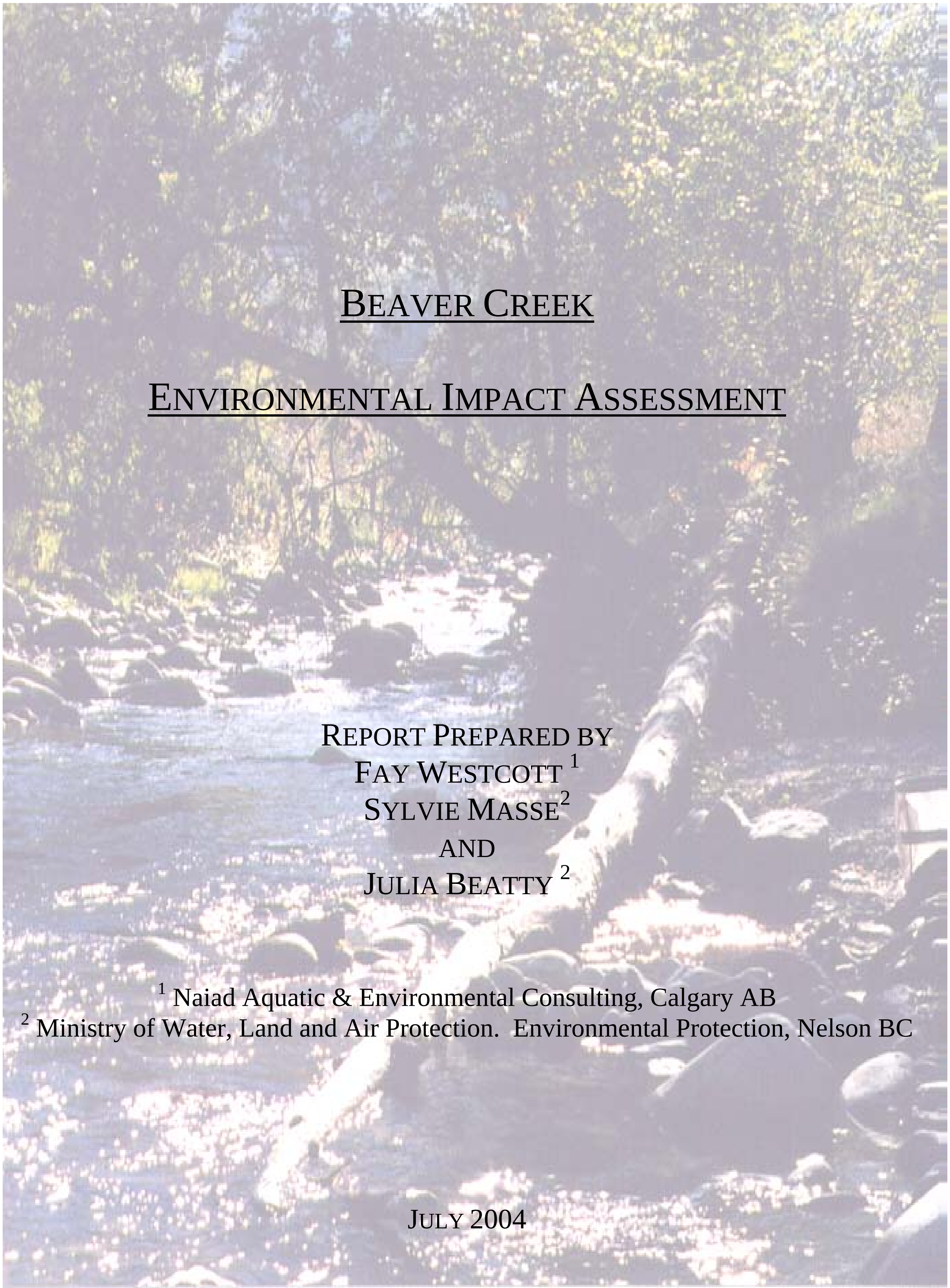

BEAVER CREEK

ENVIRONMENTAL IMPACT ASSESSMENT

REPORT PREPARED BY
FAY WESTCOTT [1]
SYLVIE MASSE[2]
AND
JULIA BEATTY [2]

