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WATER QUALITY IN THE JOHNSON CREEK WATERSHED AFTER THE IMPLEMENTATION OF BEST MANAGEMENT PRACTICES

by
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ABSTRACT

Monitoring was performed in the Johnson Creek watershed in 1988/89 to assess water quality as related to Class A standards and to compare conditions to a 1980/81 pre-Best Management Practice study. Water quality in 1988/89 was found to violate Class A standards for dissolved oxygen, fecal coliform, and pH. Fecal coliform, nitrate and total phosphorus concentrations increased significantly between the pre- and post-BMP implementation studies, but turbidity decreased. It appears that manure continues to reach creeks in the watershed regardless of the BMPs; this may be predominately due to improper management techniques and/or non-participating farms.

INTRODUCTION

Background

With passage of the 1972 Federal Water Pollution Control Act Amendments (PL 92-500) came a growing concern regarding the quality of the nation's water resources. Under Section 208 of this Act, each state was required to develop an Areawide Water Quality Management Program to address point and nonpoint pollution problems. The 1972 Act established the National Pollution Discharge Elimination System (NPDES) to regulate and control point sources. Nonpoint pollution, however, was not as easily addressed since the water quality problem it creates originates over a broad area.

The Washington State 208 Dairy Waste Plan was developed in reaction to increased nonpoint water quality concerns stemming from passage of PL 92-500. It was designed to provide an opportunity for dairy farmers to voluntarily correct their waste discharge problems, and thus, reduce water quality impacts, with the implementation of Best Management Practices (BMPs: agronomic, managerial, or structural techniques for controlling nonpoint source pollution where it is generated). This plan also contained provisions for permitting and enforcement if voluntary compliance was not achieved.

Programs to control agricultural nonpoint source pollution have been developed cooperatively by the Washington Department of Ecology (Ecology), the Washington State Conservation Commission, Conservation Districts, and the U.S. Department of Agriculture, Soil Conservation Service. These programs rely primarily on voluntary participation in the implementation of BMPs with financial assistance provided for the farmer (PSWQA, 1988). A cooperative program to improve water quality for the Johnson Creek watershed, Whatcom County, was initiated in 1979 by the Soil Conservation Service, Whatcom County Conservation District, Consolidated Drainage Improvement District #31, and Ecology. The Conservation District received federal grant monies which, combined with monies from participating farmers, provided for accelerated BMP implementation in the watershed. Forty-five (from a possible fifty-seven) contracts were voluntarily established with farmers. Some of the BMPs which were implemented in the Johnson Creek drainage were: waste storage ponds, above ground manure storage; fencing; roof-water management (gutters, downspouts); containment slabs with curbs and regrading; and information regarding manure storage and application times.

The objective of the 1980/81 program was to minimize the discharge of dairy waste into Johnson Creek, and, thus, meet Class A water quality standards, as well as improve the wildlife habitat. There were two phases to the project. The first phase involved dredging several creeks in the watershed to remove both reed canary grass (*Phalaris arundinacea*) and manure. The second phase involved setting up the contracts with area farmers who chose to participate in the implementation of BMPs. The second phase also included a stream monitoring investigation (October 1980 - September 1981) to provide a baseline by which BMP effectiveness might later be measured. Results from the baseline study showed that the watershed was below Class A standards in many areas (Overdorff, 1981).

With 80 percent of the contracted projects installed (Gillies, 1990a), the Surface Water Investigations Section of Ecology performed water quality monitoring on Johnson Creek (September 1988 - May 1989). Survey objectives were:

1. Assess the present water quality of Johnson Creek and its principal tributaries as related to state Class A standards.

2. Locate the source(s) of water quality problems, if any, and determine the respective water quality impact.

3. Compare historical water quality data to current conditions in an effort to assess the effectiveness of BMP implementation.

Study Area Description

The Johnson Creek watershed (13,450 acres) is in north central Whatcom County, Washington (Figure 1). It is bordered to the north by Canada and to the south by the Nooksack River. Johnson Creek, with an average annual discharge of 40-50 cfs, is a major tributary of the Sumas River, entering 1.4 miles from the Canadian border. Principal tributaries to Johnson Creek are: Squaw Creek, North Fork Creek (Pangborn Creek), and Sumas Creek. During high runoff periods the area is also drained by a network of ditches that discharge into Johnson Creek.

The climate in the watershed is influenced by Puget Sound to the west and the Cascades on the east. The mean annual rainfall is 47 inches with approximately 33 inches falling between October and March (Gillies *et al.*, 1981). By the end of October, the ground is usually saturated and any additional rainfall drains overland (Department of Conservation, 1960).

In general, land use in the Johnson Creek basin is dominated by agricultural practices. Agriculture is most intensive in the alluvial soil of the eastern half of the watershed and the flatter upland soils, and in the organic soils found in the northwest. Most of the farmland is used as pasture and hayland (80 percent) with some cropland interspersed (7 percent). The remainder is comprised of developed areas (7 percent), woodlands (5 percent), and permanent wetlands (1 percent) (Gillies *et al.*, 1981). The local economy is based predominantly on dairy farming which produces approximately 40 million gallons of dairy wastes per year (USEPA, 1988). The density of dairy farms in Whatcom County is the highest in Washington State (White, 1989).

The Johnson Creek watershed was divided into sub-drainages and sampled accordingly. A brief description of each sampling area follows: mainstem Johnson Creek originates just north of Everson and flows approximately 12 miles north-northeast until it enters the Sumas River; Squaw Creek, approximately 3.5 miles long, enters the mainstem at river mile (RM) 7.5; Pangborn Creek flows 2.5 miles before entering the mainstem at RM 6.6; Clearbrook Road ditch site crosses Clearbrook Road 1.2 miles west of the Lynden-Sumas Highway and enters Johnson Creek at RM 5.8; Sumas Creek, about two miles long, enters Johnson Creek at RM 1.2.

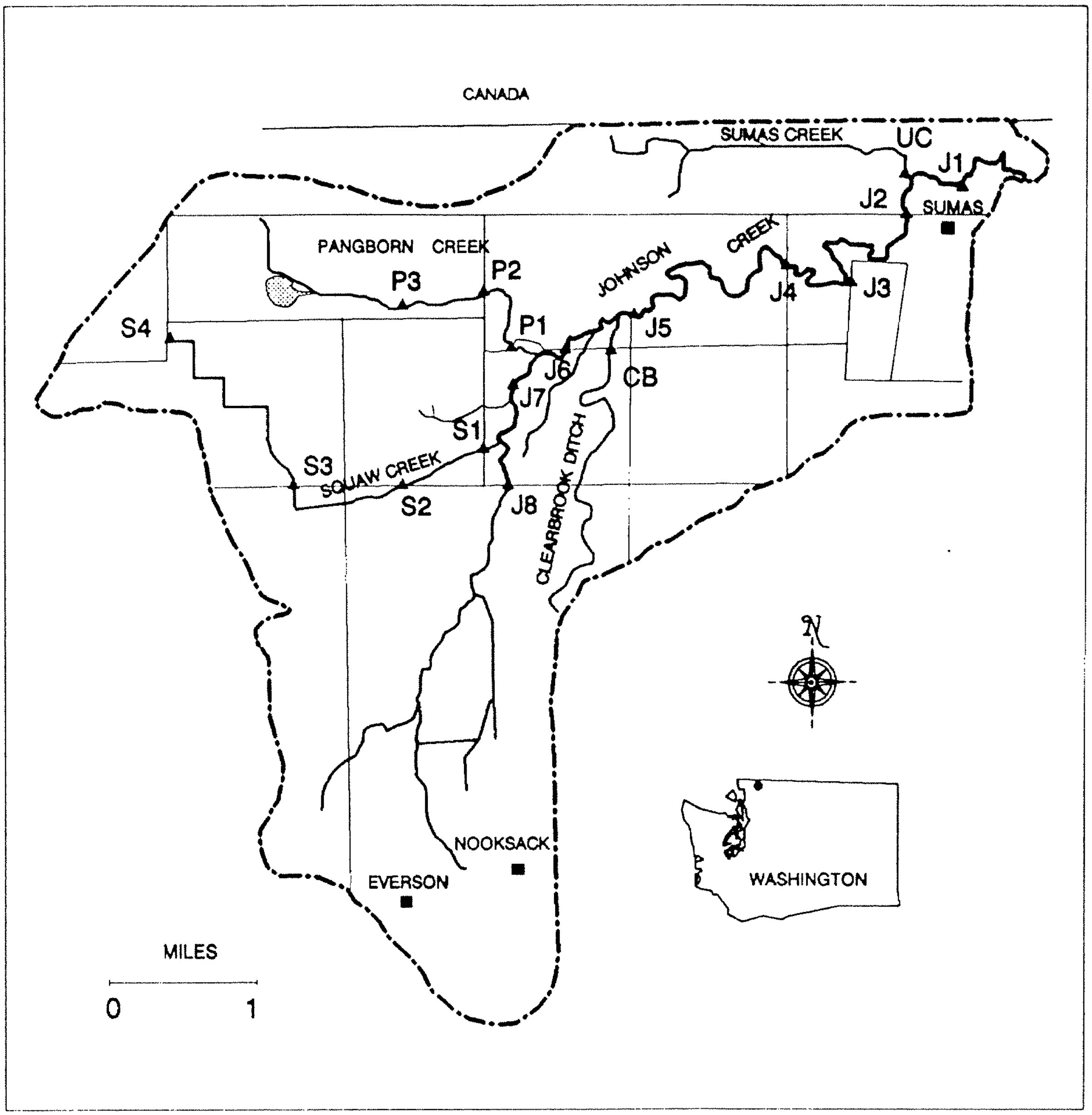

Figure 1. Station locations for the water quality monitoring study in 1988/89 in the Johnson Creek watershed, WA. Sampling sites are designated with the symbol ▲.

METHODS

Water quality sampling was conducted once a month in the watershed during September, October and December 1988, and January, February, March and May 1989. A total of 15 stations were sampled on Johnson Creek and its two principle tributaries, Squaw and Pangborn Creeks. Two additional stations were also sampled, one on Sumas Creek and one on the Clearbrook Road ditch (Figure 1). Station locations were based on sites used for the 1980/81 watershed study, and other potential loading sources to Johnson Creek (Table 1). Samples were mid-stream grabs. Parametric coverage and methodology are summarized in Tables 2 and 3.

Benthic macroinvertebrate communities were assessed in April 1989 at two sites (J2 and P3) in the Johnson Creek drainage (Figure 1). Replicate samples were taken at each site. A rapid bioassessment technique was used similar to that outlined by Plafkin *et al.* (1989)--a method for rapidly assessing the status of invertebrate communities. The following describes the sampled stations:

> Site J2, on mainstem Johnson Creek, was a deep run with laminar flow. Samples were collected approximately one foot from the shore. Substrate was muck with widely spaced cobble-sized rocks; periphyton was prevalent on the rocks collected.
>
> Site P3, on Pangborn Creek, had turbulent mid-stream flow. Sample rocks at site P3 were collected from mid-channel. The substrate was pebble-to-cobble-sized with dense filamentous alga growth.

At each site, three cobble-sized rocks were washed into a 600 um mesh sieve and the contents rinsed into a tray. Organisms were randomly taken from the tray for ten minutes; estimates of relative abundance were made by visual inspection of each sample. Invertebrates were preserved in 70 percent ethanol for subsequent identification to the family level using the taxonomic keys of Pennak (1978) and Merritt and Cummins (1984).

Precipitation can have a marked effect on water quality from nonpoint sources. Rainfall data were obtained from National Oceanic and Atmospheric Administration (NOAA) daily precipitation reports for the Clearbrook station in Whatcom County. These data were expressed as one- and three-day precipitation accumulation values.

