of Fisheries and Ecology's Southwest Regional Office (SWRO) were notified in each case.

Storm Event Monitoring

Baseline Storms

Baseline storm event data are contained in Appendices D and E. Baseline storm event data were evaluated by comparison to baseline routine data.

During storm events, both turbidity and TSS tended to increase. In November 1991, the first storm of the wet season, TSS concentrations were highest. Increases were likely caused by the storm drain discharge, bank erosion, surface runoff, and resuspension of bottom sediments. Sequential samples from storms on November 19-20, 1991, and January 28-29, 1992, indicated that TSS was generally higher downstream. During the January 1992 storm, TSS was significantly higher at the downstream sites than at RM 4.2. Increased TSS at the downstream sites may be due to additional erosion and resuspension of sediment between upstream and downstream sites. Visual inspections of the construction site did not reveal runoff of sediment to the creek.

D.O. concentrations generally increased at all sites during storm events. D.O. concentrations and saturation were significantly higher at the downstream sites. This increase was most likely a result of reaeration as the water moved downstream.

Fecal coliform levels also increased during storm events. Concentrations were highest at RM 4.2 (2,300 cfu/100 mL), RM 3.8 (1,950 cfu/100 mL), and RM 3.7 (260 cfu/100 mL) in November 1991. The storm drain that discharges into Woodland Creek just below Lake Lois was found to be a

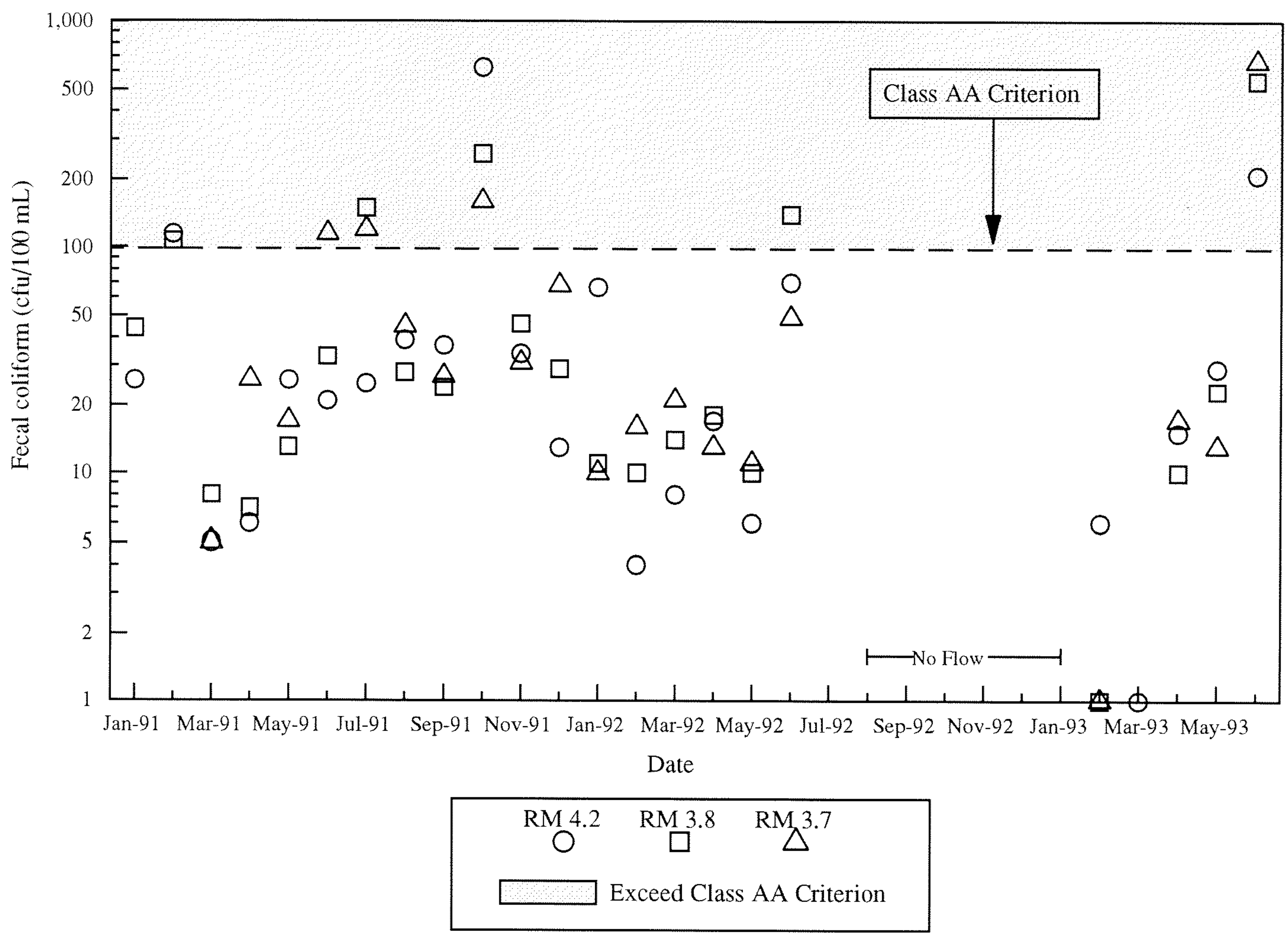

Figure 4. Fecal coliform concentrations compared to the second part of the Class AA criterion.

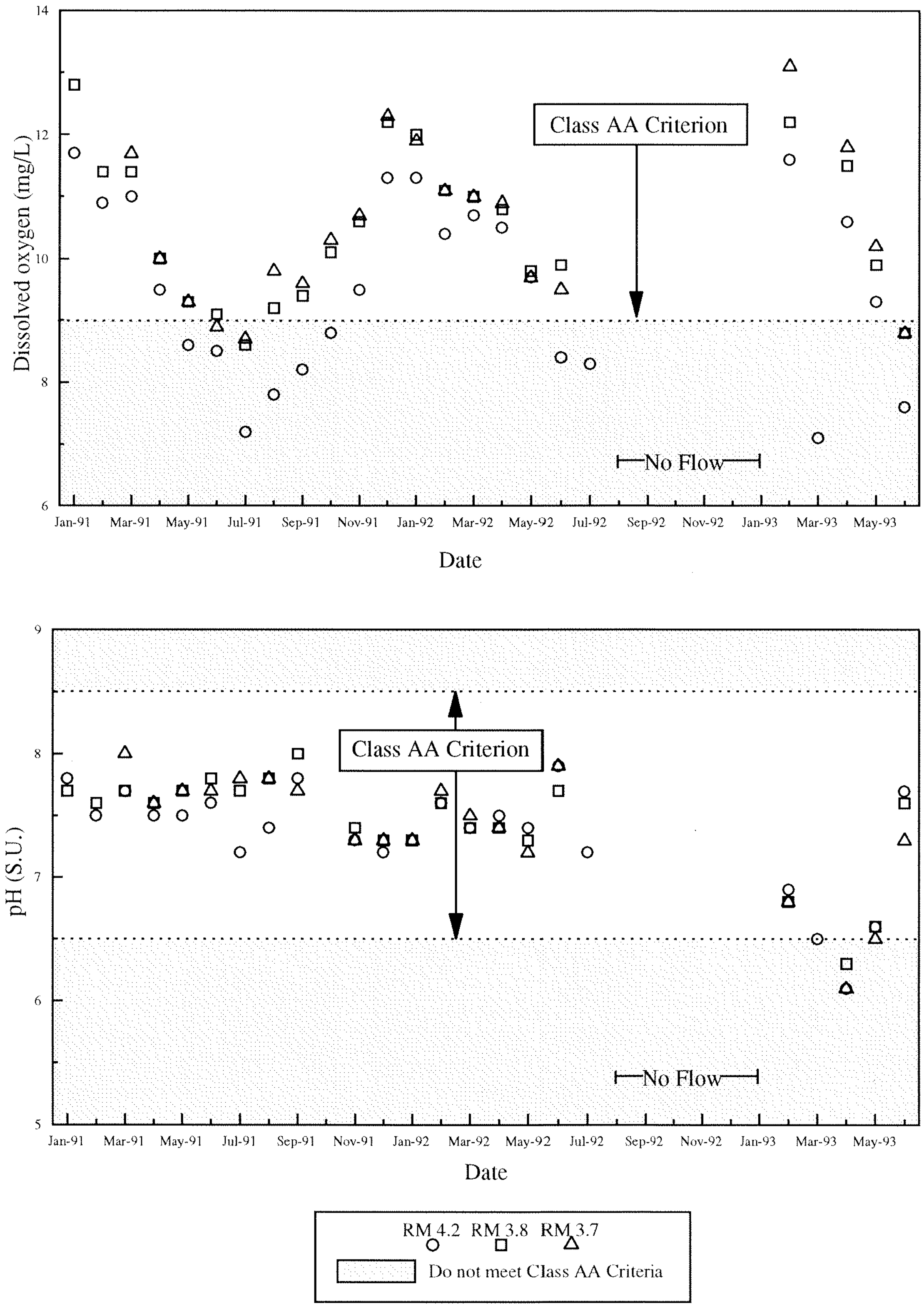

Figure 5. Dissolved oxygen and pH concentrations compared to Class AA criteria.

primary loading source (Appendix D). On the January 29, 1992 storm event, additional samples were taken above and below the storm drain. Results were 140 cfu/100 mL above the drain and 15,000 cfu/100 mL below the drain. These data were provided to the City of Lacey and Thurston County Department of Health for follow-up. Other sources of bacteria may include septic failures, surface runoff of wildlife and domestic animal waste, or bacteria in resuspended sediments.

Impact Storms

Storms during the impact monitoring period did not coincide with base-flow in the creek. During storm events, the storm drain below Lake Lois was the only visible source of water to the creek. Nonetheless, water quality samples were collected during these events (Appendix F). Data were not compared, however, to baseline storm event data.

On October 18, 1992, heavy rain caused a large volume of water to discharge from the storm drain below Lake Lois. Turbidity and TSS concentrations were slightly elevated at the three upstream sites. There was no runoff from the Ecology building construction site to the creek. Heavy rain on November 21, 1992, produced a similar situation. Turbidity concentrations were elevated in the morning (21 NTU - 81 NTU) and decreased by afternoon as the rain subsided (12 NTU).

To document our visual observations that the storm drain was the source of elevated turbidity and TSS concentrations, samples were taken below the storm drain on subsequent rain events. During three separate rain events in January 1993, turbidity and/or TSS concentrations directly below the storm drain were very high. Mean turbidity for the three events was 132 mg/L and mean TSS was 425 mg/L.

During a heavy rain event on March 22, 1993, sheets of sediment-laden water were observed running off Desmond Drive. Turbidity and TSS samples taken from runoff at the base of Desmond Drive were 900 NTU and 1,320 mg/L, and samples taken directly above a newly installed stormwater vault on Martin Way were 2,500 NTU and 5,300 mg/L. The runoff did not reach Woodland Creek but entered the stormwater vault. The construction company and Ecology's Southwest Regional Office (SWRO) were notified. Improved best management practices (BMPs) were implemented to remedy this situation.

Sediment Analysis

In August 1991, sediment at all sites was primarily gravel and sand (Figure 6). In July 1993, RM 4.2 appeared to have shifted to equal parts of gravel/sand and silt. The increase in silt may be due to deposition from turbid water entering the creek from the storm drain.