[1] Naiad Aquatic & Environmental Consulting, Calgary AB
[2] Ministry of Water, Land and Air Protection. Environmental Protection, Nelson BC

JULY 2004

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Executive Summary

Introduction and Purpose

Beaver Creek is a small gradient stream that is located in the West Kootenay region of southeastern British Columbia. It has high fisheries values, supporting several species of sportfish. Several water licenses are issued for Beaver Creek, for irrigation, livestock watering, fire fighting and domestic water supply purposes. The important fishery also supports a good deal of recreational use. As it flows from its headwaters, through the Village of Fruitvale to its confluence with the Columbia River, the creek is impacted by several point and non-point sources of pollution, including recreational, municipal, agricultural and industrial activities. These pollution sources influence not only the water quality and ecological health of the creek, but also its ability to meet the requirements of its varied users.

In the fall of 1999, the Ministry of Water, Land and Air Protection (formerly the Ministry of Environment, Lands and Parks) undertook a study to assess the water quality and ecological structure and function of Beaver Creek, in response to concerns that contaminants, primarily nutrients and pathogens, may play a role in its deteriorating water quality. The study's emphasis was to investigate, in a preliminary way, the potential impacts of the discharge of treated sewage from Fruitvale's sewage treatment plant (STP) following improvements at the plant during the 1990s. These upgrades to the plant in 1995 included a ground disposal system that incorporated primary and secondary aeration, flocculant treatment, and discharge through rapid infiltration (RI) basins. Concerns about the STP's function resulted in additional upgrades in 1997, which included the installation of underdrains that collect treated effluent from the RI basins and discharges it into Beaver Creek. This new system operates more effectively but somewhat reduces the treatment performance that disposal of effluent to ground usually affords.

Although the foremost concern was the potential impact of the Fruitvale STP discharge on the ecological status as well as recreational and drinking water uses of Beaver Creek, urban runoff from the communities of Fruitvale and Montrose and agricultural runoff are acknowledged to also contribute to the cumulative pollutant load within the drainage.

Methods

The sampling program was conducted over a five week period in September 1999, at six discrete locations along the creek and at Fruitvale's effluent discharge. Effluent quality, receiving water quality and biological sampling data were used to assess the potential impacts on the water quality and benthic stream ecology of Beaver Creek, with comparisons made to historical water quality data collected in 1990 and 1993.

The water quality results were also compared to B.C. Approved and Working Water Quality Guidelines for drinking water, recreation and the protection of aquatic life. These results were also assessed in the context of whether the sewage treatment facility would comply with requirements under the *Municipal Sewage Regulation*. A benthic invertebrate assessment was also conducted, and the results were compared to biometric indices to determine the health and complexity of the communities.

Results and Conclusions

Key results of the 1999 sampling included:

- The STP effluent contained much higher nutrient (nitrogen and phosphorus) concentrations, but lower bacterial levels than background water quality in Beaver Creek suggesting the STP effectively removes bacteria but does not remove nutrients in sewage to background creek levels.

- Along Beaver Creek ammonia, nitrate, total nitrogen, total phosphorus and ortho-phosphate increased at the site immediately downstream of the STP outfall.

- Bacterial concentrations were fairly consistent along the length of Beaver Creek.

- The abundance and diversity of benthic invertebrate communities slightly decreased along Beaver Creek. The most dramatic decrease was found between the sites just upstream and 400 m downstream of the STP discharge. Although one might conclude that could be the result of the STP effluent contaminants, a clear "cause and effect" relationship could not be developed due to inherent differences in stream habitat between the sites (substrate type, depth of overlying water and riparian growth).