Data Analysis

All references to significance refer to the accepted level of statistical significance ($p \leq 0.05$). Two-sample comparisons were made using the Mann-Whitney test. Correlations between parameters were evaluated using Spearman rank correlation analysis. Results below the analytical detection limit were included in calculations as one-half of the detection limit.

Quality Assurance

Samples for laboratory analysis were immediately iced, stored in the dark, and delivered to the EPA/Ecology Environmental Laboratory in Manchester, Washington within 24 hours. Nutrient samples were then delivered to Aquatic Research Incorporated for analysis.

Table 1. Station name and location description for the 1988/89 study. Corresponding station names used in the 1980/81 study are included.

LOCATION 1988/89	1980/81*	DESCRIPTION
Johnson Creek		
J8	#9	RM 8.0 where crosses Lynden-Sumas Highway; upstream side of bridge.
J7	-	RM 6.8; downstream side of foot bridge.
J6	-	RM 6.4 where crosses Clearbrook Road; upstream side of bridge.
J5	#4	RM 5.8 at the end of Nooksack Road; upstream side of bridge.
J4	#3	RM 3.5 where crosses Lynden-Sumas Highway, north of intersection with Clearbrook Road; upstream side of bridge.
J3	#2	RM 2.8 where parallels Hill Road; downstream side of private bridge.
J2	#1 (1980)	RM 1.4 where crosses Lynden-Sumas Highway at Lyons Park; upstream side of bridge.
J1	#1 (1981)	RM 1.1 at 3rd and Cherry Streets; upstream side of bridge.
Squaw Creek		
S4	#12	RM 2.7 where crosses Hammer Road; upstream side of bridge.
S3	#8	RM 1.4 where crosses Lynden-Sumas Highway, west of West Trap Line Road; upstream side of bridge.
S2	#11	RM 0.7 where crosses Lynden-Sumas Highway, east of West Trap Line Road; downstream side of bridge.
S1	#10	RM 0.2 where crosses Van Buren Road; upstream side of the two culverts.

Table 1. (continued).

LOCATION		DESCRIPTION
1988/89	1980/81*	
Pangborn Creek		
P3	#7	RM 1.5. Access is from Pangborn Road between Trap Line and Van Buren Roads.
P2	-	RM 0.7 where crosses Van Buren Road; upstream side of bridge.
P1	#6	RM 0.1. Access is from Clearbrook Road.
Sumas Creek		
UC	-	RM 0.05 downstream side of the culvert.
Clearbrook Road Ditch		
CB	-	RM 0.2 where crosses Clearbrook Road.

* Station from 1980/81 study which corresponds to the present sampling site.

Table 2. Water quality parameters measured during the 1988/89 Johnson Creek watershed study.

	SAMPLE SITES																
	Johnson Creek								Pangborn Creek			Squaw Creek				Sumas Creek	Clearbrook Ditch
Station	J1	J2	J3	J4	J5	J6	J7	J8	P1	P2	P3	S1	S2	S3	S4	UC	CB
River Mile (RM)	1.1	1.4	2.8	3.8	5.8	6.6	7.3	8.0	0.1	0.7	1.5	0.2	0.7	1.4	2.7	0.05	0.2
Parameter*																	
Discharge	X	-	-	X	-	-	X	-	X	-	X	X	-	X	-	X	-
Temperature	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
pH	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
Conductivity	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
D.O. **	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	-
TSS	X	-	X	X	-	-	X	X	X	-	X	X	-	X	X	X	-
Turbidity	X	-	X	X	-	-	X	X	X	-	X	X	-	X	X	X	-
Nutrients ***	X	-	X	X	-	-	X	X	X	-	X	X	-	X	X	X	-
COD	X	-	X	X	-	-	X	X	X	-	X	X	-	X	X	X	-
BOD_5	X	-	-	-	-	-	-	X	-	-	-	-	-	-	-	-	-
FC Bacteria	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Macroinvertebrates	-	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-	-

* D.O. = dissolved oxygen; TSS = total suspended solids; COD = chemical oxygen demand; BOD_5 = biochemical oxygen demand; FC = fecal coliform bacteria

** Sites J2,3,5,6; P2; S2,4 were not analyzed for D.O. after January

*** Nitrate+nitrite (NO_3+NO_2-N), ammonia (NH_3-N), total phosphorus (TP-P)

Table 3. Parametric coverage and methodology employed in the Johnson Creek watershed study, 1988/89.

Parameter	Analytical Method	Reference(1)	Laboratory(2)
Discharge	Marsh-McBirney, Swoffer, or Gurley	Ecology	Field
Temperature	Mercury	-	"
Specific Conductance	Beckman Model	-	"
pH	Beckman Model	-	"
Dissolved Oxygen	Winkler, Azide Modified	SM 421A	"
Turbidity	Nephelometric	SM 214A	Ecology
Total Suspended Solids	Gravimetric	SM 209C	Ecology
Nitrate+Nitrite (as Nitrogen)	Cadmium Reduction	EPA 353.2	Aquatic Research
Ammonia (as Nitrogen)	Phenate	EPA 350.1	Aquatic Research
Total Phosphorus (as Phosphorus)	Ascorbic Acid	EPA 365.1	Aquatic Research
Fecal Coliform Bacteria	Membrane Filter	SM 909C	Ecology
Chemical Oxygen Demand	Reflux Digestion	SM 508C	Ecology
Biochemical Oxygen Demand,5-day	Bioassay	SM 507	Ecology

(1) Ecology: Guidance for Conducting Water Quality Asessments, Ecology, 1989.
SM: Standard Methods for the Examination of Water and Wastewater, 16th ed., APHA *et al.*, 1985.
EPA: Methods for Chemical Analysis of Water and Wastes, USEPA 600/4-79-020, 1983.

(2) Ecology: EPA/Ecology Environmental Laboratory, Manchester, WA
Aquatic Research: Aquatic Research Incorporated, Seattle, WA

Randomly selected replicate samples were taken at ten percent of the sites to assess both field and analytical variability. The average of replicated samples was reported when appropriate and used in subsequent calculations. Relative percent difference (RPD), the difference between two replicates expressed as a percentage of their mean, was used to measure the similarity of replicates. Results were illustrated using box and whisker plots (Figure 2). Box plots graphically depict the distribution of a series of data points (McGill *et al.*, 1978). The box itself represents the interquartile range (IQR), with the median displayed as a line within the box. Vertical lines project above and below the box to the maximum and minimum data values; values which exceed the IQR by 1.5 times are plotted individually. Figure 2 shows the distribution of RPDs for replicated parameters. All but two samples were acceptable. Two replicate pairs for nitrate had high variability. Site S1, in January, had nitrate concentrations of 18.02 mg/L and 3.72 mg/L yielding an RPD of 132 percent. After reviewing trends on Squaw Creek during January and other months, the 3.72 mg/L value was omitted from the data set. The second aberrant replicate pair for nitrate was for site S3 in February. The replicate concentrations were 4.28 mg/L and 13.10 mg/L with a RPD of 101 percent. The 13.10 mg/L was omitted from the data set following similar logic.

Three other parameters showed some apparent variability. The variability in fecal coliform bacteria (FC) replicates most likely resulted from their natural patchiness. The high RPDs seen in ammonia and total suspended solids (TSS) were determined to be insignificant because as replicates approach the detection limit the RPD is artificially high (e.g. replicate values of 1 and 2 mg/L, yield a RPD of 67 percent).

RESULTS AND DISCUSSION

Precipitation

Figure 3 compares the ten year average rainfall to rainfall during 1988/89 and 1980/81 between the months of September and May. Information on precipitation characteristics for the sampling dates in 1988/89 are contained in Table 4. Based on precipitation information, all water quality data were considered representative of the wet season.

Rainfall in 1988/89 was highest in January. A total of 6.80 inches fell during the month with the highest daily total falling on the day of sampling (1.18 inches) and two days prior to sampling (1.16 inches). The mainstem and the sampled tributaries had their highest discharge in January. The high one-day and three-day rainfall accumulations support the visual observation of a runoff event (Table 4). Flow and precipitation were positively correlated throughout the study period.

Historical Comparison

Figure 3 graphically compares 1980/81, 1988/89, and the ten year monthly mean precipitation for the months September through May. Although cumulative rainfall during the study periods, October through May, did not vary considerably from the ten year mean (1980/81 = 27.1 inches; 1988/89 = 31.8 inches; ten year mean = 28.6), there was a marked difference in precipitation between 1980/81 and 1988/89 during the months of October, January, and February. The variability in precipitation is of considerable importance in the

Table 4. Precipitation characteristics for the Johnson Creek watershed during the 1980/81 and 1988/89 study periods. Data analyzed were taken only from months sampled both years.

	MONTH					
YEAR	OCT	DEC	JAN	FEB	MAR	MAY
3-DAY						
1980/81	0.42	0.04	0.35	0.41	0.23	0.70
1988/89	0.00	0.87	2.56	0.46	0.64	0.37
1-DAY						
1980/81	0.09	0.04	0.14	0.00	0.23	0.56
1988/89	0.00	0.55	1.18	0.39	0.11	0.37

3-DAY = 48-hour cumulative precipitation, plus precipitation received on the sampling day (inches).

1-DAY = 24-hour cumulative precipitation on the sampling day (inches).

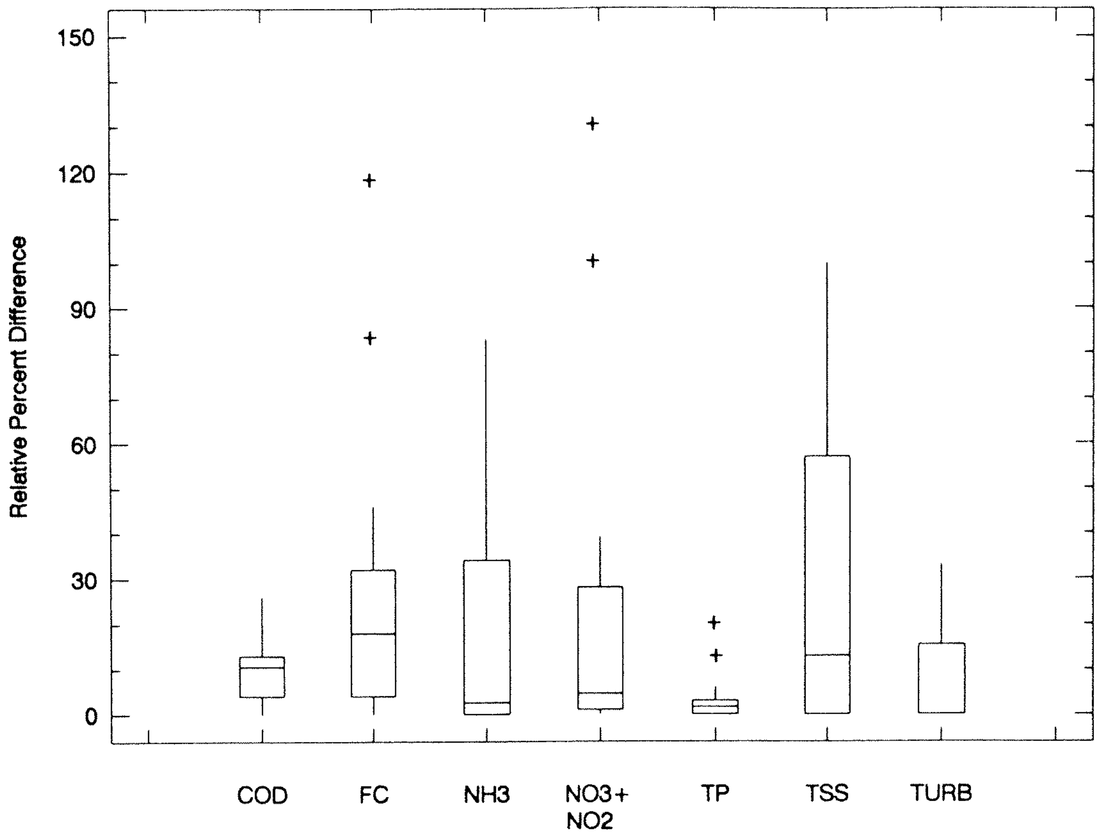

Figure 2. Comparison of replicate samples from the Johnson Creek watershed study 1988/89. (Parameter abbreviations are explained in Table 2.)