Sediment samples were analyzed for organic compounds and metals. Table 2 summarizes the data. All sediment data were compared to Ontario freshwater sediment criteria (Persaud, 1992), which define severe effect levels that would be detrimental to a majority (95%) of benthic species. None of the sites during either phase of the study exceeded the severe-effect level for polycyclic aromatic hydrocarbons (PAH). Chromium and nickel concentrations exceeded the severe-effect levels in the RM 3.7 baseline replicate sample. These higher levels may be due to variable distribution of metals in the depositional area at RM 3.7. The source of these metals may be direct runoff from Martin Way.

Table 2. Summary of sediment sampling results on Woodland Creek, August 22, 1991 and July 7, 1993.

PARAMETER	SITE								CRITERIA
	RM 4.2			RM 3.8		RM 3.7			
	Baseline	Impact	Impact Rep	Baseline	Impact	Baseline	Baseline Rep	Impact	(Persaud et al, 1992)
CONVENTIONALS									
Grain Size (%)									
Gravel (2 mm)	1	1	3	0	17	1	12	1	-
Sand (2mm-62um)	87	51	45	91	65	74	84	77	-
Silt (62um-4um)	10	38	42	9	12	21	4	16	-
Clay (<4 um)	2	11	10	0	5	4	0	6	-
Total Organic Carbon (%)	4.0	11.6	11.9	1.2	4.2	3.9	3.5	4.3	-
Solids (%)	44	27	25	36	53	23	60	55	-
METALS (mg/kg dry)									
Cadmium	0.83 P	0.62 P	0.8 P	0.65 P	0.28 P	0.75 P	0.95	0.2 U	10
Chromium	86.5	27.1	28.8	53.7	19.9	52.1	**116**	21.6	110
Copper	26.6	42.6	46.3	25.3	20.7	20.6	20.1	20.7	110
Lead	94.5	112	112	25.1	33.9	29.5	17.3	41.1	250
Nickel	72.2 J	24.4 J	26.9	55.3 J	21.4	56.9 J	**149**	22.7 J	75
Zinc	120	165	180	69.6	79.7	71.8	60.1	90	820
POLYCYCLIC AROMATIC HYDROCARBONS (PAH) (ug/kg)									
LOW MOLECULAR WEIGHT PAH									
Acenaphthene	85 J	1100 U	1100 U	350 U	1100 U	350 U	350 U	1100 U	-
Phenanthrene	1,200	470 J	610 J	63 J	110 J	150 J	38 J	83 J	-
Flourene	97 J	1100 U	1100 U	350 U	1100 U	350 U	350 U	1100 U	-
Naphthalene	56 J	1100 U	1100 U	350 U	1100 U	350 U	350 U	1100 U	-
2-Methylnaphthalene	38 J	1100 U	1100 U	350 U	1100 U	350 U	350 U	1100 U	-
Anthracene	150 J	1100 U	1100 U	200 U	1100 U	25 J	7 J	1100 U	-
TOTAL LPAH	1,600 J	470 J	610 J	63 J	110 J	175 J	45 J	83 J	-
HIGH MOLECULAR WEIGHT PAH									
Benzo (a) pyrene	560 J	1100 U	480	350 U	77 J	350 U	350 U	80 J	-
Benzo (a) anthracene	740 J	510 J	510 J	350 U	110 J	350 U	350 U	100 J	-
Pyrene	2,500	870 J	940	78 J	180 J	270 J	65 J	160 J	-
Benzo (ghi) perylene	570 J	1100 U	1100 U	670 U	1100 U	100 J	670 U	1100 U	-
Benzo (b) fluoranthene	1,200	1100 U	1100 U	670 U	180 J	180 J	670 U	190 J	-
Fluoranthene	2,000	1250	1500	74 J	250 J	260 J	51 J	230 J	-
Chrysene	890	635 J	760 J	350 U	130 J	350 U	350 U	140 J	-
Indeno(1,2,3-c,d)pyrene	350 U	1100 U	400 J	350 U	69 J	350 U	350 U	1100 U	-
TOTAL HPAH	8,500 J	3,265 J	4,590 J	152 J	927 J	810 J	116 J	900 J	-
TOTAL PAH DECTECTED (ug/kg)	10,000 J	3,160 J	5,200 J	215 J	1,037 J	985 J	161 J	983 J	-
NORMALIZED TO %TOC	250,000	27,241	43,697	18,000	24,690	25,000	4,600	22,860	1,000,000
OTHER PAH									
1-Methylnaphthalene	35 J	-	-	350 U	-	350 U	350 U	-	-
Carbazole	190 J	1100 U	1100 U	1800 U	1100 U	1800 U	1800 U	1100 U	-
Phthalate Acid Esters (ug/kg)									
Butylbenzylphthalate	350 U	310 J	380	350 U	91 J	350 U	350 U	-	-
bis(2-ethylhexyl)phthalate	400 U	3300	2600	400 U	470 J	400 U	400 U	650	-

- = No value.

U = The analyte was not detected at or above the reported result.

P = Concentration above instrument detection limit but below established minimum quantitation limit

J = Estimated concentration

▭ - Exceeds severe effect level for freshwater sediment criteria (Persaud et al., 1992)

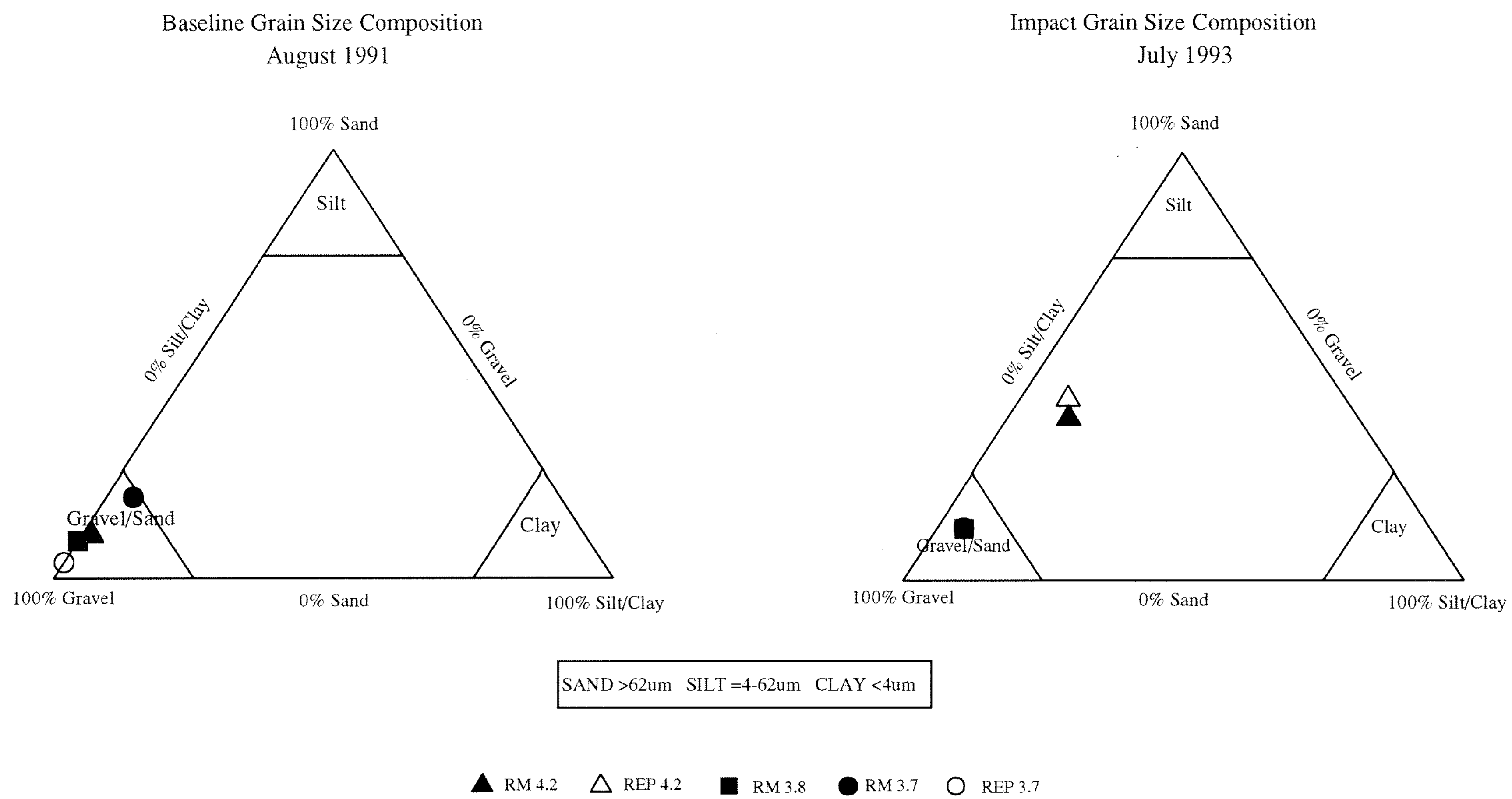

Figure 6. Grain size composition of sediment collected at three Woodland Creek sites on August 22, 1991 and July 7, 1993.

In general, baseline and impact sediment at RM 4.2 had higher levels of organics and metals than the downstream sites. The source of these contaminants was most likely the storm drain below Lake Lois. Slightly lower organics in the 1993 RM 4.2 sample may be a reflection of the June 1991 diversion of 85% of the stormwater discharge through a constructed wetland (see Figure 1).

At all sites, chromium and nickel concentrations decreased by an order of magnitude between baseline and impact monitoring. These changes may also be partially attributed to the 1991 diversion of stormwater, lower precipitation, and runoff during impact monitoring.

Macroinvertebrate and Habitat Analysis

Benthic macroinvertebrate species found in Woodland Creek are listed in Appendix G. Habitat data are in Appendix H.

The benthic macroinvertebrate (aquatic insect) community and habitat of Woodland Creek were not impacted by construction activities. However, the macroinvertebrate community was less diverse than what is expected in relatively unimpacted, perennial Puget Sound reference streams (Plotnikoff, 1992). The predominant species collected in Woodland Creek function as "collector-gatherers," which are organisms that consume dead organic material.

Table 3 provides a comparison of species richness at each site to a Puget Sound reference score (Plotnikoff, 1992). Species richness (the number of different species) is an indication of the variety of habitat available to macroinvertebrates. This parameter is influenced by in-stream habitat alteration or natural disturbances (*e.g.*, a flood). Intermittent flow is likely the dominant function depressing species richness in Woodland Creek compared to the Puget Sound reference. In general, RM 4.2 had a higher number of species than the downstream sites. This may be due to slightly higher and consistent flows at RM 4.2, contributed in part by the proximity to Lake Lois and the Lacey storm drain described earlier.

Table 3. Species richness of macroinvertebrates in Woodland Creek.

Date	RM 4.2	RM 3.8	RM 3.7	Reference Range (Median)
Baseline				
Sep-91	13	11	10	24-35 (30)
Dec-91	13	6	7	7-31 (21)
Impact				
May-92	12	10	15	9-28 (21)
May-93	8	11	8	9-28 (21)

The macroinvertebrate species present in Woodland Creek were primarily identified as species tolerant of pollution. Table 4 reports low EPT Index scores in comparison to Puget Sound reference streams (Plotnikoff, 1992). The EPT Index represents the number of pollution intolerant species from the orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Trichoptera (caddisflies) (Plafkin, *et al.*, 1989). Differences between baseline and impact surveys are most likely reflecting seasonal differences. Macroinvertebrates are strongly influenced by flow and seasonal conditions. There were fewer pollution intolerant species at RM 4.2 than at the downstream sites during each of the two impact surveys. Although slightly higher and consistent flows contributed to higher species richness at RM 4.2, the impacts from the storm drain probably limited the number of pollution intolerant species.