The STP effluent contained substantially higher concentrations of nutrients than did all the sampling sites along Beaver Creek. Not surprisingly, ammonia, nitrate, total nitrogen, total phosphorus, and ortho-phosphate all increased significantly downstream of the STP outfall (approximately 400 metres downstream of the point of discharge), compared with upstream concentrations. These increases are attributed to the Village of Fruitvale's effluent discharge to Beaver Creek. The increases in nutrient concentrations found at the site 400 m downstream of the STP outfall are somewhat ameliorated further downstream as a result of chemical reactions, dilution from tributaries and/or biological uptake. Inputs from fertilizers or other non-point sources are also likely to have influenced nutrient levels in Beaver Creek. Nutrient dynamics are complex and likely the result of several interactive factors. Although the nutrient concentrations within the creek did not exceed drinking water quality guidelines, increased nutrients may be responsible for negative changes in stream invertebrate community structure.

Total and faecal coliform bacteria and *E. coli* concentrations in the STP effluent were lower than those measured in the creek both upstream and downstream. These results, coupled with the findings that bacterial concentrations within Beaver Creek were occasionally higher at the uppermost sites in the watershed indicate that the STP effectively removes much of the microbial content in the effluent, and that other non-point sources of bacteria, including septic tanks, urban runoff, livestock and domestic and wild animals may be a greater contributor to bacteria in the creek. The faecal coliform and *E. coli* concentrations in the creek exceeded water quality guidelines for drinking water and primary contact recreation. These results raise concerns regarding the need to adequately treat Beaver Creek water prior to use for domestic purposes and the possible risks associated with primary contact recreational use of the creek.

The biological monitoring data showed that abundance and diversity of benthic invertebrates decreased along the length of the creek, with more sensitive taxa being replaced by pollution-tolerant taxa, which indicate possible impairments to the water quality of Beaver Creek. It is clear that the STP discharge contributes to the impairment of water quality, however a more detailed investigation would need to be conducted to more directly link this response with the STP effluent discharge.

In comparison to historic water quality results, the 1999 data indicate the following:

- Phosphorus and bacteria concentrations in the STP effluent measured at "end of pipe", improved based on both the 1990 and 1993 effluent data.

- The total inorganic nitrogen (which is ammonia, nitrite and nitrate added together) in STP effluent, although slightly improved over 1993 data, has not changed compared with the 1990 effluent samples.

- Total inorganic nitrogen in STP effluent has not significantly changed from 1990s levels, but the form of inorganic nitrogen in effluent has shifted. In the early to mid 1990s most of the inorganic nitrogen in STP effluent was in the form of ammonia. Due to improved aeration at the plant, ammonia is oxygenated and converted into nitrate, thereby increasing nitrate concentrations.

- Although nitrate concentrations in Beaver Creek immediately downstream of the STP improved compared with 1990 data, there is no significant difference with 1993 data, leading to the conclusion that there has not been any improvement with respect to nitrate levels in the creek since the early 1990s.

- Phosphorus and microbial concentrations measured in Beaver Creek immediately downstream of the STP have not significantly improved compared with 1990 and 1993 data.

Upgrades to the Fruitvale STP appeared to have been successful in significantly improving the effluent quality, as measured by decreases in ammonia, phosphorus and microbial concentrations when comparing 1990 and 1999 levels. These improvements were likely brought about by an increase in the aeration of the lagoons, which enhances the conversion of ammonia into nitrate, as well as the addition of flocculants and RI basins, which appear to have been effective at phosphorus and bacteria removal.

However, these effluent improvements did not result in improvements to the water quality of Beaver Creek below the STP discharge. Downstream of the STP outfall, although ammonia concentrations decreased slightly from 1993 to 1999, nitrate concentrations increased and overall the inorganic nitrogen was unchanged. Total phosphorus concentrations in Beaver Creek were essentially unchanged throughout the 1990s, and the faecal coliforms, *E. coli* and enterococci concentrations downstream of the STP outfall all increased from 1993 to 1999 levels.