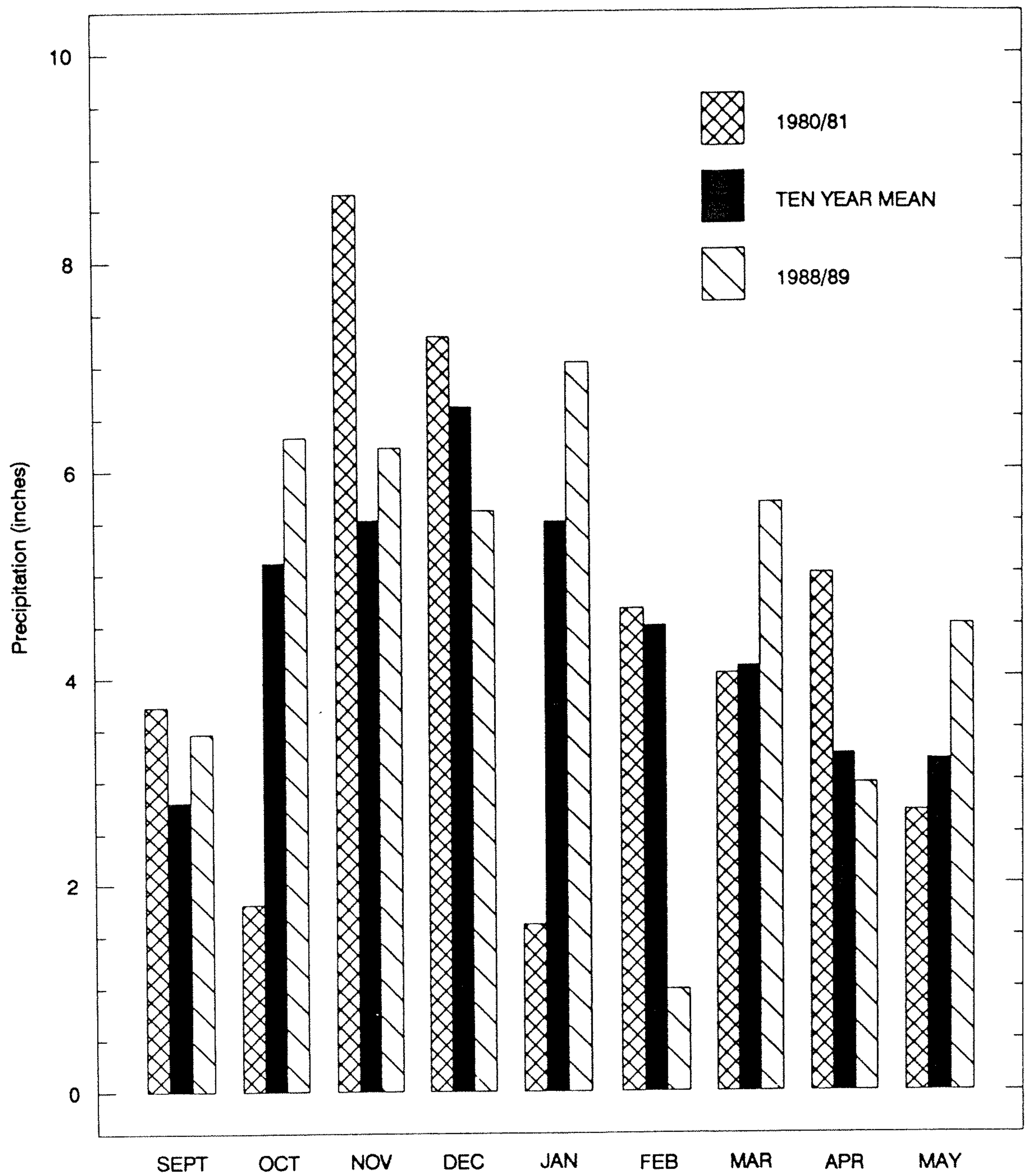

Figure 3. Monthly precipitation data in the Johnson Creek watershed between the months of September and May during 1980/81 and 1988/89 compared with the ten year mean.

interpretation of nonpoint data. Due to high rains in October 1988, the regular manure spreading schedule was delayed resulting in spreading during wet weather (Gillies, 1990a). This delay may be the primary cause of high nutrient and FC levels found in the 1988/89 study (Appendix A).

Dissolved Oxygen

To meet Washington's Class A standard for dissolved oxygen (D.O.) in freshwater, concentrations must exceed 8 mg/L. Violations in D.O. concentration occurred throughout the watershed during the 1988/89 study (Appendix A).

Dissolved oxygen concentrations in mainstem Johnson Creek violated the Class A criterion 91 percent of the time. This resulted from the combined effects of several factors, e.g. low flow, low turbulence, and increased organic runoff.

Biochemical oxygen demand (BOD) was measured at the upstream (J8) and downstream (J1) sample sites. The higher BOD values tended to correspond with the low D.O. values in September, January, and February, especially for site J8. BOD data are limited; however, it appears that the BOD in the water column influenced the oxygen regime.

Instream concentrations of oxygen are affected by sediment oxygen demand. The oxidation of organic matter and, to a smaller degree, invertebrate mixing of the sediments exert a demand on the overlying waters. The rate of sediment oxygen demand relates to organic sources, sedimentation/scouring, decomposition, and vertical transport at the sediment/ water interface (Hatcher, 1986). The combination of a predominately agricultural land use, meandering flow with low velocities, and its soft 'mucky' bottom presents a situation where sediments could be exerting a large oxygen demand on the surface waters of mainstem Johnson Creek.

Squaw Creek experienced a 27% violation of the D.O. criterion; D.O. tended to increase midreach then decreased further downstream. Oxygen concentrations in Squaw Creek violated the Class A water quality standard predominantly at site S1 when percent saturation was also low. During low flow periods, e.g., early fall, the dense growth of reed canary grass likely decreases velocity and promotes sedimentation of organic matter, making it available to oxygen consuming microbes. This low D.O. condition would be exacerbated by macrophyte decay later in the season. Due to the sedimentation which occurs at this site, SOD could also be high.

The D.O. in Pangborn Creek increased downstream. Site P3 was consistently below 8 mg/L with site P2 below standard 75% of the time. Site P1 never violated the standard. The D.O. at the upstream sites on Pangborn Creek and the 56% overall D.O. violation on the tributary are primarily the result of natural conditions; the creek originates from a series of bogs and marshes which are characteristically low in oxygen. Although additional organic loading likely occurs, the turbulence of the creek is enough to reaerate the water as it progresses toward the mouth.

Sumas Creek violated the D.O. standard in December, February, and March, and had oxygen saturation values below 60 percent during these months. This oxygen depression is coincident with high COD, FC, NH_3, and total phosphorus (TP) concentrations and indicates a pollution source.

Historical Comparison

Median D.O. concentrations in mainstem Johnson Creek decreased at every site relative to the earlier study (Appendix B). Additionally, a statistically significant decrease in the percent saturation of D.O. in mainstem Johnson Creek was found (Table 5). Although BMPs have been implemented in the watershed, manure is still entering the channel. Herd size has increased at some of the farms without concurrent BMP alterations (Gillies, 1990a). This may be a source for increased organic input.

Conversely, there has been significant improvement in the D.O. concentrations on Pangborn Creek (Appendix B). Concentration and percent saturation both increased at site P1 and P3 in 1988/89 when compared to the data from the 1980/81 study (Table 5). A major alteration since 1980 has been the hand removal of debris from the creek by Department of Fisheries personnel. This dropped the channel approximately 1.5 feet in some areas (Gillies, 1990a). The removal of debris from the channel could result in increased velocity and turbulence, allowing for greater reaeration.

Chemical Oxygen Demand

COD measures the oxygen equivalent of organic matter in a sample that is oxidized by a strong chemical (APHA, 1985). There are no Class A standards for this parameter. COD was strongly correlated with NH_3 and TP in the watershed and moderately correlated to TSS.

	r	p (≤)
COD -NH_3	0.83	0.001
-TP	0.81	0.001
-TSS	0.63	0.001

COD concentrations increased in mainstem Johnson Creek in mid-winter. However, there was little difference between upstream and downstream sites during the same time period. This lack in concentration variability combined with increased flow downstream indicates increased COD loading along the mainstem.

During September and October, the uppermost site on Johnson Creek (J8) had more than two times the COD concentrations of the downstream sites (Appendix A). Concurrently, TSS and conductivity were very high, D.O. was low, and nitrates were uncharacteristically lower than downstream sites. Ammonia values at J8 were also high (the COD test, however, does not oxidize ammonia (APHA, 1985). From the available data, it appears that there is a pollution source in the upper basin during base flow periods.

Levels of COD and TSS were moderately correlated in Johnson ($r=0.77$, $p \leq 0.001$), Squaw ($r=0.66, p \leq 0.01$), and Pangborn Creeks ($r=0.60$, $p \leq 0.01$). Increases in COD most likely reflect increases in the volatile organic component of suspended solids. The 1980/81 study did not include COD sampling.

Table 5. Comparison of water quality in Johnson Creek watershed between 1980/81 and 1988/89 during the months Oct, Dec, Jan, Feb, Mar, and May. Data from Appendix C.

Location	Parameter	Median Concentration (mg/L) 1980	1988	Significance Level* ($p \leq$)
Johnson Creek				
All Sites	DOSAT**	64	57	0.05
	NO_3	2.61	4.70	0.001
J4	NO_3	2.62	4.55	0.05
J1	pH	7.3	7.1	0.05
	NO_3	2.64	4.40	0.05
Squaw Creek				
All Sites	TURB***	6	2	0.01
	NO_3	3.82	4.76	0.01
	TP	0.05	0.16	0.05
S4	NO_3	4.51	7.60	0.01
Pangborn Creek				
All Sites	TURB	2	1	0.05
	NO_3	5.43	8.62	0.01
	D.O.	6.25	8.75	0.05
P3	D.O.	4.0	5.5	0.001
	DOSAT	33	47	0.05
	NO_3	5.39	10.00	0.05
P1	D.O.	8.9	10.4	0.01
	DOSAT	73	88	0.05
	TURB	3	1	0.05
	NO_3	5.43	8.15	0.05
All Watershed Sites	FC****	200	410	0.05
	TURB	6	2	0.01
	NO_3	3.28	4.80	0.001
	TP	0.11	0.23	0.01

* Based on large-sample approximation of the Mann-Whitney statistic, confirmed by small-sample tests where appropriate (NCASI, 1985). Tests whether median values from the two studies are significantly different.

** Percent saturation of dissolved oxygen.

*** Turbidity values are reported in NTU.

**** # organisms/100 mL

Fecal Coliform

The Class A standard for state water quality specifies that FC are not to exceed a geometric mean of 100 organisms/100 mL, with not more than 10 percent of the samples exceeding 200 organisms/100 mL.

In 1988/89, FC concentrations in the Johnson Creek watershed were high, variable, and regularly violated the Class A standard. The highest values in the basin were found in February, except in the Clearbrook Ditch which had an extremely high concentration in October (Table 6).

The highest mean concentrations were found in February. Precipitation was less than half of the ten year mean monthly value for February (Figure 3) and flows had subsided; however, loading to the system was at its highest at all sites except J4 and UC (Appendix C). Manure spreading was observed on frozen, snow covered fields adjacent to Johnson Creek in February. This likely resulted in direct entry of manure slurry.

Table 6. Geometric means of 1988/89 fecal coliform bacteria (#/100 mL) for the Johnson Creek watershed.