Table 4. EPT Index for Woodland Creek.

Date	RM 4.2	RM 3.8	RM 3.7	Reference Range (Median)
Baseline				
Sep-91	3	3	1	14-20 (18)
Dec-91	0	1	0	1-17 (12)
Impact				
May-92	2	5	6	13-16 (14)
May-93	0	3	3	13-16 (14)

Data from RM 3.1

RM 3.1 is located just upstream of the culverts that pass Woodland Creek under Interstate-5 (Figure 1). This site is influenced by loading sources from the Nisqually Trout Farm, a large stormwater discharge from the City of Lacey, a storm drain from the Tanglewilde residential development, a wetland area to the southwest, and the newly constructed Martin Village shopping center. As a result, water quality at this site was much different than the three sites monitored upstream (Table 1). In comparison, temperatures were cooler during the summer and warmer during the winter months, and discharge was consistently higher. Generally, conductivity, TSS, turbidity, and TP levels were higher at RM 3.1, and D.O. concentrations and saturation were lower than those found farther upstream.

During storm events, grab samples were taken at this site. In November 1991, extremely turbid water was found at RM 3.1 and reported to Ecology's spill team and the City of Lacey. Follow-up investigations led to the identification and remediation of failing sediment retention facilities at the Martin Village construction site, located near the creek between RM 3.7 and RM 3.1.

Conclusions

- The primary objective of this study was to assess water quality impacts from runoff resulting from construction activities. Water quality monitoring results and visual inspections of Woodland Creek before, during, and after construction of the new Ecology Headquarters Building demonstrated that the construction project did not adversely impact the creek. Water quality impacts from construction activities were minimized by below-normal rainfall during the impact monitoring phase, a 200-foot forested buffer between the construction site and creek, and the use of sediment best management practices.

- The Lacey storm drain (below Lake Lois and upstream of RM 4.2) was a primary loading source to Woodland Creek. Discharge from the storm drain likely contributed to the observed Class AA fecal coliform exceedances and increased turbidity and TSS during storm events. Higher metals and organics in sediment at RM 4.2 were also likely a result of this site's proximity to the storm drain. Benthic macroinvertebrates at RM 4.2 also consisted largely of pollution tolerant species.

- Intermittent and low flows were the primary reason for water quality occasionally not meeting Class AA criteria for temperature, dissolved oxygen, pH, and characteristic uses (fish migration, spawning, and rearing). Variable flow may also have contributed to differences in pH and conductivity between baseline and impact monitoring. It was beyond the scope of our study, however, to identify the extent to which flow changes were natural or human-induced.

- In addition to our finding that construction of the Ecology building did not affect Woodland Creek, the monitoring project resulted in improved sediment BMPs at the construction site, identification of a serious sediment loading impact from the Martin Village construction site, and identification of impacts associated with the Lacey storm drain discharge below Lake Lois.

Acknowledgements

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References

APHA *et al.*, (American Public Health Association, American Water Works Association and Water Pollution Control Federation), 1989. Standard Methods for the Examination of water and Wastewater, 16th ed. Washington, D.C.

EPA (U.S. Environmental Protection Agency), 1983. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020. Environmental Monitoring Supply Laboratory, Cincinnati, OH.

Huntamer, D, 1986. Laboratory User's Manual. Washington State Department of Ecology, Manchester, WA.

Michaud, J, 1989. Guidance for Conducting Water Quality Assessments. Washington State Department of Ecology, Olympia, WA.

Olympia Weather Station. Preliminary Local Climatological Data, January 1991 - September 1993. Unpublished data.

Persaud, D., R. Jaagumagi, and A. Hayton, 1992. Guidelines for the Protection and Management of Aquatic Sediment Quality in Ontario. Water Resources Branch, Ontario Ministry of the Environment, Toronto, Ontario.

Plafkin, J.L., M.T. Barbour, K.D. Porter, S.K. Gross, and R.M. Hughes, 1989. Rapid Bioassessment Protocols for use in Streams and Rivers: Benthic Macroinvertebrates and Fish. EPA Assessment and Watershed Protection Division.

Plotnikoff, R.W., 1992. Timber/Fish/Wildlife Ecoregion Bioassessment Pilot Project. Washington State Department of Ecology, Olympia, WA.

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Appendix A. Class AA (extraordinary) freshwater quality standards and characteristic uses (WAC 173-201-045).

General Characteristics:	Shall markedly and uniformly exceed the requirements for all, or substantially all uses.
Characteristic Uses:	Shall include, but not be limited to, the following: domestic, industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.
<u>Water Quality Criteria</u> Fecal Coliform:	Shall both not exceed a geometric mean value of 50 organisms/100 mL and not have more than 10% of samples exceeding 100 organisms/100 mL.
Dissolved Oxygen:	Shall exceed 9.5 mg/L.
Total Dissolved Gas:	Shall not exceed 110% saturation.
Temperature:	Shall not exceed 16.0°C due to human activities. When natural conditions exceed 16°C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3°C. Increases from nonpoint sources shall not exceed 2.8°C with a maximum of 16.3°C.
pH:	Shall be within the range of 6.5 to 8.5 with a human-caused variation within a range of less than 0.2 units.
Turbidity:	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the background turbidity is more than 50 NTU.
Toxic, Radioactive, or Deleterious Material:	Shall be below concentrations which may adversely affect characteristic water uses, cause acute or chronic conditions to aquatic biota, or adversely affect public health.
Aesthetic Values:	Shall not be impaired by the presence of materials or their effects, excluding those of natural origin, which offend the senses of sight, smell, touch, or taste.

Appendix B. Sampling methods, QA/QC, and considerations in data analysis.

Sampling Methods

Routine Water Quality Sampling
Mid-stream grab samples were collected monthly at each site. Samples were collected from downstream to upstream to prevent sample contamination. Temperature, pH, conductivity, and discharge were also measured at each site. Samples for dissolved oxygen were collected, preserved, and analyzed at Ecology's field laboratory in Tumwater. Samples for turbidity, total suspended solids, total phosphorus, and fecal coliform were preserved and shipped within 24 hours to the EPA/Ecology Laboratory in Manchester. Sample containers, processing, and analysis conformed to procedures described by EPA (1983), Huntamer (1986), and APHA *et al.* (1989).

Storm Event Water Quality Sampling
Storm events were loosely defined as approximately 1 inch of rain in 24 hours. During each storm event, automated sequential samplers collected one sample every hour for a 24-hour period at each site. Samples were analyzed for TSS and conductivity. Additionally, at the beginning and end of each storm, grab samples were collected following methods similar to those used for the routine monthly sampling events.

Three baseline storm events were monitored in April and November 1991, and January 1992 in order to obtain information on pre-construction runoff effects on sediment transport. During the April 1991 storm event only field measurements were taken because there was less rain than anticipated. During impact monitoring, the creek was not flowing during storm events, except for periodic heavy discharge from the storm drain below Lake Lois. As a result, storm event sampling during impact monitoring was limited to grab samples.

Daily Monitoring
During the impact phase of the study, the creek and construction site were visually inspected daily, and twice daily during rain events. Water quality samples were collected when the water appeared turbid. The perimeter of the site was walked to identify potential problems with sediment best management practices (e.g., uncovered sediment piles, damaged silt fences). When problems were identified, the Mortenson construction company and Ecology's Southwest Regional Office were notified accordingly.

Sediment Sampling
Sediment samples were collected in August 1991 and July 1993 from depositional areas near each of the four monitoring sites. Sampling methods followed Michaud (1991). Base-neutral-acid extractable compounds and metals were parameters of concern. Grain size, total organic carbon, and percent solids were also measured to aid in data interpretation.

Macroinvertebrate Sampling and Habitat Assessment
Macroinvertebrates were collected and preserved and habitat assessments were completed in May, September, and December 1991 to characterize baseline conditions, and May 1992 and May 1993 to characterize conditions during construction. Samples were collected from a riffle and a run in a 100-meter reach using a 1-square meter kick net. Methods for habitat assessment and macroinvertebrate collection were based on rapid bioassessment techniques (Plafkin, *et al.*, 1989). All samples were sub-sampled according to methods described by Plotnikoff (1992).

QA/QC

Routine Water Quality Sampling

A randomly selected replicate sample was taken at one of the four sites to assess field and analytical variability during each routine monitoring event. The average of the replicate samples was used in subsequent calculations. Replicate pairs were compared by determining the relative percent difference (RPD), which is the difference between the two replicates expressed as a percentage of their mean. The results are illustrated in Figure B1 using box plots. All values were considered acceptable. The variability in FC most likely resulted from the natural patchiness of bacteria. High RPDs for TSS were determined to be of little consequence because as replicates approach the detection limit, the RPD becomes artificially high (e.g., replicate values of 1 and 2 mg/L yield a RPD of 67%).

Replicate conductivity samples were taken at each site from March - June 1991, and September - October 1991 to compare data from our field meter to data from the Manchester Lab. The RPD for the lab and field data was generally less than 10%, so lab conductivity measurements were discontinued and only field conductivity data were collected and analyzed.

Replicate turbidity samples were taken at each site to compare data from a field turbidimeter to data from the Manchester Lab. We determined that the inconsistent comparisons at higher turbidity levels were due to the differences in the field and lab turbidity meters. We decided to discontinue use of the field turbidity meter and rely on lab turbidity data only. Field turbidity data were excluded from further data analysis.

Flow was measured using a Swoffer® current meter during the first 12 months of baseline monitoring. At RM 3.1, in-stream vegetation interfered with the Swoffer meter. In January 1992, flow was measured with both Swoffer and Marsh McBirney® meters to determine if there were any differences between the two. Differences ranged from 0.05 to 1.39 cfs, which was comparable to the field variability observed between replicate measurements using only the Swoffer. Consequently, the Marsh McBirney meter was used for the remainder of the study in order to remedy the potential interference of in-stream vegetation.

Storm Event Water Quality Sampling

Grab samples taken before and after storm events followed the same QA/QC methods as those for routine monitoring.

Sample bottles for the ISCO® sequential sampler were washed three times with a non-phosphate detergent, rinsed three times with deionized water, and then air dried. One split sample (duplicate) was taken randomly from each sampler to help assess lab variability. RPDs for TSS and turbidity were generally less than 15%.

Sediment Sampling

Equipment for sediment sampling was cleaned according to procedures in Michaud (1991). In August 1991 a replicate sample was taken at RM 3.7 to assess combined field and lab variability. The replicate sample was collected separately from an undisturbed section of the depositional area. Variability was very high with RPDs as high as 134%. Higher levels in the replicate sample may be due to variable distribution of metals in the depositional area at RM 3.7. In July 1993 the replicate sample was taken at RM 4.2. A duplicate sample, sub-sampled from the first sample collected at RM 4.2, was taken to assess field sampling variability. RPDs for the replicate sample were 90% or less which once again was likely due to variable distribution of metals in the depositional area. RPDs for the duplicate sample were less than 12%, which indicates that lab variability was less than field variability.