With improvements to effluent quality, similar improvements in receiving water quality below the discharge would be expected. However, this was not the case, indicating that the existing components of the STP may not be treating all the effluent, or that some partially treated effluent may leak into the underlying shallow aquifer and eventually enter the creek. It is also possible that over time, the attenuation capacity of the RI basins may diminish since there is a very limited depth of gravels available for treatment of the effluent. The possibility that sewage is somehow bypassing the treatment system should be investigated, however, this should not dismiss the possibility that other non-point sources of pollution play a large role in impacting the water quality of Beaver Creek.

Recommendations

It is recommended that a watershed management plan be developed for Beaver Creek involving all stakeholders, including land owners and provincial and municipal governments. Prior to development of this plan, the following information should be collected to support and continue to clarify the findings of this report:

- Conduct an inventory of all land uses or activities that potentially contribute to point and non-point sources of pollution to the creek, including septic systems and livestock confined feeding areas.

- For future water sampling, ensure that sampling dates and water quality analyses conducted for all sites are identical, including the Fruitvale STP effluent and Beaver Creek or tributary stream sites.

- Collect concurrent flow data from the Fruitvale STP (effluent flow volumes) and Beaver Creek to allow more accurate calculation of dilution ratios and total loadings (mass, not concentration) of nutrients entering Beaver Creek.

- Better define the zone and magnitude of impact just downstream of the Village of Fruitvale's treated sewage discharge.

- Implement a more comprehensive monitoring program to include an examination of seasonal variation in water quality of both Beaver Creek and the STP outfall.

- Implement a groundwater monitoring program to determine if the RI basins and underdrains are leaking to shallow aquifers and subsequently, to Beaver Creek

- Incorporate toxicological testing of the Village of Fruitvale effluent discharge in future monitoring and assessment programs to meet the Municipal Sewage Regulation standards for streams with less than 20:1 dilution ratio with sewage discharges.

- Collect attached algae (periphyton) samples for biomass and taxonomy to help determine the presence of nuisance algae and the relative community composition of eutrophic and clean water species.

Protection of Beaver Creek may be achieved through active management and co-ordination between jurisdictions as well as regulation of activities and water uses that affect its water quality and ecological health. The ministry advocates a watershed approach to best manage point and non-point source pollution and hopes to work with communities and various stakeholder groups to achieve this result.

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1 INTRODUCTION AND PURPOSE

In the fall of 1999, the Ministry of Water, Land and Air Protection (WLAP), then the Ministry of Environment, Lands and Parks, in partnership with the Village of Fruitvale and the Water Quality Branch in Victoria, undertook a study to assess the impacts of Fruitvale's treated sewage discharge on Beaver Creek. The ministry had concerns that contaminants, primarily nutrients and pathogens, may be at unacceptable levels in the creek. Major upgrades at Fruitvale's sewage treatment plant (STP) in 1995, followed by subsequent upgrades in 1997, prompted questions regarding the efficacy of the treatment system and the potential for improvements to the water quality of Beaver Creek.

A secondary objective of this study was to carry out a preliminary evaluation of potential non-point sources of pollution on the water quality and ecological structure and function of the creek. Non-point sources of contaminants from agriculture, forestry and urban development (P. Cobbin, unpublished report) both upstream and downstream of the Village of Fruitvale's STP discharge were identified as potential contributors to deteriorating water quality in the creek.

The 1999 investigation was carried out over roughly a five week period in September of 1999, with sampling conducted at six discrete locations along the creek and at the Village of Fruitvale's effluent discharge. Effluent quality, receiving water quality and biological sampling data were used to assess the potential impacts on the water quality and benthic stream ecology of Beaver Creek. The study was designed to address both the ministry's need and the Village of Fruitvale's requirement to assess the effectiveness of the upgrades to the municipal sewage treatment plant (STP) and its influence on the water quality of Beaver Creek.

The results of this study will be used by the ministry and the Village to assess the adequacy of the Village of Fruitvale's 1997 STP upgrades and determine whether in future, the facility would comply with requirements under the *Municipal Sewage Regulation* (Waste Management Act 1999). In addition, the Village of Fruitvale may use the information to make decisions regarding the need to accommodate future expansion, upgrades and/or alterations to their STP.