	DATE						
TRIBUTARY	9/88	10/88	12/88	1/89	2/89	3/89	5/89
Johnson Creek	232	167	527	1103	2954	198	488
Pangborn Creek	150	421	1054	246	1566	56	344
Squaw Creek	498	131	241	241	2556	25	680
Sumas Creek*	310	150	8000	2498	4300	800	320
Clearbrook Ditch*	23000	42000	2000	5300	8900	1100	530

* Represents single monthly observation.

FC concentrations were not correlated with flow on the mainstem or tributaries. Sites were analyzed individually to see whether combining sites masked the correlation, but this was not found. The relationship of fecals to discharge is not always quantifiable. Other factors such as temperature, hydrologic proximity of pollution sources, livestock management practices, wildlife activity, fecal deposition age, and channel and bank storage, affect bacterial densities in runoff (Baxter-Potter, 1988). The other possibility could be that FC are entering the system directly, e.g. slurry sprayed directly into the waters, rather than being dependent on runoff.

Both Clearbrook ditch and Sumas Creek have farmers which are not participating in the BMP program (Gillies, 1990a). FC were consistently and exceptionally high in Clearbrook ditch (CB) (Appendix A). Although the direct impact of Clearbrook ditch on Johnson Creek was not quantified due to lack of flow data, this site had the highest FC count in the watershed; the October value was 42000 organisms/100 mL. Sumas Creek (UC) also had high FC values especially mid-winter. Figure 4 illustrates Sumas Creek's relative loading. The high values at site UC may be due to improperly managed manure; livestock have also been observed upstream on the creek bank.

FC concentrations (Table 6) and loadings dropped in March throughout the watershed, relative to December through February; Squaw and Pangborn Creeks met the Class A standard this month. Low values could be the result of "clean" fields--the manure having washed off previously--or reduced spraying due to emptied manure-storage lagoons.

Historical Comparison

The FC data for the entire watershed were pooled and analyzed, a significant increase FC concentrations were observed from 1980/81 to 1988/89. This is not surprising since increased sample size increases the ability to discern differences. The available data indicate that the FC increases seen in the watershed may be predominately due to the tributaries. Using the Mann-Whitney test on pooled data from Squaw and Pangborn Creek, there was a statistically significant increase in FC concentrations from 1980/81 to 1988/89 ($p = 0.05$).

When looking at the individual creeks, as reported in Table 7, the geometric mean and median values for FC on mainstem Johnson Creek do not show a noticeable change since the 1980/81 study. Mean concentrations of FC on Squaw and Pangborn Creeks increased between the monitoring years, though not significantly.

From Table 8 it can be seen that during both the 1980/81 and 1988/89 study periods the Class A standard was violated every month on mainstem Johnson Creek.

pH

The water quality standard for pH in Class A freshwater systems is between 6.5 to 8.5 standard units. Mainstem Johnson Creek usually met this standard with a median pH of 7.0 observed during the 1988/89 monitoring study. The pH fell below standard once during the study in September at site J6 (Appendix A).

The median pH on Squaw Creek was 6.9. The pH dropped below standard at the upstream sites, S4 and S3, in January, and again at S3 during February (Appendix A).

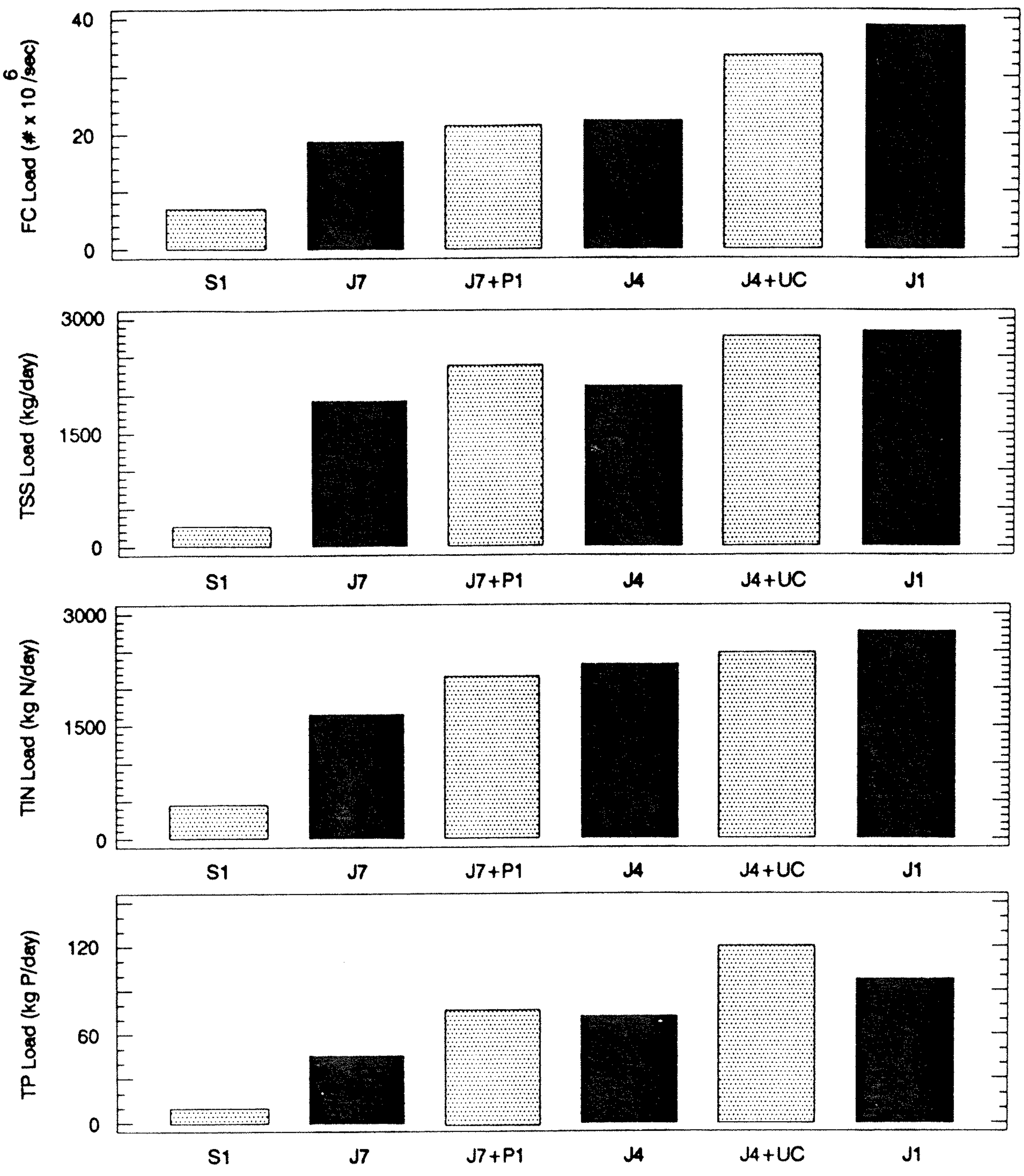

Figure 4. Mean loads for fecal coliform bacteria, total suspended solids, total inorganic nitrogen ($NO_3+NO_2+NH_3$), and total phosphorus for the Johnson Creek mainstem (including tributary contributions) during the 1988/89 study period.

Table 7. Fecal coliform bacteria geometric mean and median values for the 1980/81 and 1988/89 Johnson Creek watershed studies. Data from the months Oct, Dec, Jan, Feb, Mar, and May.

Site	GEOMETRIC MEAN (# organisms/100 mL) 1980/81	GEOMETRIC MEAN (# organisms/100 mL) 1988/89	MEDIAN (# organisms/100 mL) 1980/81	MEDIAN (# organisms/100 mL) 1988/89
Johnson Creek				
J8	605	565	800	865
J5	356	674	250	655
J4	202	521	180	360
J3	559	495	590	430
J2	290L	581	L	600
J1	1696	667	2100	600
All Sites	552	580	460	485
Squaw Creek				
S4	61	109	27	115
S3	89	123	85	140
S2	146	830	155	1215
S1	206	396	300	485
All Sites	114	266	120	210
Pangborn Creek				
P3	127	333	135	310
P1	457	512	150	625
All Sites	241	413	135	535
All Watershed Sites	244	425	200*	410

* = Indicates a statistically significant difference ($p \leq 0.05$) between 1980/81 and 1988/89 medians as measured by the Mann-Whitney non-parametric test.

L = Not enough data points for statistical review; $n <= 2$.

Pangborn Creek violated the Class A standard in September and January for sites P3 and P2. The downstream site also had lowest values during these months, but didn't drop below the standard. The median pH for the tributary was 6.9. There was a strong rank correlation between D.O. and pH ($r=0.84$, $p\leq0.001$). The low pH values found on the upper reaches of Pangborn Creek are the likely result of organic acids originating from the wetland area (Pangborn Lake) upstream. This would explain the strong correlation with D.O. which also is naturally low when coming from ground water and wetland sources.

In summary, the standard for Class A waters was sometimes violated within the watershed, however, exceedances were infrequent and likely due to natural conditions. The pH range which is not directly lethal to fish is 5-9 (USEPA, 1986); this range was not exceeded.

Table 8. Mean monthly fecal coliform concentrations (#/100 mL) for Johnson, Squaw and Pangborn Creeks for the 1980/81 and 1988/89 study periods.

Location	Year	Month					
		October	December	January	February	March	May
Johnson Creek	80/81	836	350	480	648	284	3464
	88/89	151	758	1200	2855	288	337
Squaw Creek	80/81	293	50	167	32	246	322
	88/89	131	241	241	2556	26	680
Pangborn Creek	80/81	491	42	134	92	363	2107
	88/89	462	1082	246	1549	68	383

Historical Comparison

The creeks appear to have experienced a slight decrease in pH from 1980/81 to 1988/89 (Appendix B). However, only the downstream site (J1) on Johnson Creek decreased significantly, dropping from a median value of 7.3 to 7.1 (Table 5). The decrease in pH throughout the drainage may reflect short-term environmental fluctuations rather than a long-term trend.

Total Suspended Solids

TSS were elevated in the watershed during mid-winter months. Loading was highest in January, when increased flow due to the storm event probably introduced material from runoff and resuspended sediment.

TSS on Johnson Creek was strongly correlated to turbidity, and moderately correlated to flow, ammonia, and TP:

		r	$p(\leq)$
TSS	-TURB	0.91	0.01
	-FLOW	0.79	0.001
	$-NH_3$	0.77	0.001
	-TP	0.74	0.001

The maximum TSS value in the watershed, 61 mg/L, was found at site J8 in October. Flow was still relatively low in the drainage and there had been only a trace of rain in the preceding few days (NOAA, 1988). The specific source of TSS is unclear, however, the data support the possibility of manure input. The site experiences elevated conductivity, FC, turbidity, NH_3, and depressed D.O.

There appears to be a high sedimentation rate between site J8 and site J7 (Figure 5): flow information was not available for J8 to further clarify sedimentation rates.

Sumas Creek (site UC) regularly had high suspended solids, particularly in mid-winter months. The loading from Sumas Creek into Johnson Creek was greater than either of the other tributaries (Appendix C and Figure 4). The 1980/81 study did not include TSS sampling, therefore, no historical comparisons can be made.

Turbidity

Turbidity followed the same general trend as TSS on Johnson Creek (Appendix A). Turbidity was highly correlated with TSS, flow, and NH3; and moderately correlated with TP:

		r	$p(\leq)$
TURB	-TSS	0.91	0.01
	-FLOW	0.86	0.001
	$-NH_3$	0.84	0.001
	-TP	0.65	0.001

As observed with TSS, the upstream site (J8) experienced fall concentrations noticeably higher than sites downstream. The maximum turbidity value in the watershed was 110 NTU at J8 in October. Turbidity tended to decrease from site J8 to J7 and showed a stable or slightly increasing trend further downstream. On the tributaries, turbidity generally increased downstream with higher values occurring in January and February. Turbidity and NH_3 were strongly correlated in Squaw Creek ($r=0.82$, $p\leq 0.001$) and Pangborn Creek ($r=0.86$, $p\leq 01$).