Macroinvertebrate Sampling and Habitat Assessments

Replicate macroinvertebrate samples were collected at each site during the baseline phase. Plotnikoff (1992) determined that the differences in total number of species and species richness between replicate samples were very low. As a result, only one baseline sample was sub-sampled from each site. During impact monitoring, only one sample was collected at each site.

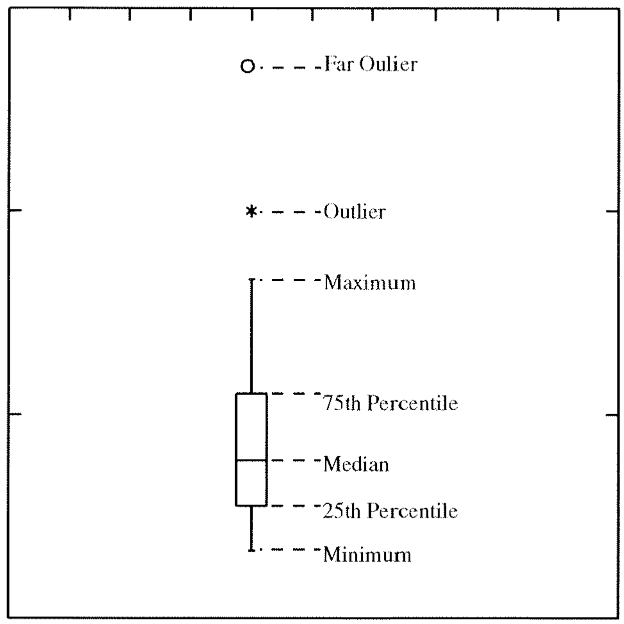
Habitat assessments were conducted in duplicate by two evaluators and the two scores were averaged. RPDs for the two scores ranged from 0-50%. The high variability was likely due to the subjectivity of the method.

Considerations in Data Analysis

Routine data are defined as data collected monthly during baseline and impact monitoring. During the baseline period, samples were collected at all sites each month. During the impact phase, the creek was dry for 11 of the 18 months of sampling. In July 1992, the creek was dry from below Lake Lois to the springs above RM 3.1. Thus, RM 3.1 was the only site with water. The level of Lake Lois did not rise enough to feed the creek continuously until the end of March 1993. By July 1993, the level of Lake Lois receded and the creek went dry again.

In order to compare upstream and downstream sites, the nonparametric Wilcoxon signed-rank test was used for all parameters. For comparisons between baseline and impact data, a parametric independent t-test was used on temperature, D.O. concentrations and saturations, and conductivity data; and on log transformed turbidity, TSS, FC, and discharge data. The nonparametric Mann-Whitney test was used for TP and pH since these parameters did not approximate a normal distribution. Differences were deemed significant at $p < 0.05$.

EXAMPLE



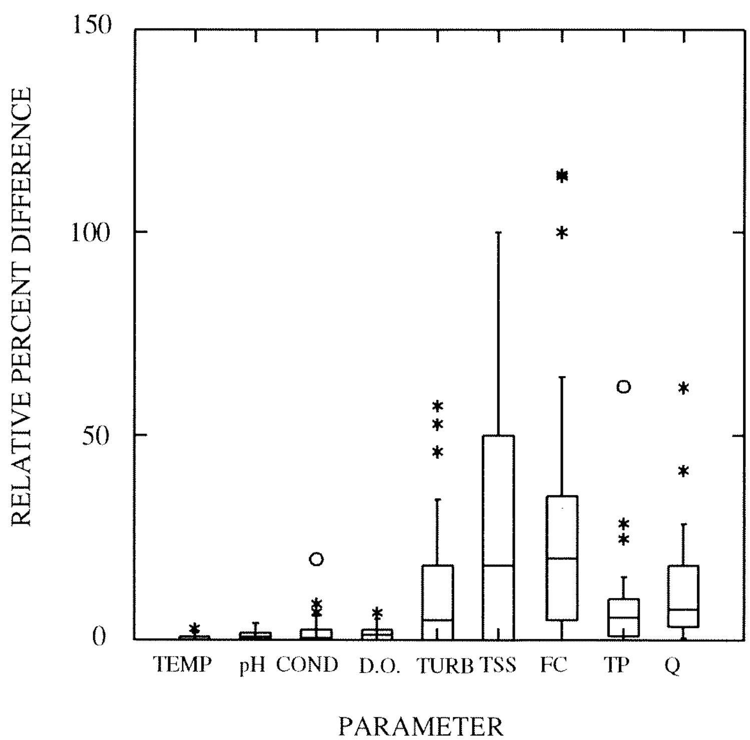


Figure B1. Relative percent difference of replicates for each parameter sampled monthly on Woodland Creek, January 1991 - July 1993.

Appendix C. Woodland Creek monthly routine data, January 1992 - July 1993.

Date	Site	Lab#	Time	Temp. (°C)	pH (S.U.)	Cond. (µmhos/cm)	D.O. (mg/L)	D.O. (%sat)	Turb. (NTU)	TSS (mg/L)	FC (cfu/100mL)	TP (mg/L)	Discharge (cfs)
16-Jan-91	4.2 R	38040	1550	6.4	7.8	105	11.7	95	4.7 J	6	11	-	15.0
16-Jan-91	4.2 R	38044	1550	6.4	7.7	105	11.7	95	4.5	5	40	-	16.4
16-Jan-91	3.8 R	38042	1205	6.4	7.8	110	12.8	104	4.7 J	6	37	-	13.8
16-Jan-91	3.8 R	38046	1205	6.4	7.7	110	12.8	104	4.2 J	6	51	-	21.0
16-Jan-91	3.1	38043	1040	7.9	7.4	80	10.2	86	3.0 J	4	14	-	32.0
13-Feb-91	4.2 R	78075	1240	7.9	7.4	110	10.8	91	2.5	5	100	-	15.6
13-Feb-91	4.2 R	78074	1300	7.8	7.6	112	11.0	92	2.4	5	120	-	16.7
13-Feb-91	3.8 R	78072	1020	7.7	7.6	112	11.5	96	2.7	5	84	-	16.0
13-Feb-91	3.8 R	78076	1100	7.7	7.6	112	11.3	94	2.7	5	130	-	12.6
13-Feb-91	3.1	78073	900	8.9	7.3	125	9.0	77	3.5	6	130	-	27.7
13-Mar-91	4.2 R	118040	1300	7.4	7.7	110	10.9	90	2.3	1	5	0.01	-
13-Mar-91	4.2 R	118041	1330	7.5	7.7	110	11.0	91	2.3	2	5	0.01	10.8
13-Mar-91	3.8 R	118042	1200	7.2	7.7	110	-	-	2.5	3	7	0.02	15.1
13-Mar-91	3.8 R	118043	1230	7.2	7.7	110	11.4	94	3.5	2	8	0.02	12.6
13-Mar-91	3.7 R	118044	1100	7.4	8.0	110	11.8	98	2.0	3	4	0.02	12.2
13-Mar-91	3.7 R	118045	1130	7.2	7.9	110	11.5	95	2.1	2	6	0.02	10.8
13-Mar-91	3.1	118046	1000	8.2	7.5	130	9.8	83	2.7	3	3	0.04	22.4
17-Apr-91	4.2 R	168025	1430	12.1	7.4	95	9.4	87	1.5	3	9	0.02 J	26.7
17-Apr-91	4.2 R	168026	1440	12.1	7.5	96	9.6	89	1.8	4	3	0.02 J	27.6
17-Apr-91	3.8 R	168023	1300	11.9	7.6	97	10.0	92	1.9	6	3	0.02 J	22.1
17-Apr-91	3.8 R	168024	1315	11.9	7.6	98	9.9	91	1.9	5	11	0.02 J	18.4
17-Apr-91	3.7	168022	1200	12.0	7.6	96	10.0	92	2.0	7	26	0.02 J	26.0
17-Apr-91	3.1 R	168020	1030	11.4	7.2	110	8.6	79	1.4	5	6	0.04 J	43.9
17-Apr-91	3.1 R	168021	1045	11.3	7.1	110	8.6	78	1.6	5	6	0.04 J	-
15-May-91	4.2 R	208033	1115	15.0	7.5	112	8.5	84	3.0	3	26 J	0.02	14.2
15-May-91	4.2 R	208036	1130	15.0	7.5	112	8.7	86	-	-	-	-	13.1
15-May-91	3.8 R	208032	1020	14.4	7.7	112	9.3	91	2.1	4	9 J	0.03	12.1
15-May-91	3.8 R	208035	1030	14.4	7.7	110	-	-	2.0	3	17 J	0.02	15.0
15-May-91	3.7 R	208031	940	14.0	7.7	115	-	-	1.9	3	14 J	0.02	15.7
15-May-91	3.7 R	208034	950	14.1	7.7	110	9.3	90	1.9	5	20 J	0.02	15.6
15-May-91	3.1	208030	900	12.0	7.1	132	7.9	73	1.2	3	14 J	0.04	28.0
12-Jun-91	4.2 R	248045	1500	17.1	7.5	120	8.4	87	1.4	2	20	0.04 U	8.8
12-Jun-91	4.2 R	248046	1505	16.9	7.6	115	8.6	88	1.1	2	21	0.04 U	-
12-Jun-91	3.8 R	248043	1340	16.8	7.8	115	9.1	93	1.2	3	38	0.04 U	8.4
12-Jun-91	3.8 R	248044	1345	16.9	7.8	115	9.1	94	1.4	3	28	0.04 U	7.9
12-Jun-91	3.7 R	248041	1230	16.6	7.7	125	8.9	91	1.9	3	120	0.04 U	8.9
12-Jun-91	3.7 R	248042	1235	16.6	7.7	125	8.9	91	2.1	4	110	0.04 U	8.7
12-Jun-91	3.1	248040	1100	13.1	7.0	138	8.1	77	1.1	2	32	0.04 U	20.0
17-Jul-91	4.2 R	298043	1313	19.3	7.2	125	7.2	78	0.6	1	25	0.16	3.2
17-Jul-91	4.2 R	298044	1328	19.3	7.2	122	7.2	78	0.4	1	24	0.14	2.8
17-Jul-91	3.8	298042	1236	19.0	7.7	122	8.6	92	1.0	3	150	0.16	3.1
17-Jul-91	3.7	298041	1211	19.0	7.8	122	8.7	93	1.6	7	120	0.11	3.1
17-Jul-91	3.1	298040	1100	13.3	7.1	145	7.4	71	1.4	2	71	0.13	12.5
21-Aug-91	4.2	348050	1240	22.1	7.4	130	7.8	89	1.0	2	39 X	0.03	1.4
21-Aug-91	3.8 R	348051	1145	21.0	7.7	129	9.2	103	0.7	2	37 X	0.04	1.2
21-Aug-91	3.8 R	348052	1200	21.1	7.8	130	9.1	102	0.9	3	19 X	0.04	1.1
21-Aug-91	3.7	348053	1100	20.4	7.8	132	9.8	108	0.8	2	45 X	0.04	1.2
21-Aug-91	3.1	348054	1000	12.3	6.9	150	7.0	65	0.9	1	26	0.07	11.0

Appendix C. Continued.