2 STUDY AREA

2.1 BIOPHYSICAL DESCRIPTION

Beaver Creek is a low gradient stream (average gradient 1.76%) located in the West Kootenay region of southeastern British Columbia, and drains approximately 267 km^2 within the Bonnington Mountain Range (Figure 2.1). The creek is about 20 km in length, with its headwaters in a low marshy area adjacent to Erie Lake, from which it flows westerly, eventually emptying into the Columbia River south of Trail, B.C., approximately 10 km from the international border (RL&L 1995). Two natural falls exist in the creek and are located 0.8 km and 4 km upstream of its confluence with the Columbia River.

The mainstem of Beaver Creek flows through a variety of terrain, from fairly wide valley bottoms to more narrow and steep sided ravines and mountains. The watershed includes three distinct biogeoclimatic zones (Timberland Consultants Ltd. 2001). Low elevation areas lie within the Dry Warm Interior Cedar Hemlock sub-zone (ICHdw) and the Columbia-Shuswap Moist Warm Interior Cedar-Hemlock Variant (ICHmw2) sub-zone. Upper elevations in the watershed lie within the Columbia Wet Cold Englemann Spruce-Subalpine Fir Variant (ESSFwcl) and Alpine Tundra (AT) zones. The area, considered to be in B.C.'s Interior wet-belt, receives an annual average of 731.9 mm of precipitation; 533.2 mm as rainfall and 224.6 mm as snow (Environment Canada website www.cmc.ec.gc.ca/climate/normals/E_B.C._WMO.HTM).

Water Survey of Canada (WSC) has historically measured streamflow on Beaver Creek at two sites (Water Survey of Canada 1991) (Figure 2.1). One of those sites, Beaver Creek at Fruitvale (WSC station number 08NE042) was monitored only in 1930 and only for the months of June through September. Of the flows reported in 1930, the highest monthly average was recorded in June at 2.63 m^3/s, with monthly lows of 0.104 and 0.106 m^3/s recorded in July and September, respectively (Figure 2.2). The flow measured at this site represents only 196 km^2 (approximately 72%) of the total drainage area of Beaver Creek.

The other Water Survey of Canada site recorded Beaver Creek flows just upstream of the mouth of the Columbia River (WSC station number 08NE106) between 1969 and 1978. For that period of record, the lowest average monthly flows were 0.743, 0.537 and 0.542 m^3/s recorded in August, September and October, respectively (Figure 2.2). The 7Q2 (lowest 7 day average flow over two years) was 0.268 m^3/s (WSC pers. com. 2003). From August to January, the average monthly flows remained at or below 1.00 m^3/s. Peak flows generally occurred in May, while the lowest average monthly flow for the period of record was 0.199 m^3/s, recorded in September 1973 (Water Survey of Canada 1991).

Beaver Creek is regionally important in terms of its fish values, with its low gradient, good pool-to-riffle ratio, dense overhanging riparian vegetation and suitable gravel making it ideal for salmonid production (Andrusak 1982). The creek is unique within the Kootenays and supports a highly productive and regionally significant eastern brook trout (*Salvelinus fontinalis*) population. The mainstem of the creek also supports rainbow trout (*Onchorhynchus mykiss*), mountain whitefish (*Prosopium williamsoni*), longnose dace (*Rhinichthys cataractae*), torrent sculpin (*Cottus rhyotheus*), shorthead sculpin (*Cottus confuses*), mottled sculpin (*Cottus bairdi*), and prickly sculpin (*Cottus asper*) (RL&L 1995).

Beaver Falls, approximately 4 km above the confluence with the Columbia River, appears to present a barrier to the movement of fish upstream as well as downstream, to some degree. Of the species of fish listed above, only eastern brook trout, rainbow trout and torrent sculpin are found above Beaver Falls (RL&L 1995). Between Beaver Falls and the Columbia River, the fish population appears to be more diverse, including shorthead sculpin and mottled sculpin, both of which are blue-listed and considered species “of Special Concern” in B.C. (Ministries of Sustainable Resource Management and Water, Land and Air Protection website: http://srmapps.gov.bc.ca/apps/eswp/). These species have characteristics that make them sensitive or vulnerable to human activities or natural events.