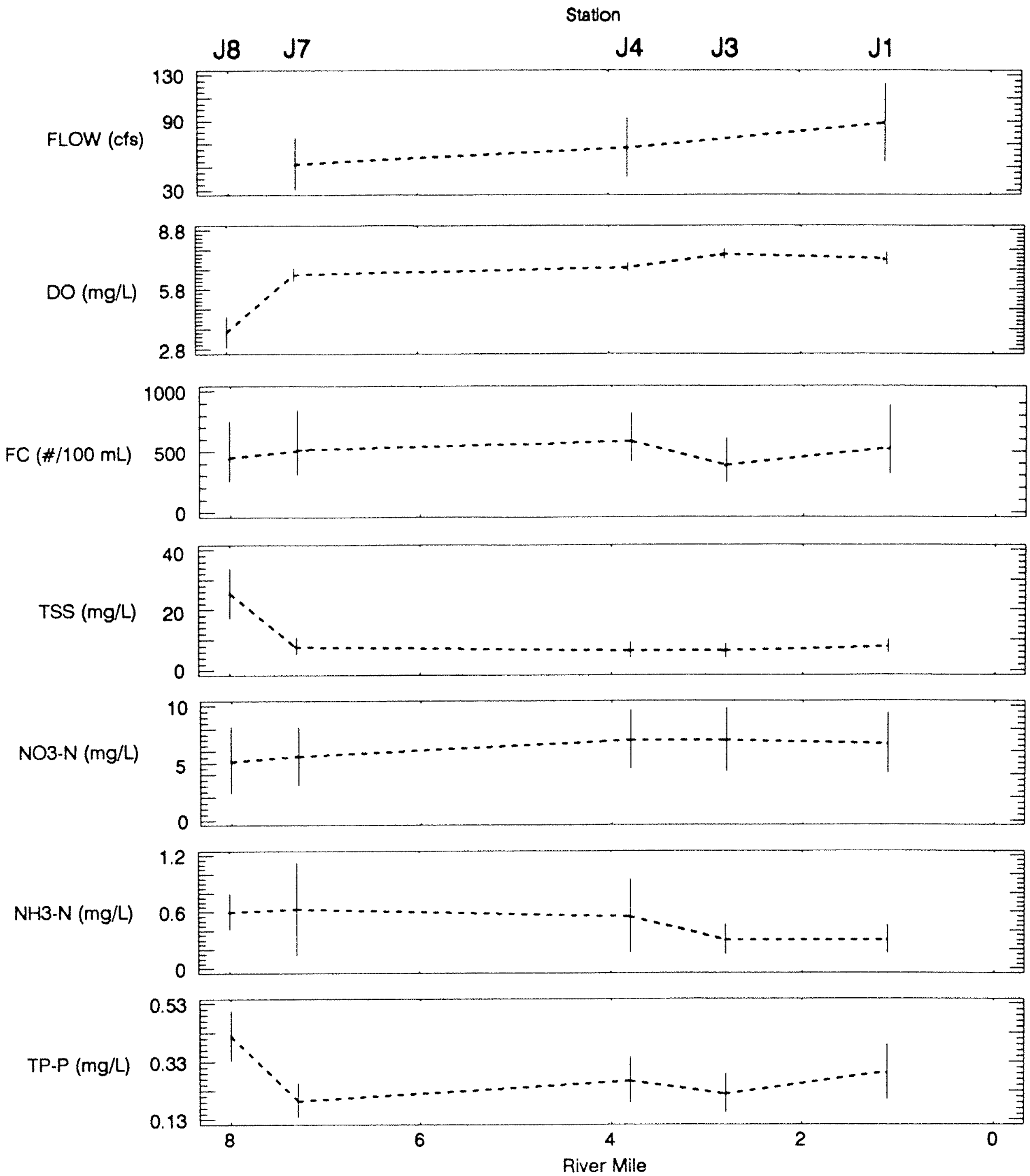

Figure 5. Mean flow and mean concentrations of dissolved oxygen, fecal coliform bacteria, total suspended solids, nitrate, ammonia, and total phosphorus on mainstem Johnson Creek for the 1988/89 study period. The corresponding standard errors are shown.

Historical Comparison

There was a significant decline in turbidity from 1980/81 and 1988/89 in Squaw and Pangborn Creeks, and in the watershed as a whole (Table 5). This is most likely the result of the extensive fencing program implemented to exclude livestock from the creeks (Gillies, 1990c). The reduction of livestock access and increased bank revegetation (resulting from reduced trampling) would decrease erosion and thus turbidity.

Nutrients

Nitrate concentrations were exceptionally high in January on the mainstem and on Squaw and Pangborn Creeks, as shown in the following table:

	Nitrate (mg N/L)					
	January 1989			Other Months 1988/89		
	min	max	mean	min	max	mean
Johnson Creek	19.90	23.43	21.73	0.01	5.00	3.75
Squaw Creek	18.02	54.62	36.56	2.30	10.16	4.94
Pangborn Creek	32.05	38.60	35.32	4.50	12.70	9.31
Sumas Creek	2.73			3.30	5.50	4.47

Although there is no Class A water quality standard to compare to these nitrate values, a perspective can be gained when considering that weak-to-medium strength domestic sewage has a total nitrogen-N concentration of 20-40 mg N/L (Metcalf & Eddy, 1972). Additionally, the drinking water standard of 10 mg/L was violated

January nitrate concentrations in Johnson, Squaw, and Pangborn Creeks increased by more than four times from the previous month (Appendix A). A correlation was not found between nitrate and flow over the study period, but the elevated nitrate levels in January most likely were linked to the runoff event. The rains may have carried aged dairy wastes from adjacent agricultural lands into the creeks. Nitrate levels seen in the Johnson Creek watershed were higher than those found in other Western Washington lowland streams (Tetra Tech, 1989). Lab verification of the data suggests that the values represent the situation as it existed; however, due to the 50 part dilution necessary for analysis, accuracy may have been affected.

Nitrate concentrations in Sumas Creek in January were much lower that other sites and may stem from the fact that there are only two farms in the sub basin. However, the creek did experience elevated FC, NH_3 and TP concentrations, relative to the rest of the watershed (Appendix A). This suggests that fresh manure may have been entering the water rather than aged manure which is higher in NO_3. Additionally, the absence of high nitrate on

Sumas Creek during January appears to rule out the possibility of sample bottle contamination.

Unionized ammonia levels (Appendix A) were found to exceed the chronic four day criterion for salmonids (USEPA, 1986) during February in the entire watershed. High ammonia levels may have been caused by direct input of manure slurry. High COD values for this month also suggest an organic pollutant source: COD had a strong correlation to NH3 ($r=0.84$, $p \leq 0.001$).

TP concentrations also tended to peak during February in the entire watershed. There was a moderate to strong correlation of TP and TSS on mainstem Johnson Creek ($r=0.74$, $p \leq 0.001$). This is expected since phosphorus adsorbs to sediment particles. This correlation diminished on Squaw Creek ($r=0.54$, $p \leq 0.05$) and disappeared on Pangborn Creek. This reduction may be related to small sample size or the decrease in turbidity that was observed on the two tributaries.

The high NH_3 and TP concentrations found in February could be a result of fresh waste manure entering the creeks.

Historical Comparison

Median nitrate concentration increased significantly between 1980/81 and 1988/89 at many sites throughout the watershed (Table 5). The episodic flush of January 1989 was suspected as a cause of the significant nitrate increase. However, when the January data were removed from the data base, nitrates remained significantly higher in both mainstem Johnson Creek and Squaw Creek. This finding suggests that nitrate loading has increased over the past decade. TP levels in the watershed also increased significantly between the two study periods, suggesting that phosphorus loading in the drainage has increased as well (Table 5).

Macroinvertebrates

Eleven families of macroinvertebrates were found at each of the two sample sites (J2 and P3). There were some taxonomic similarities (Appendix D); however, direct comparison of macro-invertebrate populations between the sites is limited by the dissimilarity in aquatic habitat. Therefore, it was not possible to discern land use impacts from changes in habitat.

An abundant population of *Chironomidae* (true flies) at site J2 suggested the availability of adequate food in the form of deposited detrital material. The common occurrence of *Baetidae* (mayfly) and the presence of *Lumbriculidae* (aquatic worm) suggest sediment rich in organics, which is supported by the visual observation of a depositional shore area at this site. The occurrence of fewer *Simuliidae* (black flies) and *Culicidae* (mosquitoes) could be related to depleted oxygen levels (Appendix A). An individual of the family *Gammaridae* (scuds) was found at this site. Usually they prefer unpolluted waters with constant physical and chemical conditions (Pennak,1978); low D.O. and high nutrient levels at site J2 indicate organic enrichment which are contradictory to this family's preferred environment. However, Gaufin (1958) found some taxa of *Gammaridae* to be moderately tolerant of organic pollution which may explain the rare occurrence.

The macroinvertebrates which were abundant at P3 were indicative of an organically enriched system (Appendix D). Individuals from the family *Planorbidae* (discoidal snail) were present. These pulmonate snails are usually limited to aquatic environments with adequate D.O. concentrations (Pennak, 1978). Presumably, those present at this site were exploiting oxygenated riffle areas.

Historical Comparison

Trend analysis of the macroinvertebrate data was not feasible between the study years. The site location on lower Johnson Creek differed between the investigations of 1980/81 and 1988/89. Differences in collection methodology also limited comparison.

Pollution Rating

A method for rating pollution potential was developed by the Soil Conservation Service in Whatcom County as a means to objectively evaluate nonpoint pollution problems associated with dairy farming. This rating system provides a means for comparing the relative severity between individual farms or watersheds. The following explains the rating scheme as described by Gillies (1990b):

> The overall pollution rating for a farm is based on the amount of manure nitrogen produced by livestock as well as the weighted average of nine evaluation factors (the nine evaluation factors and the relative weight of each is shown in Appendix E). The Pollution Rating for an individual farm is determined by calculating the ratio of the weighted-average-rating for the farm (r), to the maximum rating (which is always six), and multiplying that by the maximum potential pollution rating. This is expressed in the following equation:
>
> Pollution Rating = $r/6 \times 6(6 \times \text{NITRO})^{1/2}$
> Where: r = weighted average of the nine questions
> NITRO = pounds of nitrogen produced per day by the farms livestock (0.4 lbs per day for each 1000 lb animal unit)

The Pollution Ratings are categorized by their degree of severity: <30=minimal; 31-40=small; 41-60=moderate; >60=severe.

During 1981 through 1984, the Whatcom County Conservation District completed pollution ratings on 49 farms in the Johnson Creek watershed. The average rating was 72, with 55 percent of the inventoried farms having pollution ratings greater than 65. These results indicated the potential for severe dairy waste impacts to water quality (Gillies, 1990b).

With the implementation of 91 percent of the planned water quality improvements (BMPs), the Conservation District re-rated 41 farms in April 1990 (eight farms participated in the dairy buy-out program and were not re-rated). The average pollution rating dropped to a moderate rating of 44 (Gillies, 1990b). This suggests the potential for improvement in water quality as a result of BMP implementation, however, the apparent improvement is not reflected in the overall 1988/89 water quality data.

CONCLUSIONS

- Sources of pollution continue to affect water quality in the entire Johnson Creek watershed. This is especially apparent at sites UC, CB, and J8.

- Precipitation in late October 1988 resulted in manure management difficulties and wet weather manure spreading. With continued wet weather spreading, water quality improvement may never reach the Class A standard desired.

- Violations in D.O. concentrations occurred throughout the watershed in 1988/89. There was a significant decrease from 1980/81 to 1988/89 in D.O. percent saturation in mainstem Johnson Creek. Although Pangborn Creek had low D.O., there was significant improvement in oxygen concentrations between the two study periods.