Date	Site	Lab#	Time	Temp. (°C)	pH (S.U.)	Cond. (µmhos/cm)	D.O. (mg/L)	D.O. (%sat)	Turb. (NTU)	TSS (mg/L)	FC (cfu/100mL)	TP (mg/L)	Discharge (cfs)
18-Sep-91	4.2	388030	1320	17.9	7.8	135	8.2	86	1.0 U	20	37	0.05	0.5
18-Sep-91	3.8	388031	1230	16.6	8.0	130	9.4	96	1.0 U	1 U	24	0.12	0.3
18-Sep-91	3.7 R	388032	1150	16.1	7.7	130	9.6	97	1.0 U	2	27	0.10	0.3
18-Sep-91	3.7 R	388033	1150	16.1	7.7	130	9.5	96	1.0 U	1	27	0.19	0.3
18-Sep-91	3.1	388034	1050	11.4	7.0	150	7.1	65	1.0 U	3	11	0.09	9.1
15-Oct-91	4.2 R	428030	1245	-	-	-	8.8	-	1.0 U	1	680	0.02	0.1
15-Oct-91	4.2 R	428031	1245	-	-	-	8.8	-	1.0 U	2	580	0.02	0.1
15-Oct-91	3.8	428032	1145	-	-	-	10.1	-	1.0 U	1	260	0.03	0.1
15-Oct-91	3.7	428033	1115	-	-	-	10.3	-	1.2	1	160	0.02	0.0
15-Oct-91	3.1	428034	1031	-	-	-	7.1	-	1.0 U	2	9	0.05	8.3
13-Nov-91	4.2	468030	1200	10.0	7.3	110	9.5	84	2.3	4	34	0.05	1.0
13-Nov-91	3.8	468031	1120	9.9	7.4	108	10.6	93	1.8	3	46	0.04	1.0
13-Nov-91	3.7	468032	1050	9.8	7.3	105	10.7	94	1.6	3	31	0.04	0.8
13-Nov-91	3.1 R	468033	1000	10.2	7.2	125	6.9	61	2.5	2	29	0.08	4.7
13-Nov-91	3.1 R	468034	1000	10.1	7.2	125	7.0	62	2.6	3	24	0.08	5.9
18-Dec-91	4.2	518020	1215	4.8	7.2	88	11.3	88	2.0	2	13	0.03	5.5
18-Dec-91	3.8	518021	1110	4.4	7.3	95	12.2	94	3.0	3	29 S	0.02	5.3
18-Dec-91	3.7 R	518022	1015	4.3	7.2	81	12.3	94	4.0	3	57 S	0.03	4.9
18-Dec-91	3.7 R	518023	1015	4.3	7.3	80	12.3	94	4.0	6	79 S	0.04	-
18-Dec-91	3.1	518024	930	7.6	7.1	105	8.2	68	5.0	10	80	0.07	17.1
15-Jan-92	4.2	38020	1241	5.7	7.3	97	11.3	90	2.0	3	67	0.03	4.1
15-Jan-92	3.8	38021	1130	5.7	7.3	95	12.0	95	2.0	1 U	11	0.03	4.3
15-Jan-92	3.7 R	38022	1025	5.7	7.3	80	12.0	95	2.0	3	9	0.03	4.1
15-Jan-92	3.7 R	38023	1025	5.6	7.3	85	11.8	94	2.0	1	11	0.03	4.0
15-Jan-92	3.1	38024	918	8.4	7.0	114	7.9	67	2.0	4	2	0.08	12.7
12-Feb-92	4.2	78020	1145	7.4	7.6	96	10.4	86	1.7	7	4	0.03	13.9
12-Feb-92	3.8 R	78021	1050	7.3	7.6	94	11.1	92	1.6	3	8	0.02	12.6
12-Feb-92	3.8 R	78022	1050	7.3	7.6	96	11.2	92	1.3	3	11	0.02	12.4
12-Feb-92	3.7	78023	1005	7.3	7.7	93	11.1	91	1.4	3	16	0.02	12.5
12-Feb-92	3.1	78024	925	8.3	7.5	107	9.6	82	1.9	5	5	0.05	23.3
18-Mar-92	4.2	128050	1100	10.7	7.4	100	10.7	96	2.1	5	8	0.03	5.2
18-Mar-92	3.8 R	128051	1015	10.3	7.4	98	11.0	98	2.3	5	15	0.04	9.0
18-Mar-92	3.8 R	128052	1020	10.3	7.4	98	11.1	98	2.4	5	12	0.04	9.2
18-Mar-92	3.7	128053	940	10.1	7.5	100	11.0	98	2.0	6	21	0.04	9.3
18-Mar-92	3.1	128054	855	9.5	7.5	121	8.7	76	2.2	6	6	0.06	18.2
07-Apr-92	4.2	158020	1255	11.2	7.5	96	10.5	95	1.8	3	17	0.03	8.3
07-Apr-92	3.8	158021	1151	10.8	7.4	94	10.8	97	2.1	4	18	0.04	7.6
07-Apr-92	3.7	158022	1050	10.5	7.4	94	10.9	97	1.2	3	13	0.04	7.3
07-Apr-92	3.1 R	158023	950	10.0	7.9	112	8.2	72	1.4	2	18	0.07	17.1
07-Apr-92	3.1 R	158024	950	10.0	7.9	112	7.8	69	1.3	4	19	0.07	17.9
13-May-92	4.2 R	208000	1140	16.4	7.3	100	9.9	101	1.2	5	6	0.02	4.7
13-May-92	4.2 R	208001	1150	16.4	7.4	100	9.4	96	1.1	5	6	0.02	5.5
13-May-92	3.8	208002	1035	15.6	7.3	102	9.8	99	1.0	5	10	0.02	5.1
13-May-92	3.7	208003	1000	15.4	7.2	105	9.7	97	1.1	4	11	0.02	4.6
13-May-92	3.1	208004	915	12.0	7.4	125	7.7	71	1.7	9	14	0.07	14.1
10-Jun-92	4.2	248000	1137	19.6	7.9	109	8.4	91	0.7	3	70	0.04	1.2
10-Jun-92	3.8	248001	1035	18.4	7.7	109	9.9	106	0.7	9	140	0.04	1.7
10-Jun-92	3.7 R	248002	957	18.1	7.8	119	9.7	103	0.9	7	49	0.04	0.4
10-Jun-92	3.7 R	248003	1005	18.1	7.9	109	9.3	99	0.9	3	48	0.04	0.5
10-Jun-92	3.1	248004	904	11.5	7.0	135	7.1	65	0.5	3	17	0.08	9.9

Date	Site		Lab#	Time	Temp. (°C)	pH (S.U.)	Cond. (μmhos/cm)	D.O. (mg/L)	D.O. (%sat)	Turb. (NTU)	TSS (mg/L)		FC (cfu/100mL)		TP (mg/L)	Discharge (cfs)
08-Jul-92	4.2	R	288015	1244	16.9	7.3	100	8.3	85	1.0	1			LAC	0.05	0.1
08-Jul-92	4.2	R	288016	1156	16.8	7.0	107	8.4	86	1.0	1			LAC	0.05	-
08-Jul-92	3.8	*	288017	1107	15.3	7.3	110	8.4	83	2.5	28			LAC	0.13	0.0
08-Jul-92	3.7	*	288018	1040	16.0	6.7	102	1.3	13	1.1	2			LAC	0.05	0.0
08-Jul-92	3.1		288019	932	11.4	6.8	142	7.0	64	1.5	1			LAC	0.09	7.1
12-Aug-92	4.2		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
12-Aug-92	3.8		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
12-Aug-92	3.7		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
12-Aug-92	3.1	R	338020	920	11.4	7.1	114	6.4	58	1.2	7		120		0.12	8.3
12-Aug-92	3.1	R	338021	940	11.5	7.3	139	6.4	58	1.7	4		100		0.11	8.8
12-Aug-92	DRAIN		338022	-	-	-	-	-	-	-	-		440		-	-
09-Sep-92	4.2		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
09-Sep-92	3.8		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
09-Sep-92	3.7		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
09-Sep-92	3.1	R	378009	945	10.5	7.1	109	6.7	60	0.7	2		20		0.10	6.4
09-Sep-92	3.1	R	378008	950	10.5	7.0	112	6.7	60	1.3	1		39		0.10	6.0
09-Sep-92	DRAIN		378005	-	-	-	-	-	-	-	-		100	S	-	-
09-Sep-92	DRAIN	R	378006	-	-	-	-	-	-	-	-		160		-	-
13-Oct-92	4.2		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
13-Oct-92	3.8		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
13-Oct-92	3.7		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
13-Oct-92	3.1	R	428005	945	10.1	7.1	130	6.5	58	1.3	1	U	32		0.12	7.3
13-Oct-92	3.1	R	428006	945	10.1	7.2	132	6.3	56	1.4	1	U	33		0.12	7.7
18-Nov-92	4.2	^	478207	1025	9.3	6.9	60	7.0	61	6.1	2		32		0.04	-
18-Nov-92	3.8		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
18-Nov-92	3.7		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
18-Nov-92	3.1		478205	905	9.7	7.0	108	7.2	64	8.5	8		270		0.11	11.3
09-Dec-92	4.2	^	508018	855	4.5	6.7	55	10.8	83	7.0	3		490	J	0.03	-
09-Dec-92	3.8		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
09-Dec-92	3.7		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
09-Dec-92	3.1		508015	815	7.5	6.2	115	8.1	67	6.0	7		84		0.09	10.5
09-Dec-92	DRAIN		508019	-	-	-	-	-	-	-	-		57		-	-
13-Jan-93	4.2		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
13-Jan-93	3.8		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
13-Jan-93	3.7		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
13-Jan-93	3.1	R	38015	1025	8.6	6.8	138	7.8	67	5.5	14		51		0.13	7.1
13-Jan-93	3.1	R	38016	1040	8.5	7.0	140	7.5	64	3.2	13		41		0.12	7.3
10-Feb-93	4.2	R	78024	1250	6.0	7.0	105	11.2	90	0.8	2		7		0.02	0.3
10-Feb-93	4.2	R	78023	1250	6.0	6.8	105	12.0	96	0.5	2		5		0.02	0.6
10-Feb-93	3.8		78022	1115	5.5	6.8	98	12.2	97	0.5	1		1		0.01	0.5
10-Feb-93	3.7		78021	1040	5.3	6.8	100	13.1	103	0.6	1		1	U	0.01	0.3
10-Feb-93	3.1		78020	1000	9.4	6.7	138	7.8	68	1.9	6		6		0.09	9.6
10-Mar-93	4.2		118012	1045	5.5	6.5	97	7.1	56	0.4	1		1	U	0.02	-
10-Mar-93	3.8		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
10-Mar-93	3.7		NO FLOW	-	-	-	-	-	-	-	-		-		-	-
10-Mar-93	3.1	R	118010	945	9.4	6.5	135	7.8	68	1.4	5		7		0.09	9.2
10-Mar-93	3.1	R	118011	945	9.4	6.6	140	7.8	68	1.4	5		8		0.09	-
14-Apr-93	4.2		168074	1205	11.8	6.1	100	10.6	98	1.2	2		15		0.02	4.6
14-Apr-93	3.8	R	168072	1117	10.9	6.2	95	11.7	106	1.2	2		11		0.02	3.9
14-Apr-93	3.8	R	168074	1117	10.9	6.4	98	11.4	103	1.2	2		9		0.02	3.9
14-Apr-93	3.7		168071	1040	10.3	6.1	97	11.8	105	1.3	2		17		0.02	3.7
14-Apr-93	3.1		168070	1005	9.5	6.3	122	9.3	81	1.6	2		10		0.05	14.0

Appendix C. Continued.