During the 1999 water quality study, many signs of beaver activity as well as piscivorous and other bird species (e.g. great blue heron, dippers and mallard ducks) were observed within the watershed.

2.2 Human Use and Development

Land uses within the Beaver Creek watershed include recreational (Beaver Creek Provincial Park), residential, agricultural (mostly hobby farms), forest harvesting and industrial (saw mill), all of which may impact the water quality and quantity in Beaver Creek and its tributaries. In the upland areas, the predominant resource use is timber extraction, with some historic mineral exploration. The communities of Fruitvale (population 2,025 as of the 2001 B.C. Provincial census) and Montrose (population 1,097 as of 2001) have developed in close proximity to the creek, with the creek flowing through the middle of the Fruitvale community.

This urban and rural residential development may be assumed to have had some negative impact on Beaver Creek. Prior to 1994, both communities discharged treated sewage directly into Beaver Creek, however, the Village of Montrose now disposes of their secondarily treated sewage through ground injection. Since 1997, the Village of Fruitvale has disposed of their secondary treated sewage via infiltration in gravel basins. The treated and ground-filtered sewage is then collected below the infiltration basins, in perforated sub-surface collection pipes and discharged directly into Beaver Creek (B.C. Ministry of Water, Land and Air Protection files).

A water license query (Ministry of Sustainable Resource Management website: http://www.elp.gov.bc.ca:8000/pls/wtrwhse/water_licences.input) reported approximately 60 water use licenses for domestic and irrigation water intakes on Beaver Creek and its tributaries. The largest tributaries to Beaver Creek - Kelly, Linnie, Bath, Barclay and Fruitvale Creeks - had predominantly domestic water uses. Of those 60 water licenses, only fourteen exist on the mainstem of Beaver Creek; nine of these are below the Fruitvale STP discharge. Of those nine water licenses, two are on ministry files as being issued for domestic purposes. One of these intakes for domestic use is located approximately 1,200 m downstream of the Fruitvale STP discharge, prompting concerns regarding drinking water quality. Upstream of the Village of Fruitvale, both irrigation licenses and unlicensed and unimpeded access to Beaver Creek are available for watering livestock.

Recreational use of Beaver Creek is high, particularly the section of Beaver Creek below the Village of Fruitvale, which is used during summer months for swimming, angling and general recreation by local residents and visitors to the area. In the early 1980's, Ptolemy and Russell (1983) reported Beaver Creek had an outstanding number of catchable trout per square metre of stream. In 1994, the lower section of the creek sustained a substantial 3,000 to 5,000 angler days per year sport fishery (B. Lindsay pers. com. 1994). Despite pressure from non-point source pollution on the creek from land development, agriculture and urban development over the last 20 years, the creek continues to be unique in the Kootenays, supporting a highly productive eastern brook trout (*Salvelinus fontinalis*) population that consistently produces fish in the 20 to 50 cm size range, making it potentially one of the best resident eastern brook trout fisheries in the Kootenays (RL&L 1995).

Beaver Creek is also regularly used by children and adults for contact recreation during the summer months. The Boy Scouts of Canada operate a camp approximately 400 m downstream of the Village of Fruitvale STP. Children attending the camp likely explore the banks of the creek and wade in its waters. Further downstream near Highway 22, people swim and fish in the pools adjacent to the Buckhaven Garden Centre. Below this area, the creek flows to its confluence with the Columbia River through the Beaver Creek Provincial Park, established in 1965 as a small day-use and camp ground with boat launch access to the Columbia River. The park is now operated under a B.C. Parks Use Permit by the Trail Kiwanis Club. Attendance at the park has generally risen since 1988 with currently an estimated 1,000 to 1,500 annual visitors, many of whom come in contact with Beaver Creek though swimming and wading (H. Branton, pers. com. 2003).