- COD in the watershed was strongly correlated to NH_3 and TP, and moderately correlated to TSS. Increases in COD most likely reflected increases in the volatile organic component of suspended solids. It appears that these parameters are related to introduction of fresh waste material.

- FC concentrations in the watershed regularly violated the standard for Class A waters. FC levels were also found to be significantly greater in 1988/89 than in the earlier study; this appears to be predominately due to high FC concentrations in Squaw and Pangborn Creeks. Concentrations were especially high at sites CB and UC, areas where there are farms which did not participate in the BMP program. These findings suggest that current dairy waste management is not adequate in the watershed.

- The watershed had a significant decrease in turbidity between the 1980/81 study and the present study period. This is probably the result of increased fencing which prevented livestock access to the creeks and allowed for bank revegetation.

- Nitrate and TP concentrations increased significantly between the 1980/81 and 1988/89 monitoring efforts.

- Nitrate concentrations were highest in January during the runoff event when aged manure was being washed off the fields. High concentrations of TP and toxic levels of ammonia were found in February. Manure spreading on frozen fields was observed during the February sampling day. Wastes may have entered the creeks.

- The Pollution Rating Index for the watershed has improved somewhat, dropping from 72 (severe) to 44 (moderate) over the past decade. The 1990 rating may be conservative since farms which did not participate in the BMP program were not rated. These farms have manure management problems which continue to affect water quality.

- In general, water quality in the Johnson Creek Basin is impaired. BMPs, as implemented to date, have not improved water quality, however, without BMPs the resource could have shown drastic deterioration after ten years.

RECOMMENDATIONS

- The high FC concentrations seen throughout the watershed justify further on-site investigation into possible pollution sources.

- From the FC data collected, as well as from visual observation, it is likely that dairy wastes are directly entering the Clearbrook ditch. The source(s) need to be identified and remedied.

- The apparent pollution source near the upstream site on Johnson Creek (J8) should be investigated during low flow periods.

- Alternatives to wet weather manure spreading need to be pursued if improvements in water quality are to be realized. Practical constraints limiting spreading during the dry season need to be further evaluated i.e., adequate availability of applicators.

- Continue to encourage farmers in the watershed to use sound waste-manure management to prevent its introduction to surface water.

- Inform Ecology's Northwest Regional Office Dairy Waste Inspector of problem areas in the watershed. If necessary, activate enforcement channels available through the Memorandum of Agreement between Ecology and the Conservation District when voluntary cooperation in properly managing manure is not obtained.

- Farm management plans should be dynamic, e.g., if a farm has an increase in herd size, there should be an appropriate increase in manure storage capacity.

- Johnson Creek watershed currently does not meet Class A standards. After current problems are investigated and remedies initiated a follow-up study should be considered to monitor water quality progress in the watershed. Collection of high and low flow data should be performed. Study design should be compatible with the 1988/89 study to allow for comparison.

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APPENDICES

Appendix A. Results from the 1988/89 Johnson Creek watershed study.

Date	Station	Temp (°C)	Cond (umhos/cm)	pH (units)	D.O. (mg/L)	D.O. (sat)	Flow (CFS)	Flow (m3/s)	TURB* (NTU)	TSS* (mg/L)	NO_3+NO_2 (mg N/L)	NH_3* (mg N/L)	Un-ionized** NH_3 (ug N/L)	TIN (mg N/L)	Total P (mg P/L)	FC (#/100 mL)	COD (mg O/L)	BOD_5* (mg O/L)
1988																		
09/13	J1	10.5	240	7.2	8.69	78%	11.4	0.32	1	4	3.10	0.03	0.092	3.13	0.04	63	10	3 U
REP	J1	-	-	-	-	-	-	-	1	5	3.60	0.03	0.092	3.63	0.04	250	9	-
09/13	J2	10.7	240	7.2	7.77	70%	-	-	-	-	-	-	-	-	-	100	-	-
09/13	J3	10.9	230	7.0	8.26	75%	-	-	1 U	1	3.30	0.02	0.042	3.32	0.03	80	6	-
09/13	J4	10.7	230	7.0	7.70	70%	4.0E	0.11E	-	-	-	-	-	-	-	1100	-	-
09/13	J5	11.7	260	6.8	4.54	42%	-	-	1 U	3	3.30	0.03	0.040	3.33	0.06	210	11	-
09/13	J6	11.8	250	6.1	4.74	44%	-	-	-	-	-	-	-	-	-	530	-	-
09/13	J7	12.2	230	6.8	5.94	56%	0.5E	0.01E	1 U	2	1.80	0.02	0.027	1.82	0.04	500	7	-
09/13	J8	11.6	480	6.6	3.23	30%	-	-	9	42	0.02	0.59	0.452	0.61	0.33	110	54	10 U
09/13	P1	13.5	270	6.9	8.62	83%	0.4	0.01	1	5	8.30	0.03	0.064	8.33	0.10	440	12	-
09/13	P2	12.5	290	6.4	4.80	45%	-	-	-	-	-	-	-	-	-	2900	-	-
09/13	P3	11.2	300	5.7	4.00	37%	1.0	0.03	1	1	1	0.01U	0.003UP	12.50	0.06	23	9	-
REP	P3	-	-	-	-	-	-	-	1 U	3	12.70	0.01	0.006P	12.71	0.06	17	9	-
09/13	CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-
09/13	S1	12.7	250	6.9	6.70	64%	0.4	0.01	1 U	2	2.30	0.01	0.016	2.31	0.04	92	13	-
09/13	S2	16.0	250	6.7	7.96	81%	-	-	-	-	-	-	-	-	-	270	-	-
09/13	S3	13.2	240	7.3	10.30	99%	0.4	0.01	1	2	3.20	0.01	0.046	3.21	0.02	1300	9	-
09/13	S4	14.4	210	6.7	7.60	75%	-	-	2	6	4.90	0.04	0.049	4.94	0.04	1900	8	-
09/13	UC	9.6	250	7.2	9.18	81%	1.5	0.04	2	10	5.50	0.03	0.082	5.53	0.04	310	11	-
10/11	J1	11.0	248	7.2	6.30	57%	13.2	0.37	1 U	3	3.60	0.02	0.068	3.62	0.07	110	14	3 U
10/11	J2	11.0	246	7.2	6.60	60%	-	-	-	-	-	-	-	-	-	160	-	-
10/11	J3	10.9	241	7.2	7.70	70%	-	-	1 U	3	3.20	0.01	0.033	3.21	0.04	130	9	-
10/11	J4	10.8	242	7.1	7.30	66%	9.4	0.27	1 U	2	3.50	0.01	0.024	3.51	0.05	240	13	-
REP	J4	-	-	-	-	-	-	-	1	2	3.40	0.01	0.024	3.41	0.05	150	11	-
10/11	J5	11.0	267	7.0	4.40	40%	-	-	-	-	-	-	-	-	-	290	-	-
10/11	J6	10.9	262	7.0	5.50	50%	-	-	-	-	-	-	-	-	-	320	-	-
10/11	J7	10.6	250	7.1	6.50	59%	0.6E	0.02E	1 U	2	2.00	0.01	0.260	2.01	0.04	160	11	-
10/11	J8	11.2	470	6.6	0.40	4%	-	-	110	61	0.01	0.67	0.584	0.68	0.59	92	58	4
10/11	P1	11.4	292	7.3	10.20	94%	1.3	0.04	1 U	4	8.10	0.01	0.044	8.11	0.18	520	17	-
10/11	P2	11.0	294	7.0	8.20	75%	-	-	-	-	-	-	-	-	-	350	-	-
10/11	P3	11.2	292	6.7	5.70	52%	1.3	0.04	1 U	2	11.00	0.01U	0.005U	11.00	0.20	410	17	-
REP	P3	-	-	-	-	-	-	-	1 U	2	11.00	0.01	0.010	11.01	0.20	410	19	-
10/11	CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	42000	-	-
10/11	S1	11.5	268	7.0	6.40	59%	0.5	0.01	1 U	3	3.50	0.01	0.023	3.51	0.04	110	15	-
10/11	S2	10.6	267	7.0	9.10	82%	-	-	-	-	-	-	-	-	-	110	-	-

Appendix A. (continued).

Date	Station	Temp (°C)	Cond (umhos/cm)	pH (units)	D.O. (mg/L)	D.O. (sat)	Flow (CFS)	Flow (m3/s)	TURB* (NTU)	TSS* (mg/L)	NO_3+NO_2 (mg N/L)	NH_3* (mg N/L)	Un-ionized** NH_3 (ug N/L)	TIN (mg N/L)	Total P (mg P/L)	FC (#/100 mL)	COD (mg O/L)	BOD_5* (mg O/L)
1988																		
10/11	S3	10.5	258	7.4	11.20	101%	0.4	0.01	1 U	2	3.10	0.07	0.372	3.17	0.01	200	10	-
10/11	S4	11.6	210	7.0	8.90	82%	-	-	1 U	2	5.30	0.01	0.021	5.31	0.02	120	5	-
10/11	UC	9.9	254	7.3	9.30	83%	3.5	0.10	2	12	5.50	0.03	0.110	5.53	0.05	150	10	-
12/06	J1	7.9	275	7.1	6.79	57%	61.2	1.73	2	3	3.90	0.13	0.235	4.03	0.36	1700	29	3 U
REP	J1	-	-	-	-	-	-	-	2	3	4.30	0.13	0.235	4.43	0.37	1500	28	-
12/06	J2	7.7	283	7.1	6.67	56%	-	-	-	-	-	-	-	-	-	730	-	-
12/06	J3	7.8	278	7.1	6.55	55%	-	-	2	2	4.70	0.06	0.108	4.76	0.24	350 S	26	-
12/06	J4	7.7	270	7.0	6.11	51%	56.5	1.60	2	1U	4.40	0.05	0.083	4.45	0.22	320	24	-
12/06	J5	7.7	282	7.0	5.61	47%	-	-	-	-	-	-	-	-	-	970	-	-
12/06	J6	7.7	274	7.0	6.47	54%	-	-	-	-	-	-	-	-	-	120	-	-
12/06	J7	7.6	276	6.9	6.03	51%	42.9	1.22	2	2	4.10	0.02	0.026	4.12	0.21	260	27	-
12/06	J8	7.4	317	6.9	4.14	35%	-	-	4	3	5.00	0.03	0.033	5.03	0.33	1500S	28	3 U
12/06	P1	8.2	232	7.1	10.65	91%	10.2	0.29	1	32	4.80	0.24	0.499	5.04	0.01	1300	65	-
12/06	P2	8.3	247	6.7	4.90	42%	-	-	-	-	-	-	-	-	-	1000	-	-
12/06	P3	8.3	252	6.6	4.86	41%	9.0	0.25	1	11	4.50	0.58	0.385	5.08	0.24	900S	81	-
12/06	CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2000P	-	-
12/06	S1	7.9	228	6.8	7.64	64%	15.2	0.43	4	4	3.00	0.14	0.153	3.14	0.17	420	37	-
12/06	S2	8.0	216	6.9	8.58	73%	-	-	-	-	-	-	-	-	-	2200	-	-
12/06	S3	8.4	261	6.6	9.90	85%	12.4	0.35	4	15	3.70	0.05	0.033	3.75	0.17	79	40	-
REP	S3	-	-	-	-	-	-	-	4	14	3.80	0.05	0.033	3.85	0.16	57	35	-
12/06	S4	9.4	190	6.8	8.15	71%	-	-	1	9	6.40	0.04	0.450	6.44	0.15	54	32	-
12/06	UC	8.2	248	6.9	6.71	57%	10.2	0.29	6	12	3.30	0.58	0.678	3.88	0.24	8000JL	48	-
1989																		
01/18	J1	5.9	181	7.1	8.09	65%	266.4	7.54	17	20	22.58	0.41	0.632	22.99	0.50	700	40	3
01/18	J2	5.9	195	7.0	7.91	63%	-	-	-	-	-	-	-	-	-	800	-	-
01/18	J3	5.8	194	7.0	7.71	62%	-	-	13	16	23.43	0.49	0.653	23.92	0.43	1600	39	-
01/18	J4	5.7	184	7.0	7.50	60%	204.1	5.78	15	17	19.90	0.46	0.567	20.37	0.45	1600	37	-
01/18	J5	5.7	176	6.8	7.31	58%	-	-	-	-	-	-	-	-	-	1300	-	-
01/18	J6	5.7	170	6.8	7.45	59%	-	-	-	-	-	-	-	-	-	670	-	-
01/18	J7	5.6	173	7.0	6.94	55%	164.4	4.66	21	19	20.75	0.66	0.789	21.41	0.46	1100	39	-
01/18	J8	5.6	211	6.9	5.28	42%	-	-	34	32	22.01	1.07	1.167	23.08	0.76	1600	44	8 U
01/18	P1	6.5	183	6.7	10.52	86%	30.0	0.85	2	17	32.05	0.39	0.295	32.44	0.80	550	64	-
01/18	P2	6.5	179	6.2	6.06	49%	-	-	-	-	-	-	-	-	-	280 U	-	-
01/18	P3	6.4	176	6.1	5.23	43%	22.9	0.65	1	8	38.60	0.12	0.023	38.72	0.83	110	71	-
01/18	CB	-	-	-	-	-	-	-	-	-	-	-	-	-		5300	-	-

Appendix A. (continued).