Date	Site		Lab#	Time	Temp. (°C)	pH (S.U.)	Cond. (µmhos/cm)	D.O. (mg/L)	D.O. (%sat)	Turb. (NTU)	TSS (mg/L)	FC (cfu/100mL)		TP (mg/L)	Discharge (cfs)
03-May-93	4.2		198030	1055	14.3	6.6	99	9.3	91	1.6	3	29	SX	0.02	5.6
03-May-93	3.8	R	198031	1005	13.9	6.6	98	9.8	95	2.0	4	17	SX	0.02	4.5
03-May-93	3.8	R	198032	1005	13.9	6.7	98	10.1	97	2.0	4	28	SX	0.02	-
03-May-93	3.7		198033	935	13.8	6.5	99	10.2	98	2.2	5	13	SX	0.02	5.0
09-Jun-93	4.2		248040	1200	17.8	7.7	98	7.6	80	2.0	4	210		0.03	2.4
09-Jun-93	3.8		248041	1105	17.3	7.6	82	8.8	92	4.9	9	550	S	0.04	3.0
09-Jun-93	3.7	R	248042	1025	17.3	7.3	88	8.7	91	5.5	18	680	J	0.05	3.1
09-Jun-93	3.7	R	248044	1025	17.3	7.4	88	8.8	91	5.5	18	660	J	0.06	3.3
09-Jun-93	3.1		248043	935	12.3	5.7	138			2.0	6	320		0.07	14.6
14-Jul-93	4.2		NO FLOW	-	-	-	-	-	-	-	-	-		-	-
14-Jul-93	3.8		NO FLOW	-	-	-	-	-	-	-	-	-		-	-
14-Jul-93	3.7		NO FLOW	-	-	-	-	-	-	-	-	-		-	-
14-Jul-93	3.1	R	298011	920	11.3	6.1	171	6.7	61	0.8	3	22		0.08	9.2
14-Jul-93	3.1	R	298012	920	11.3	6.3	171	6.8	62	0.7	2	23		0.08	-

- = No data
* = sampled pools far removed from regular sampling areas; data not included in further analysis.
^= storm drain water (no flow from Lake Lois)
R = Replicate sample.
J = The analyte was positively identified. The associated numerical result is an estimate.
U = The analyte was not detected at or above the reported result.
X = High background count.
S = Spreader (colonies possibly masked by other bacteria).
LAC = Lab accident.
DRAIN = Storm drain below Lake Lois.

Appendix D. Woodland Creek baseline storm event data from grab samples, January 1991 - March 1992.

Date	Site	Lab #	Time	Temp. (°C)	pH (S.U.)	Cond. (µmhos/cm)	D.O. (mg/L)	D.O. (%sat)	Turb. (NTU)	TSS (mg/L)	FC (cfu/100mL)	TP (mg/L)	DISCHARGE (cfs)
24-Apr-91	4.2	178595	1230	12.6	7.6	110	9.4	89	3	-	-	-	20.3
	4.2	178594	646	-	-	-	-	-	3	-	-	-	-
	4.2		847	12.1	7.4	-	9.0	83	-	-	-	-	-
	3.8	178596	706	-	-	-	-	-	3	-	-	-	-
	3.8		815	11.9	7.4	117	10.0	93	-	-	-	-	-
	3.8	178597	1340	12.8	7.7	110	10.0	94	5	-	-	-	22.5
	3.7		755	11.8	7.6	115	10.0	92	-	-	-	-	-
	3.7	178598	715	-	-	-	-	-	3	-	-	-	-
	3.7	178599	1315	12.7	7.8	110	10.2	96	3	-	-	-	21.5
25-Apr-91	4.2		905	11.8	8.0	112	9.2	85	-	-	-	-	20.0
	3.8		820	11.4	8.1	112	10.1	92	-	-	-	-	23.7
	3.7		735	11.5	7.9	100	10.1	92	-	-	-	-	21.1
19-Nov-91	4.2	478180	950	8.5	7.8	80	10.0	85	10	8	400	0.07	-
	3.8	478181	912	8.5	7.8	79	10.9	93	6	8	190	0.05	2.2
	3.7	478182	840	8.5	7.7	71	11.0	94	6	6	260	0.05	1.4
	3.1	478184	806	9.8	7.8	110	7.0	62	3	2	47	0.07	5.1
20-Nov-91	4.2	478185	1350	8.5	7.8	76	10.1	86	17	26	2300	0.09	-
	4.2		1700	8.2	7.8	100	-	-	-	-	-	-	-
	3.8		1630	8.7	7.8	100	-	-	-	-	-	-	-
	3.8	478186	1315	8.3	7.8	90	11.2	95	7	8	1950	0.05	2.9
	3.7		1545	8.7	7.5	96	-	-	-	-	-	-	-
	3.7	478187	1245	8.2	7.8	95	11.2	95	5	8	98	0.05	-
	3.1	478188	1150	8.9	7.6	68	7.9	68	66	41	550	0.21	23.7
28-Jan-92	4.2	58400	1440	8.0	7.4	69	10.9	91	9	19	230	0.06	13.3
	3.8	58402	1345	7.8	7.6	79	11.3	95	8	25	210	0.07	-
	3.7	58403	1330	8.0	7.4	72	11.3	95	9	33	260	0.09	11.4
	3.1	58404	1105	9.3	7.3	60	9.0	78	15	41	1400 J	0.12	-
29-Jan-92	4.2	58406	1458	8.0	7.1	75	10.7	90	16	2 J	220	0.04	15.0
	3.8	58407	1530	8.0	7.1	84	11.3	95	21	5 J	190	0.04	16.0
	3.7	58408	1455	8.0	7.4	85	11.3	95	25	5 J	260	0.04	-
	3.1	58410	1425	9.4	7.6	83	8.7	76	37	5 J	195	0.07	-
	AD	58411	-	-	-	-	-	-	-	-	140	-	-
	BD	58412	-	-	-	-	-	-	-	-	15000	-	-

- = No data
J = The analyte was positively identified. The associated numerical result is an estimate.
AD = Above the storm drain (below Lake Lois).
BD = Below the storm drain (below Lake Lois).

Appendix E. Woodland Creek baseline storm event data collected by automated sequential samplers, January 1991 - March 1992.

Date	Site	Lab #	Time	Cond. (uhmos/cm)	TSS (mg/L)
04/24/91	4.2	-	800	109	-
	4.2	-	900	109	-
	4.2	-	1000	109	-
	4.2	-	1100	109	-
	4.2	-	1200	109	-
	4.2	-	1300	109	-
	4.2	-	1400	109	-
	4.2	-	1500	109	-
	4.2	-	1600	109	-
	4.2	-	1700	109	-
	4.2	-	1800	109	-
	4.2	-	1900	109	-
	4.2	-	2000	109	-
	4.2	-	2100	109	-
	4.2	-	2200	109	-
	4.2	-	2300	109	-
	4.2	-	2400	109	-
04/25/91	4.2	-	100	109	-
	4.2	-	200	109	-
	4.2	-	300	109	-
	4.2	-	400	109	-
	4.2	-	500	109	-
	4.2	-	600	109	-
	4.2	-	700	109	-
04/24/91	3.8	-	800	109	-
	3.8	-	900	108	-
	3.8	-	1000	109	-
	3.8	-	1100	109	-
	3.8	-	1200	109	-
	3.8	-	1300	108	-
	3.8	-	1400	108	-
	3.8	-	1500	109	-
	3.8	-	1600	109	-
	3.8	-	1700	109	-
	3.8	-	1800	109	-
	3.8	-	1900	109	-
	3.8	-	2000	109	-
	3.8	-	2100	109	-
	3.8	-	2200	109	-
	3.8	-	2300	109	-
	3.8	-	2400	109	-
04/25/91	3.8	-	100	109	-
	3.8	-	200	104	-
	3.8	-	300	109	-
	3.8	-	400	109	-
	3.8	-	500	109	-
	3.8	-	600	109	-
	3.8	-	700	109	-
04/24/91	3.7	-	800	110	-
	3.7	-	900	109	-
	3.7	-	1000	109	-
	3.7	-	1100	109	-
	3.7	-	1200	109	-
	3.7	-	1300	-	-
	3.7	-	1400	-	-
	3.7	-	1500	-	-
	3.7	-	1600	-	-
	3.7	-	1700	109	-
	3.7	-	1800	-	-
	3.7	-	1900	-	-
	3.7	-	2000	-	-
	3.7	-	2100	-	-
	3.7	-	2200	108	-
	3.7	-	2300	-	-
	3.7	-	2400	-	-
04/25/91	3.7	-	100	-	-
	3.7	-	200	-	-
	3.7	-	300	109	-
	3.7	-	400	-	-
	3.7	-	500	-	-
	3.7	-	600	-	-
	3.7	-	700	109	-

Appendix E. Continued.

Date	Sit	Lab #	Time	Cond. (uhmos/cm)	TSS (mg/L)
11/19/91	4.2	478190	1500	44	59
	4.2	478191	1600	51	20
	4.2	478192	1700	54	53
	4.2	478193	1800	44	23
	4.2	478194	1900	61	13
	4.2	478195	2000	82	10
	4.2	478196	2100	60	26
	4.2	478197	2200	69	9
	4.2	478198	2300	90	7
11/20/91	4.2	478199	0	92	7
	4.2	478200	100	92	5
	4.2	478201	200	101	6
	4.2	478202	300	99	5
	4.2	478203	400	102	5
	4.2	478204	500	102	5
	4.2	478205	600	102	4
	4.2	478206	700	96	97
	4.2	478207	800	58	78
	4.2	478208	900	47	26
	4.2	478209	1000	77	8
	4.2	478210	1100	92	7
	4.2	478211	1200	95	8
	4.2	478212	1300	91	8
	4.2	478213	1400	71	17
11/19/91	3.8	478215	1500	66	77
	3.8	478216	1600	46	30
	3.8	478217	1700	57	18
	3.8	478218	1800	42	46
	3.8	478219	1900	47	20
	3.8	478220	2000	66	11
	3.8	478221	2100	64	13
	3.8	478222	2200	51	12
	3.8	478223	2300	72	9
11/20/91	3.8	478224	0	87	6
	3.8	478225	100	90	6
	3.8	478226	200	95	5
	3.8	478227	300	99	4
	3.8	478228	400	99	4
	3.8	478229	500	101	6
	3.8	478230	600	101	5
	3.8	478231	700	97	8
	3.8	478232	800	56	75
	3.8	478233	900	46	45
	3.8	478234	1000	54	16
	3.8	478235	1100	79	9
	3.8	478236	1200	91	7
	3.8	478237	1300	90	8
	3.8	478238	1400	89	16
11/19/91	3.7	478240	1500	80	61
	3.7	478241	1600	47	37
	3.7	478242	1700	52	15
	3.7	478243	1800	43	54
	3.7	478244	1900	47	22
	3.7	478245	2000	62	12
	3.7	478246	2100	77	17
	3.7	478247	2200	54	15
	3.7	478248	2300	67	10
11/20/91	3.7	478249	0	88	6
	3.7	478250	100	89	7
	3.7	478251	200	95	6
	3.7	478252	300	97	6
	3.7	478253	400	98	6
	3.7	478254	500	97	6
	3.7	478255	600	99	7
	3.7	478256	700	97	8
	3.7	478257	800	60	39
	3.7	478258	900	47	50
	3.7	478259	1000	51	20
	3.7	478260	1100	75	9
	3.7	478261	1200	88	8
	3.7	478262	1300	88	9
	3.7	478263	1400	90	16

Appendix E. Continued.