Date	Station	Temp (°C)	Cond (umhos/cm)	pH (units)	D.O. (mg/L)	D.O. (sat)	Flow (CFS)	Flow (m3/s)	TURB* (NTU)	TSS* (mg/L)	NO_3+NO_2 (mg N/L)	NH_3* (mg N/L)	Un-ionized** NH_3 (ug N/L)	TIN (mg N/L)	Total P (mg P/L)	FC (#/100 mL)	COD (mg O/L)	BOD_5 (mg O/L)
1989																		
01/18	S1	5.8	139	6.7	9.75	78%	53.0E	1.50E	6	7	18.02	0.21	0.128	18.22	0.17	600	31	-
REP	S1	-	-	-	-	-	-	-	6	5	3.72	0.20	0.134	3.92	0.19	500	28	-
01/18	S2	6.2	154	6.6	10.10	82%	-	-	-	-	-	-	-	-	-	230	-	-
01/18	S3	6.5	193	6.3	9.80	80%	32.0	0.91	6	11	54.62	0.12	0.054P	54.74	0.39	59 U	33	-
01/18	S4	7.9	180	6.5	8.20	69%	-	-	2	7	37.04	0.25	0.125P	37.29	0.23	110	19	-
01/18	UC	5.7	139	6.7	8.52	68%	43.6	1.24	17	17	2.64	0.74	0.526	3.38	1.26	2600	44	-
REP	UC	-	-	-	-	-	-	-	17	17	2.81	0.74	0.526	3.55	1.07	2400	46	-
02/22	J1	3.5	247	6.6	7.50	56%	118.9	3.37	9	10	4.73	1.14	0.490	5.87	0.72	5100	55	11
02/22	J2	3.2	255	6.9	-	-	-	-	-	-	-	-	-	-	-	2300	-	-
02/22	J3	3.1	195	6.9	-	-	-	-	10	9	4.80	1.18	1.002	5.98	0.45	2200	50	-
02/22	J4	3.0	237	6.9	6.80	51%	93.5	2.65	7	9	6.59	1.46	1.230	8.05	0.53	2700	53	-
REP	J4	-	-	-	-	-	-	-	7	5	4.45	3.54	2.983C	7.99	0.54	1100S	51	-
02/22	J5	2.3	234	6.5	-	-	-	-	-	-	-	-	-	-	-	4200S	-	-
02/22	J6	2.0	230	6.9	-	-	-	-	-	-	-	-	-	-	-	3600S	-	-
02/22	J7	2.0	218	7.0	7.10	51%	93.1	2.64	14	15	3.82	3.57	3.107C	7.39	0.34	2700S	69	-
02/22	J8	1.8	236	6.9	5.20	37%	-	-	28	29	4.59	1.45	0.986	6.04	0.52	2900	64	12
02/22	P1	5.4	238	7.0	10.10	80%	19.5	0.55	3	11	7.54	2.53	3.189C	10.08	3.09	1500	64	-
02/22	P2	5.1	241	6.7	-	-	-	-	-	-	-	-	-	-	-	1600S	-	-
02/22	P3	5.0	239	6.6	4.50	35%	15.3	0.43	2	1U	8.23	2.55	1.359C	10.78	1.75	1600S	62	-
02/22	CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8900S	-	-
02/22	S1	1.8	185	7.0	9.20	66%	27.7	0.78	8	9	3.71	3.48	3.119C	7.18	0.59	3800S	66	-
02/22	S2	1.9	168	6.9	-	-	-	-	-	-	-	-	-	-	-	5700S	-	-
02/22	S3	3.2	200	6.3	9.30	69%	16.5	0.47	6	17	4.28	1.47	0.502P	5.74	0.43	1000	56	-
REP	S3	-	-	-	-	-	-	-	7	16	13.10	2.08	0.710CP	15.18	0.42	970	52	-
02/22	S4	6.5	195	6.8	-	-	-	-	2	1	6.95	1.08	0.897	8.02	0.45	2000	35	-
02/22	UC	3.7	214	6.5	7.80	59%	18.2	0.52	18	42	3.75	3.44	1.280C	7.19	4.23	4300	80	-
03/28	J1	6.8	265	7.1	6.50	53%	125.5	3.55	5	10	4.70	0.33	0.560	5.03	0.30	500S	53	4
REP	J1	-	-	-	-	-	-	-	4	9	4.70	0.36	0.610	5.06	0.29	-	41	-
03/28	J2	7.1	255	7.2	-	-	-	-	-	-	-	-	-	-	-	380	-	-
03/28	J3	7.1	265	7.2	-	-	-	-	4	12	4.80	0.33	0.689	5.13	0.27	180	52	-
03/28	J4	7.6	265	7.2	6.80	57%	86.0E	2.41E	4	11	4.70	0.28	0.622	4.98	0.26	400	48	-
03/28	J5	8.6	255	7.2	-	-	-	-	-	-	-	-	-	-	-	180S	-	-
03/28	J6	8.2	248	7.3	-	-	-	-	-	-	-	-	-	-	-	54	-	-
03/28	J7	7.8	255	7.3	8.10	68%	70.3	1.99	5	12	4.60	0.10	0.304	4.70	0.22	77	38	-
03/28	J8	7.4	308	7.1	-	-	-	-	6	9	4.90	0.23	0.459	5.13	0.36	230	40	3
03/28	P1	8.5	235	7.7	9.80	84%	15.1	0.43	1	16	8.20	0.04	0.345	8.24	0.50	46	41	-

Appendix A. (continued).

Date	Station	Temp (°C)	Cond (umhos/cm)	pH (units)	D.O. (mg/L)	D.O. (sat)	Flow (CFS)	Flow (m3/s)	TURB* (NTU)	TSS* (mg/L)	NO_3+NO_2 (mg N/L)	NH_3* (mg N/L)	Un-ionized** NH_3 (ug N/L)	TIN (mg N/L)	Total P (mg P/L)	FC (#/100 mL)	COD (mg O/L)	BOD_5* (mg O/L)
1989																		
03/28	P2	8.4	240	6.9	-	-	-	-	-	-	-	-	-	-	-	38	-	-
03/28	P3	8.4	239	6.9	7.20	62%	9.1	0.26	1	7	9.00	0.09	0.105	9.09	0.58	100	53	-
03/28	CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1100 S	-	-
03/28	S1	8.3	212	6.8	10.20	87%	13.1	0.37	2	8	4.10	0.10	0.092	4.20	0.09	50 J	36	-
03/28	S2	8.7	220	7.0	-	-	-	-	-	-	-	-	-	-	-	210 S	-	-
03/28	S3	8.3	238	6.8	10.50	90%	9.9	0.28	2	7	5.00	0.09	0.101	5.09	0.06	15 J	32	-
03/28	S4	9.0	215	7.0	-	-	-	-	1	7	8.30	0.01	0.016	8.31	0.06	3	16	-
REP	S4	-	-	-	-	-	-	-	1	6	8.20	0.01	0.160	8.21	0.06	3	13	-
03/28	UC	7.1	245	7.0	6.30	52%	10.5	0.30	5	9	4.00	0.96	1.556	4.96	0.57	800 S	52	-
05/23	J1	11.1	245	7.3	7.60	69%	30.4	0.86	3	5	3.80	0.06	0.216	3.86	0.08	280	16	3 U
05/23	J2	11.5	253	7.3	-	-	-	-	-	-	-	-	-	-	-	470	-	-
05/23	J3	11.2	200	7.3	-	-	-	-	2	2	4.08	0.05	0.185	4.13	0.09	500	17	-
REP	J3	-	-	-	-	-	-	-	2	1	5.41	0.05	0.185	-	0.09	520	15	-
05/23	J4	11.3	248	7.2	6.15	56%	21.5	0.61	2	3	4.27	0.05	0.174	4.32	0.09	290	14	-
05/23	J5	11.0	270	7.2	-	-	-	-	-	-	-	-	-	-	-	340	-	-
05/23	J6	10.8	260	7.2	-	-	-	-	-	-	-	-	-	-	-	1100	-	-
05/23	J7	11.2	255	7.3	5.40	49%	7.2	0.20	2	5	2.17	0.05	0.190	2.22	0.08	2000	19	-
05/23	J8	12.3	300	7.3	-	-	-	-	5	2	0.49	0.22	0.868	0.71	0.05	220	29	3 U
05/23	P1	10.5	263	7.5	10.60	95%	9.3	0.26	1	5	9.80	0.02	0.128	9.82	0.11	700	16	-
05/23	P2	10.6	275	7.0	-	-	-	-	-	-	-	-	-	-	-	460	-	-
05/23	P3	10.7	215	6.9	7.70	70%	5.8	0.16	1	2	12.00	0.05	0.084	12.05	0.13	190	21	-
REP	P3	-	-	-	-	-	-	-	1	1	12.03	0.05	0.084	12.08	0.13	230	19	-
05/23	CB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	530	-	-
05/23	S1	10.5	190	7.2	7.95	72%	6.2	0.18	3	2	4.51	0.04	0.128	4.55	0.05	800	17	-
05/23	S2	10.6	248	7.4	-	-	-	-	-	-	-	-	-	-	-	4900	-	-
05/23	S3	10.0	235	7.5	10.50	93%	9.3	0.26	2	1U	4.46	0.01	0.052	4.47	0.02	140	13	-
05/23	S4	9.8	232	7.0	-	-	-	-	1	2	10.16	0.01	0.019	10.17	0.21	390	10	-
05/23	UC	9.5	235	7.4	8.90	78%	6.7	0.19	3	14	4.76	0.07	0.029	4.82	0.11	320	13	-

*E=field estimate; U=below detection; J=lab estimate, not accurate; L=total plate count >200; S=spreader, value greater than reported.

**U=to calculate this value 1/2 the detection limit was used ;P=greater than; the calculation required a pH of at least 6.5, therefore the value shown is less than the actual value; C=value exceeds the chronic criteria for salmonid waters.

Appendix B. Comparing median values from the 1980/81 Johnson Creek study to the 1988/89 study. Values were taken from months: Oct, Dec, Jan, Feb, Mar, and May.

Site	Year	Parameter							
		NO_3 (mg N/L)	NH_3 (mg N/L)	TP (mg P/L)	D.O. (mg/L)	DOSAT (% sat)	pH (units)	Turbidity (NTU)	Flow (cfs)
Johnson Creek									
J8	1980	1.25	1.34	0.18	5.90	46	7.1	9	N
	1988	4.75	0.45	0.44	4.67	36	6.9	17	N
J5	1980	3	L	0.10	6.90	56	7.2	4	N
	1988	N	N	N	5.61	47	7.0	N	N
J4	1980	2.62*	L	0.12	9.20	66	7.2	10	38
	1988	4.55	0.17	0.24	6.80	57	7.1	3	70.8
J3	1980	2.87	N	L	9.50	74	7.2	14	N
	1988	4.77	0.20	0.26	7.70	62	7.1	3	N
J2	1980	2.38	L	0.13	8.50	68	7.2	8	N
	1988	N	N	N	6.67	60	7.1	N	N
J1	1980	2.64*	0.12	0.11	7.25	63	7.3*	9	44.8
	1988	4.40	0.24	0.33	7.15	57	7.1	4	90.1
All Sites	1980	2.61*	0.15	0.14	7.50	64*	7.2	9	42.0
	1988	4.70	0.26	0.31	6.70	57	7.1	4	73.2
Squaw Creek									
S4	1980	4.51*	0.01	0.03	8.55	76	6.8	1	N
	1988	7.60	0.03	0.18	8.20	71	6.9	1	N
S3	1980	3.97	0.05	0.07	9.80	85	7.1	7	5.9
	1988	4.37	0.08	0.11	10.20	87	6.7	3	11.2
S2	1980	3.23	0.13	0.10	9.10	81	7.1	8	N
	1988	N	N	N	9.10	82	7.0	N	N
S1	1980	2.85	0.08	0.07	9.40	72	7.1	8	N
	1988	3.90	0.12	0.13	8.60	69	6.9	4	14.2
All Sites	1980	3.82*	0.05	0.05*	9.40	80	7.0	6 *	5.9
	1988	4.76	0.08	0.16	9.25	79	6.9	2	12.8
Pangborn Creek									
P3	1980	5.39*	0.24	0.26	4.0*	33*	6.5	1	7.4
	1988	10.00	0.12	0.41	5.50	47	6.7	1	9.0
P1	1980	5.43*	0.05	0.20	8.9*	73*	7.3	3 *	8.8
	1988	8.15	0.14	0.34	10.40	88	7.2	1	12.6
All Sites	1980	5.43*	0.17	0.22	6.25*	55	7.0	2 *	8.7
	1988	8.62	0.12	0.37	8.75	75	6.9	1	9.7
All Watershed Sites									
	1980	3.28*	0.12	0.11*	8.45	69	7.1	6 *	9.7
	1988	4.80	0.12	0.23	7.64	64	7.0	2	15.3

* = indicates a statistically significant difference (p< =0.05) between 1980/81 and 1988/89 as measured by the Mann Whitney non-parametric test.
L = not enough data points for statistical review; n=1.
N = data not collected

Appendix C. Loading results for Johnson Creek, 1988/89.

Date	Station	Flow (cfs)	TSS (kg/day)	TIN (kg/day)	Total P (kg/day)	FC* (#/second)	COD Load (kg/day)	TDS (kg/day)
09/13/88	J1	11.4	125.2	94.0	1.1	4.02E+05	264.3	4673.2
10/11/88	J1	13.2	97.0	117.0	2.3	4.12E+05	452.5	5610.5
12/06/88	J1	61.2	449.3	633.4	54.7	2.77E+07	4267.9	28826.9
01/18/89	J1	266.4	13036.4	14982.1	323.3	5.28E+07	26072.8	82585.7
02/22/89	J1	118.9	2909.9	1709.3	208.6	1.70E+08	16004.3	50311.6
03/28/89	J1	125.5	2916.1	1550.2	90.6	1.78E+07 S	14427.2	56941.5
05/23/89	J1	30.4	372.0	287.0	5.6	2.41E+06	1190.4	12759.3
09/13/88	J4	4.0 E	-	-	-	1.25E+06	-	1575.5
10/11/88	J4	9.4	45.9	79.4	1.1	5.18E+05	275.4	3887.4
12/06/88	J4	56.5	69.2	615.5	30.4	5.12E+06	3319.8	26143.4
01/18/89	J4	204.1	8488.2	10169.4	223.7	9.25E+07	18474.3	64310.6
02/22/89	J4	93.5	1600.4	1833.6	122.3	4.56E+07	11888.5	37929.0
03/28/89	J4	86.0 E	2314.4	1047.8	54.7	9.74E+06	10099.2	39029.0
05/23/89	J4	21.5	157.7	227.0	4.5	1.76E+06	736.1	9127.1
09/13/88	J7	0.5 E	2.4	2.2	0.0	7.08E+04	8.6	196.9
10/11/88	J7	0.6 E	2.9	3.0	0.1	2.72E+04	16.1	256.9
12/06/88	J7	42.9	210.0	432.5	22.0	3.16E+06	2834.4	20282.0
01/18/89	J7	164.4	7641.9	8610.0	183.8	5.12E+07	15686.0	48707.0
02/22/89	J7	93.1	3417.3	1684.3	76.8	7.12E+07 S	15719.4	34765.0
03/28/89	J7	70.3	2064.5	808.6	37.8	1.53E+06	6537.4	30708.8
05/23/89	J7	7.2	87.5	38.8	1.5	4.05E+06	332.4	3122.4
09/13/88	P1	0.4	5.4	9.0	0.1	5.48E+04	12.9	203.5
10/11/88	P1	1.3	12.7	25.8	0.6	1.91E+05	54.1	650.1
12/06/88	P1	10.2	796.2	125.4	0.2	3.74E+06	1617.3	4040.7
01/18/89	P1	30.0	1246.5	2378.5	58.4	4.67E+06	4692.6	9392.5
02/22/89	P1	19.5	525.9	481.8	147.6	8.30E+06	3059.5	7964.2
03/28/89	P1	15.1	590.7	304.2	18.5	1.97E+05	1513.6	6073.0
05/23/89	P1	9.3	113.2	222.3	2.6	1.83E+06	362.1	4166.2
09/13/88	P3	1.0	5.0	30.8	0.1	5.78E+03	22.5	524.0
10/11/88	P3	1.3	6.1	35.0	0.6	1.45E+05	55.0	625.1
12/06/88	P3	9.0	241.4	111.5	5.3	2.29E+06 S	1777.6	3871.1
01/18/89	P3	22.9	448.6	2170.9	46.7	7.14E+05	3981.2	6908.3
02/22/89	P3	15.3	18.7	403.5	65.5	6.93E+06 S	2320.7	6262.3
03/28/89	P3	9.1	155.0	201.3	12.8	2.56E+05	1173.5	3704.2
05/23/89	P3	5.8	21.1	169.7	1.8	3.40E+05	281.3	2117.1
09/13/88	S1	0.4	1.9	2.2	0.0	1.02E+04	12.4	167.0
10/11/88	S1	0.5	3.7	4.4	0.0	1.59E+04	18.7	234.1
12/06/88	S1	15.2	149.1	117.1	6.3	1.81E+06	1379.5	5950.6
01/18/89	S1	53.0 E	778.0	2363.1	23.3	8.26E+06	3825.1	12616.4
02/22/89	S1	27.7	609.9	486.8	40.0	2.98E+07 S	4472.7	8776.0
03/28/89	S1	13.1	256.0	134.4	2.9	1.85E+05 J	1152.0	4748.8
05/23/89	S1	6.2	30.3	69.0	0.7	1.40E+06	257.9	2017.4

Appendix C. (continued).

Date	Station	Flow (cfs)	TSS (kg/day)	TIN (kg/day)	Total P (kg/day)	FC* (#/second)	COD Load (kg/day)	TDS (kg/day)
09/13/88	S3	0.4	1.8	2.8	0.0	1.33E+05	7.9	148.0
10/11/88	S3	0.4	1.9	3.0	0.0	2.21E+04	9.5	172.3
12/06/88	S3	12.4	440.9	115.6	5.0	2.36E+05	1140.4	5555.9
01/18/89	S3	32.0	861.4	4286.7	30.5	5.35E+05 U	2584.3	10580.0
02/22/89	S3	16.5	667.3	245.1	17.2	4.61E+06	2183.8	5661.7
03/28/89	S3	9.9	168.9	122.8	1.4	4.19E+04 J	771.9	4018.8
05/23/89	S3	9.3	11.3	101.2	0.3	3.67E+05	294.2	3722.7
09/13/88	UC	1.5	36.7	20.3	0.1	1.32E+05	40.4	642.2
10/11/88	UC	3.5	103.6	47.8	0.4	1.50E+05	86.4	1535.5
12/06/88	UC	10.2	300.6	97.2	6.0	2.32E+07 L	1202.5	4349.1
01/18/89	UC	43.6	1815.0	370.7	124.9	3.09E+07	4804.4	10388.3
02/22/89	UC	18.2	1873.2	320.9	188.7	2.22E+07	3568.0	6681.0
03/28/89	UC	10.5	231.9	127.8	14.7	2.39E+06 S	1339.6	4418.1
05/23/89	UC	6.7	229.5	79.0	1.7	6.07E+05	213.1	2696.4

* = y.yyE+xx represents y.yy times 10 raised to the xx power.
E = Estimated value, thus corresponding loads are estimated as well.
L = Total plate count greater than 200.
S = Spreader; value greater than reported.
- = data not collected

Appendix D. Macroinvertebrate families found at two sites in the Johnson Creek watershed during the 1988/89 study period. Organism abundance is keyed as R (Rare) = 1, P (Present) = 2-4, C (Common) = 5-25, and A (Abundant) = >25. Location description followed by 'R' denotes replicate sample.

	LOCATION			
Taxonomic Group	P3	P3R	J2	J2R
TURBELLARIA (flatworms)				
Planariidae	-	P	-	-
ANNELIDA (segmented worms)				
Naididae	A	A	-	-
Lumbriculidae	-	-	-	P
AMPHIPODA (scuds)				
Gammaridae	-	-	-	R
HYDRACARINA (mites)				
Hydracarina	C	-	R	-
EPHEMEROPTERA (mayflies)				
Baetidae	-	-	C	C
PLECOPTERA (stoneflies)				
Nemouridae	P	P	-	-
Chloroperlidae	-	-	-	R
Perlodidae	-	P	-	-
TRICOPTERA (caddisflies)				
Limnephilidae	P	R	R	-
Rhyacophilidae	-	R	-	P
COLEOPTERA (beetles)				
Dytiscidae	-	-	R	-
DIPTERA (true flies)				
Chironomidae	A	A	A	A
Culicidae	A	A	C	-
Simuliidae	A	A	C	-
GASTROPODA (snails)				
Planorbidae	P	-	-	-

Appendix E. Factors used in evaluating a farms pollution potential.

FACTOR	WEIGHT[1]
Q1: Contaminated runoff from slabs	4
Q2: Seepage from stacked solid manure	2
Q3: Seepage from silos	2
Q4:[2] Waste applied in excess of crop needs	2
Q5: Direct field runoff	4
Q6: Animal access to streams or waterways	3
Q7: Flooding or ponding hazard of soils	2
Q8:[3] Animal confinement area; distance to waterways	3
Q9:[4] Closeness to urban or built-up areas	3

[1] A weighted average was determined for each farm by dividing the sum of the product weight times rating (0-6), by the sum of the weights (25).

[2] Rating criteria for Q4 refers to nitrogen application: rate 0 if waste applied spring through fall at equivalent of 1.5 animal units per acre. Rate 6 if waste applied year round, unevenly at equivalent of 3.0 animal units per acre.

[3] Q8 rating criteria; less than 250 feet to waterway - 6; 251 - 1000 feet - 4; 1001 - 3000 feet - 2; over 3000 feet - 0.

[4] Q9 rating criteria; less than 1/4 mile to built-up area - 6; 1/4 to 1/2 mile - 4; 1/2 to 2 mile - 2; over 2 miles - 0.

Gillies, 1990b.