Date	Sit	Lab #	Time	Cond. (uhmos/cm)	TSS (mg/L)
01/28/92	4.2	58455	1700	70	12
	4.2	58456	1800	82	9
	4.2	58457	1900	75	9
	4.2	58458	2000	83	7
	4.2	58459	2100	84	4
	4.2	58460	2200	82	5
	4.2	58461	2300	80	3
	4.2	58462	0	72	9
01/29/92	4.2	58463	100	75	4
	4.2	58464	200	79	2
	4.2	58465	300	70	10
	4.2	58466	400	73	6
	4.2	58467	500	82	3
	4.2	58468	600	73	2
	4.2	58469	700	79	3
	4.2	58470	800	68	8
	4.2	58471	900	73	9
	4.2	58472	1000	80	6
	4.2	58473	1100	83	4
01/28/92	3.8	58435	1700	75	19
	3.8	58436	1800	70	16
	3.8	58437	1900	70	12
	3.8	58438	2000	80	22
	3.8	58439	2100	84	6
	3.8	58440	2200	83	8
	3.8	58441	2300	83	6
	3.8	58442	0	80	12
	3.8	58443	100	76	8
01/29/92	3.8	58444	200	83	8
	3.8	58445	300	60	14
	3.8	58446	400	72	10
	3.8	58447	500	77	8
	3.8	58448	600	80	6
	3.8	58449	700	84	8
	3.8	58450	800	70	20
	3.8	58451	900	77	12
	3.8	58452	1000	75	9
	3.8	58453	1100	80	6
	3.8	58454	1200	85	6
01/28/92	3.7	58413	1700	80	15
	3.7	58414	1800	70	22
	3.7	58415	1900	81	15
	3.7	58416	2000	85	14
	3.7	58417	2100	85	10
	3.7	58418	2200	82	7
	3.7	58419	2300	80	12
	3.7	58420	0	75	10
01/29/92	3.7	58421	100	80	8
	3.7	58422	200	73	14
	3.7	58423	300	70	9
	3.7	58424	400	80	7
	3.7	58425	500	85	6
	3.7	58426	600	83	8
	3.7	58427	700	75	24
	3.7	58428	800	70	10
	3.7	58429	900	77	9
	3.7	58430	1000	81	7
	3.7	58431	1100	83	8
	3.7	58432	1200	95	6
	3.7	58433	1300	86	5
	3.7	58434	1400	85	5

- = No data

Appendix F. Woodland Creek impact storm event data, April 1992 - July 1993.

DATE	SITE	TIME	TURB (NTU)	TSS (mg/L)	FC (cfu/100mL)
10/18/92	3.7	1350	17	16	-
	3.8	1405	9.6	12	-
	4.2	1435	6.8	11	-
11/21/92	GAGE	710	81	-	-
	4.2	730	26	-	-
	3.7	740	63	-	-
	GAGE	740	58	-	-
	DRAIN	900	42	-	-
	CONWTLND	930	24	-	-
	3.7	1415	12	-	-
	3.8	1410	12	-	-
	3.8 R	1410	12	-	-
11/22/92	DRAIN	1020	8	-	-
	4.2	1035	5	-	-
12/09/92	DRAIN	935	-	-	57
01/04/93	DRAIN	935	36	360	110
	DRAIN R	935	36	340	100
01/19/93	DRAIN	920	160	-	-
	DRAIN R	920	160	-	-
01/24/93	3.8	1130	13	4	-
	4.2	1120	23	15	-
	DRAIN	1110	200	500	-
03/22/93	4.2	1440	8.2	9	-
	3.8	1425	11	6	-
	3.7	1420	13	7	-
	MW	1400	900	1320 J	-
	MWG	1400	2500	5300 J	-

- = No data
GAGE = Martin Way gage
DRAIN = Lake Lois storm drain
CONWTLND = constructed wetland outfall
MW = Martin Way, at base of Desmond Dr.
MWG = Martin Way above storm drain grate
J = The analyte was positively identified. The associated numerical result is an estimate.
R = Replicate

Appendix G. Benthic macroinvertebrate taxa in Woodland Creek.

Date	Site	Order	Family	Genus/species	Functional Group
17-Dec-93	RM 3.7	Diptera	Empididae	*Chelifera*	Predator
		Diptera	Chironomidae (pupa)	*sp.*	
		Diptera	Chironiminae (larvae)	*sp.*	Collector-gatherer
		Diptera	Empididae	*Clinocera*	Predator
		Gastropoda	Physidae	*Physella gyrina*	Scraper
		Isopoda	Unidentified	*sp.*	Collector-gatherer
		Oligochaeta	Lumbriculidae	*sp.*	Collector-gatherer
		Turbellaria	Planariidae	*sp.*	Piercer
	RM 3.8	Copepoda	Unidentified		Collector-filterer
		Diptera	Tabanidae (larvae-immature)	*sp.*	Predator/Piercer
		Diptera	Tanypodinae (larvae)	*sp.*	Predator
		Oligochaeta	Lumbriculidae	*sp.*	Collector-gatherer
		Trichoptera	Limnephilidae	*Psychoglypha sp.*	Collector-gatherer/Shredder
		Gastropoda	Physidae	*Physella gyrina*	Scraper
	RM 4.2	Coleoptera	Elmidae	*Narpus sp.*	Shredder
		Copepoda	Unidentified	*sp.*	
		Diptera	Chironiminae (larvae)	*sp.*	Collector-gatherer
		Diptera	Simuliidae	*Simulium sp*	Collector filterer
		Diptera	Tabanidae	*Chrysops sp.*	Collector-gatherer
		Diptera	Tanypodinae (larval)	*sp.*	Predator
		Isopoda	Unidentified	*Caecidotia sp.*	Collector-gatherer
		Nematoda	Unidentified	*Rhynchelmis sp.*	
		Odonata (Zygoptera)	Unidentified	*sp.*	Predator
		Oligochaeta	Naididae	*sp.*	Collector-gatherer
		Oligochaeta	Lumbriculidae	*sp.*	Collector-gatherer
		Pelecypoda	Sphaeriidae	*Pisidium sp.*	Collector-filterer
		Gastropoda	Physidae	*Physella gyrina*	Scraper
20-Sep-91	RM 3.7	Acari (Water Mites)	Hydracarina	*sp.*	Piercer
		Diptera	Simuliidae	*Simulium canadanse*	Collector-filterer
		Diptera	Simuliidae	*Simulium vittatum*	Collector-filterer
		Diptera	Empididae	*Hemerodromia sp.*	Predator/Collector-gatherer
		Diptera	Chironomidae	Tanypodinae	Predator
		Gastropoda	Physidae	*Physa sp.*	Scraper
		Oligochaeta	Lumbriculidae	*sp.*	Collector-gatherer
		Oligochaeta	Naididae	*sp.*	Collector-gatherer
		Plecoptera	Nemouridae	*Zapada sp.*	Shredder
		Turbellaria	Planariidae	*sp.*	Piercer
	RM 3.8	Diptera	Simuliidae	*Simulium vittatum*	Collector-filterer
		Diptera	Chironomidae	Tanypodinae	Predator
		Diptera	Empididae	*Hemerodromia sp.*	Predator/Collector-gatherer
		Ephemeroptera	Baetidae	*Baetis sp.*	Collector-gatherer/Scraper
		Gastropoda	Physidae	*Physa sp.*	Scraper
		Nematoda	Unidentified	*sp.*	Collector-gatherer
		Oligochaeta	Lumbriculidae B	*sp.*	Collector-gatherer
		Oligochaeta	Lumbriculidae A	*sp.*	Collector-gatherer
		Pelecypoda	Sphaeriidae	*Pisidium sp.*	Collector-filterer
		Plecoptera	Nemouridae	*Zapada sp.*	Shredder
		Trichoptera	Lepidostomatidae	*Lepidostoma sp.*	Shredder
	RM 4.2	Amphipoda	Talitridae	*Hyalella azteca*	Collector-gatherer
		Diptera	Tipulidae	*Tipula sp.*	Shredder/Collector-gatherer
		Diptera	Chironomidae	*pupae*	Collector-gatherer
		Diptera	Empididae	*Hemerodromia sp.*	Predator/Collector-gatherer
		Diptera	Chironomidae	*larvae*	Collector-gatherer
		Diptera	Simuliidae	*Simulium vittatum*	Collector-filterer
		Ephemeroptera	Baetidae	*Baetis sp.*	Collector-gatherer/Scraper

Appendix G. Continued.

Date	Site	Order	Family	Genus/species	Functional Group
		Isopoda	Asellidae	*Asellus sp.*	Collector-gatherer
		Nematoda	Unidentified		Collector-gatherer
		Oligochaeta	Lumbriculidae B	*sp.*	Collector-gatherer
		Oligochaeta	Lumbriculidae A	*sp.*	Collector-gatherer
		Trichoptera	Rhyacophilidae	*Rhyacophila sp.*	Predator
		Trichoptera	Lepidostomatidae	*Lepidostoma sp.*	Shredder
		Turbellaria	Planariidae	*sp.*	Piercer
19-May-92	RM 3.7	Acari	Hydracarina	*sp.*	Piercer
		Coleoptera	Sciomyzidae (pupae)	*sp.*	Predator
		Coleoptera	Dytiscidae (larva)	*sp.*	Predator
		Collembola	Unidentified	*sp.*	
		Diptera	Chironominae (larvae)	*sp.*	Collector-gatherer
		Diptera	Hydropsychidae	*Hydropsyche sp.*	Collector-filterer
		Diptera	Tipulidae	*Dicranota sp.*	Predator
		Diptera	Chironomidae (pupa)	*sp.*	
		Ephemeroptera	Baetidae	*Baetis bicaudatus*	Collector-gatherer/Scraper
		Ephemeroptera	Baetidae	*Baetis tricaudatus*	Collector-gatherer/Scraper
		Isopoda	Unidentified	*Caecidotia sp.*	Collector-gatherer
		Nematoda	Unidentified	*Rhynchelmis sp.*	Collector-gatherer
		Oligochaeta	Lumbriculidae A	*sp.*	Collector-gatherer
		Plecoptera	Nemouridae	*Zapada sp.*	Shredder
		Plecoptera	Perlodidae	*Rickera sp.*	Predator
		Plecoptera	Perlodidae	*Cultus sp.*	Predator
	RM 3.8	Diptera	Chironomidae (pupa)	*sp.*	
		Diptera	Chironomidae	*Chironominae*	Collector-gatherer
		Diptera	Tipulidae	*Dicranota sp.*	Predator
		Diptera	Empididae	*Chelifera sp.*	Predator
		Diptera	Sciomyzidae (pupa)	*sp.*	Predator
		Ephemeroptera	Baetidae	*Baetis bicaudatus*	Collector-gatherer/Scraper
		Ephemeroptera	Baetidae	*Baetis tricaudatus*	Collector-gatherer/Scraper
		Oligochaeta	Lumbriculidae	*sp.*	Collector-gatherer
		Plecoptera	Perlodidae	*Cultus sp.*	Predator
		Plecoptera	Perlodidae	*Rickera sp.*	Predator
		Trichoptera	Hydropsychidae	*Hydropsyche sp.*	Collector-filterer
13-May-93	RM 3.7	Diptera	Simuliidae	*Simulium canadense*	Collector-filterer
		Diptera	Chironomidae (pupa)	*sp.*	
		Diptera	Ceratopogonidae	*Bezzia sp.*	Predators
		Diptera	Simuliidae	*Simulium vittatum*	Collector-filterer
		Diptera	Chironomidae	*Chironominae (larva)*	Collector-gatherer
		Ephemeroptera	Baetidae	*Baetis tricaudatus*	Collector-gatherer/Scraper
		Nematoda	Unidentified	*Rhynchelmis sp.*	Collector-gatherer
		Plecoptera	Nemouridae	*Zapada sp.*	Shredder
		Plecoptera	Perlodidae	*Cultus sp.*	Predator
	RM 3.8	Acari	Hydracarina	*sp.*	Piercer
		Coleoptera	Dytiscidae (larva)	*sp.*	Predator
		Diptera	Tipulidae	*Antoches sp.*	Collector-gatherer
		Diptera	Chironomidae (pupa)	*sp.*	
		Diptera	Chironomidae	*Chironominae (larva)*	Collector-gatherer
		Diptera	Simuliidae	*Simulium canadense*	Collector-filterer
		Diptera	Simuliidae	*Simulium vittatum*	Collector-filterer
		Diptera	Tipulidae	*Dicranota sp.*	Predator
		Ephemeroptera	Baetidae	*Baetis bicaudatus*	Collector-gatherer/Scraper
		Ephemeroptera	Baetidae	*Baetis tricaudatus*	Collector-gatherer/Scraper
		Nematoda	Unidentified	*Rhynchelmis sp.*	Collector-gatherer
		Plecoptera	Perlodidae	*Cultus sp.*	Predator
	RM 4.2	Coleoptera	Dytiscidae (larva)	*sp.*	Predator

Appendix G. Continued.

Date	Site	Order	Family	Genus/species	Functional Group
		Copepoda	(Plankton)	*sp.*	Collector-filterer
		Diptera	Simuliidae	*Simulium vittatum*	Collector-filterer
		Diptera	Chironomidae	*Chironominae (larva)*	Collector-gatherer
		Diptera	Chironomidae (pupa)	*sp.*	
		Hirudinea	Unidentified	*sp.*	Piercer
		Nematoda	Unidentified	*Rhynchelmis sp.*	Collector-gatherer
		Oligochaeta	Lumbriculidae	*sp.*	Collector-gatherer
		Pelecypoda	Sphaeriidae	*Pisidium sp.*	Collector-filterer

sp. - Indicates only one species was present but not identified to species level.

Appendix H. Scores for habitat assessments conducted on Woodland Creek.

Date	Site	Habitat Group/ Habitat Parameter	Score 1	Score 2	AvScore
5/20/91	RM3.7				
		Bottom Substrate/available cover	20.00		20.00
		Embeddedness	13.00		13.00
		Flow/ Velocity	20.00		20.00
		Channel Alteration	11.00		11.00
		Bottom scouring & deposition	11.00		11.00
		Pool/riffle, run/bend ratio	15.00		15.00
		Bank stability	10.00		10.00
		Bank vegetative stability	10.00		10.00
		Streamside cover	10.00		10.00
5/20/91	RM3.8				
		Bottom Substrate/available cover	20.00		20.00
		Embeddedness	19.00		19.00
		Flow/ Velocity	20.00		20.00
		Channel Alteration	11.00		11.00
		Bottom scouring & deposition	11.00		11.00
		Pool/riffle, run/bend ratio	15.00		15.00
		Bank stability	8.00		8.00
		Bank vegetative stability	10.00		10.00
		Streamside cover	8.00		8.00
5/20/91	RM4.2				
		Bottom Substrate/available cover	20.00		20.00
		Embeddedness	16.00		16.00
		Flow/ Velocity	20.00		20.00
		Channel Alteration	15.00		15.00
		Bottom scouring & deposition	15.00		15.00
		Pool/riffle, run/bend ratio	15.00		15.00
		Bank stability	6.00		6.00
		Bank vegetative stability	10.00		10.00
		Streamside cover	8.00		8.00
9/20/91	RM3.7				
		Bottom Substrate/available cover	15.00	10.00	12.50
		Embeddedness	18.00	8.00	13.00
		Flow/ Velocity	15.00	10.00	12.50
		Channel Alteration	15.00	11.00	13.00
		Bottom scouring & deposition	15.00	10.00	12.50

Appendix H. Continued.

Date	Site	Habitat Group/ Habitat Parameter	Score 1	Score 2	AvScore
9/20/91	RM3.7				
		Pool/riffle, run/bend ratio	8.00	7.00	7.50
		Bank stability	8.00	8.00	8.00
		Bank vegetative stability	10.00	6.00	8.00
		Streamside cover	10.00	9.00	9.50
9/20/91	RM3.8				
		Bottom Substrate/available cover	20.00	15.00	17.50
		Embeddedness	13.00	9.00	11.00
		Flow/ Velocity	8.00	13.00	10.50
		Channel Alteration	15.00	11.00	13.00
		Bottom scouring & deposition	15.00	9.00	12.00
		Pool/riffle, run/bend ratio	5.00	8.00	6.50
		Bank stability	7.00	6.00	6.50
		Bank vegetative stability	8.00	6.00	7.00
		Streamside cover	10.00	9.00	9.50
9/20/91	RM4.2				
		Bottom Substrate/available cover	15.00	15.00	15.00
		Embeddedness	15.00	15.00	15.00
		Flow/ Velocity	10.00	11.00	10.50
		Channel Alteration	15.00	10.00	12.50
		Bottom scouring & deposition	15.00	8.00	11.50
		Pool/riffle, run/bend ratio	11.00	7.00	9.00
		Bank stability	5.00	5.00	5.00
		Bank vegetative stability	8.00	8.00	8.00
		Streamside cover	10.00	9.00	9.50
12/17/91	RM3.7				
		Bottom Substrate/available cover	12.00	12.00	12.00
		Embeddedness	15.00	10.00	12.50
		Flow/ Velocity	13.00	13.00	13.00
		Channel Alteration	12.00	5.00	8.50
		Bottom scouring & deposition	9.00	7.00	8.00
		Pool/riffle, run/bend ratio	15.00	14.00	14.50
		Bank stability	10.00	6.00	8.00
		Bank vegetative stability	10.00	9.00	9.50
		Streamside cover	9.00	8.00	8.50

Date	Site	Habitat Group/ Habitat Parameter	Score 1	Score 2	AvScore
12/17/91	RM3.8				
		Bottom Substrate/available cover	9.00	13.00	11.00
		Embeddedness	14.00	10.00	12.00
		Flow/ Velocity	12.00	13.00	12.50
		Channel Alteration	10.00	12.00	11.00
		Bottom scouring & deposition	11.00	9.00	10.00
		Pool/riffle, run/bend ratio	11.00	12.00	11.50
		Bank stability	8.00	5.00	6.50
		Bank vegetative stability	7.00	9.00	8.00
		Streamside cover	9.00	8.00	8.50
12/17/91	RM4.2				
		Bottom Substrate/available cover	10.00	14.00	12.00
		Embeddedness	12.00	10.00	11.00
		Flow/ Velocity	13.00	12.00	12.50
		Channel Alteration	11.00	7.00	9.00
		Bottom scouring & deposition	9.00	10.00	9.50
		Pool/riffle, run/bend ratio	12.00	14.00	13.00
		Bank stability	5.00	6.00	5.50
		Bank vegetative stability	6.00	8.00	7.00
		Streamside cover	8.00	9.00	8.50
5/19/92	RM3.7				
		Bottom Substrate/available cover	12.00	12.00	12.00
		Embeddedness	15.00	15.00	15.00
		Flow/ Velocity	19.00	13.00	16.00
		Channel Alteration	9.00	7.00	8.00
		Bottom scouring & deposition	10.00	3.00	6.50
		Pool/riffle, run/bend ratio	14.00	10.00	12.00
		Bank stability	10.00	9.00	9.50
		Bank vegetative stability	10.00	10.00	10.00
		Streamside cover	9.00	9.00	9.00
5/19/92	RM3.8				
		Bottom Substrate/available cover	17.00	14.00	15.50
		Embeddedness	13.00	10.00	11.50
		Flow/ Velocity	17.00	14.00	15.50
		Channel Alteration	9.00	7.00	8.00
		Bottom scouring & deposition	3.00	6.00	4.50

Date	Site	Habitat Group/ Habitat Parameter	Score 1	Score 2	AvScore
5/19/92	RM3.8				
		Pool/riffle, run/bend ratio	11.00	8.00	9.50
		Bank stability	8.00	8.00	8.00
		Bank vegetative stability	10.00	10.00	10.00
		Streamside cover	9.00	10.00	9.50
5/19/92	RM4.2				
		Bottom Substrate/available cover	16.00	13.00	14.50
		Embeddedness	16.00	14.00	15.00
		Flow/ Velocity	17.00	13.00	15.00
		Channel Alteration	11.00	8.00	9.50
		Bottom scouring & deposition	7.00	7.00	7.00
		Pool/riffle, run/bend ratio	13.00	11.00	12.00
		Bank stability	9.00	7.00	8.00
		Bank vegetative stability	9.00	10.00	9.50
		Streamside cover	9.00	9.00	9.00
5/13/93	RM3.7				
		Bottom Substrate/available cover	13.00	13.00	13.00
		Embeddedness	11.00	8.00	9.50
		Flow/ Velocity	17.00	18.00	17.50
		Channel Alteration	12.00	12.00	12.00
		Bottom scouring & deposition	10.00	12.00	11.00
		Pool/riffle, run/bend ratio	14.00	13.00	13.50
		Bank stability	8.00	8.00	8.00
		Bank vegetative stability	9.00	10.00	9.50
		Streamside cover	6.00	9.00	7.50
5/13/93	RM3.8				
		Bottom Substrate/available cover	15.00	19.00	17.00
		Embeddedness	10.00	11.00	10.50
		Flow/ Velocity	17.00	15.00	16.00
		Channel Alteration	13.00	12.00	12.50
		Bottom scouring & deposition	11.00	12.00	11.50
		Pool/riffle, run/bend ratio	14.00	14.00	14.00
		Bank stability	9.00	9.00	9.00
		Bank vegetative stability	9.00	10.00	9.50
		Streamside cover	9.00	8.00	8.50

Appendix H. Continued.

Date	Site	Habitat Group/ Habitat Parameter	Score 1	Score 2	AvScore
5/13/93	RM4.2				
		Bottom Substrate/available cover	18.00	19.00	18.50
		Embeddedness	17.00	18.00	17.50
		Flow/ Velocity	17.00	15.00	16.00
		Channel Alteration	11.00	13.00	12.00
		Bottom scouring & deposition	11.00	11.00	11.00
		Pool/riffle, run/bend ratio	13.00	13.00	13.00
		Bank stability	9.00	8.00	8.50
		Bank vegetative stability	9.00	10.00	9.50
		Streamside cover	9.00	8.00	8.50