These various water uses require that the water quality of Beaver Creek meet not only drinking water guidelines, but also guidelines for primary contact recreational use, livestock and irrigation.

Figure 2.1 Beaver Creek Study Area

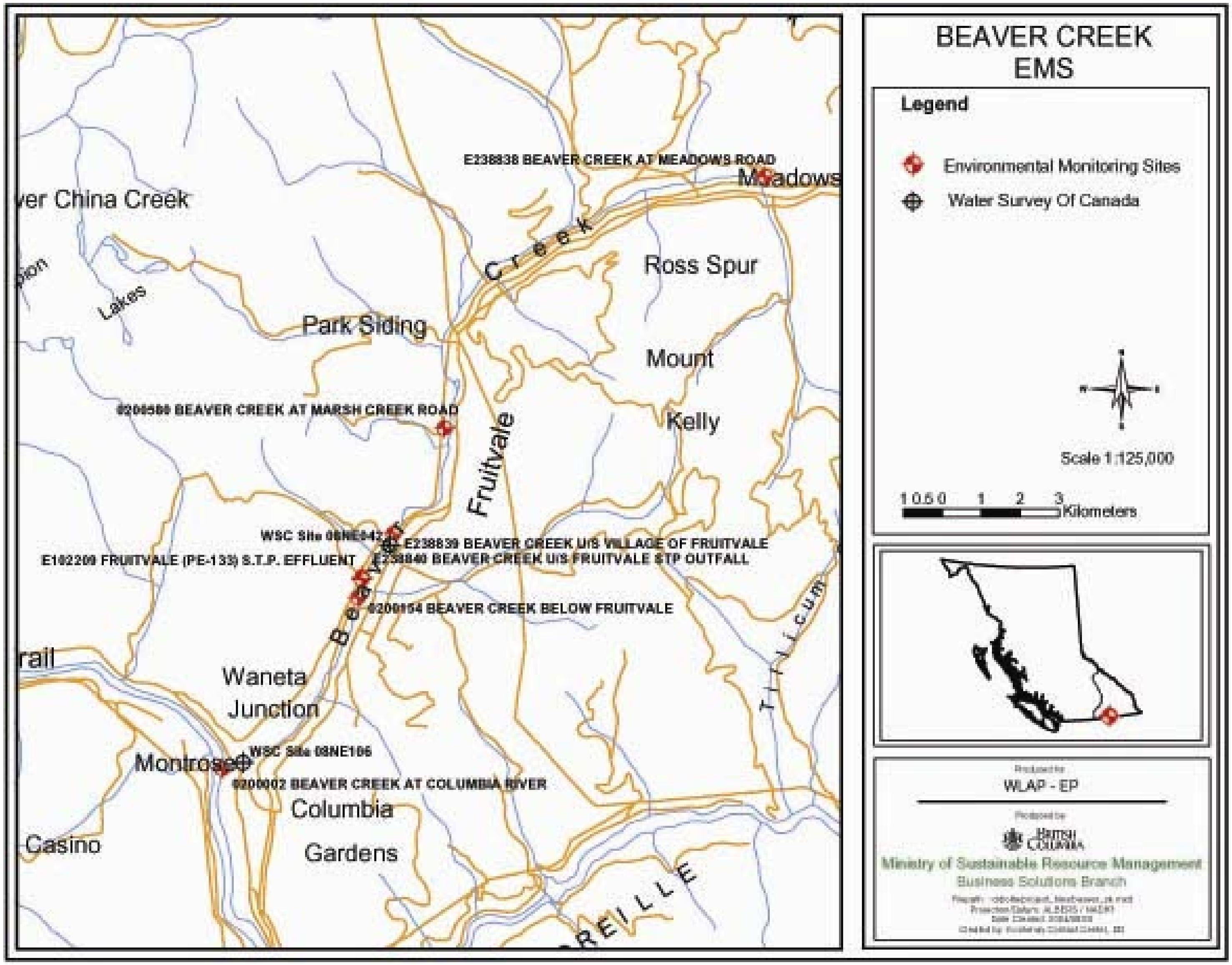
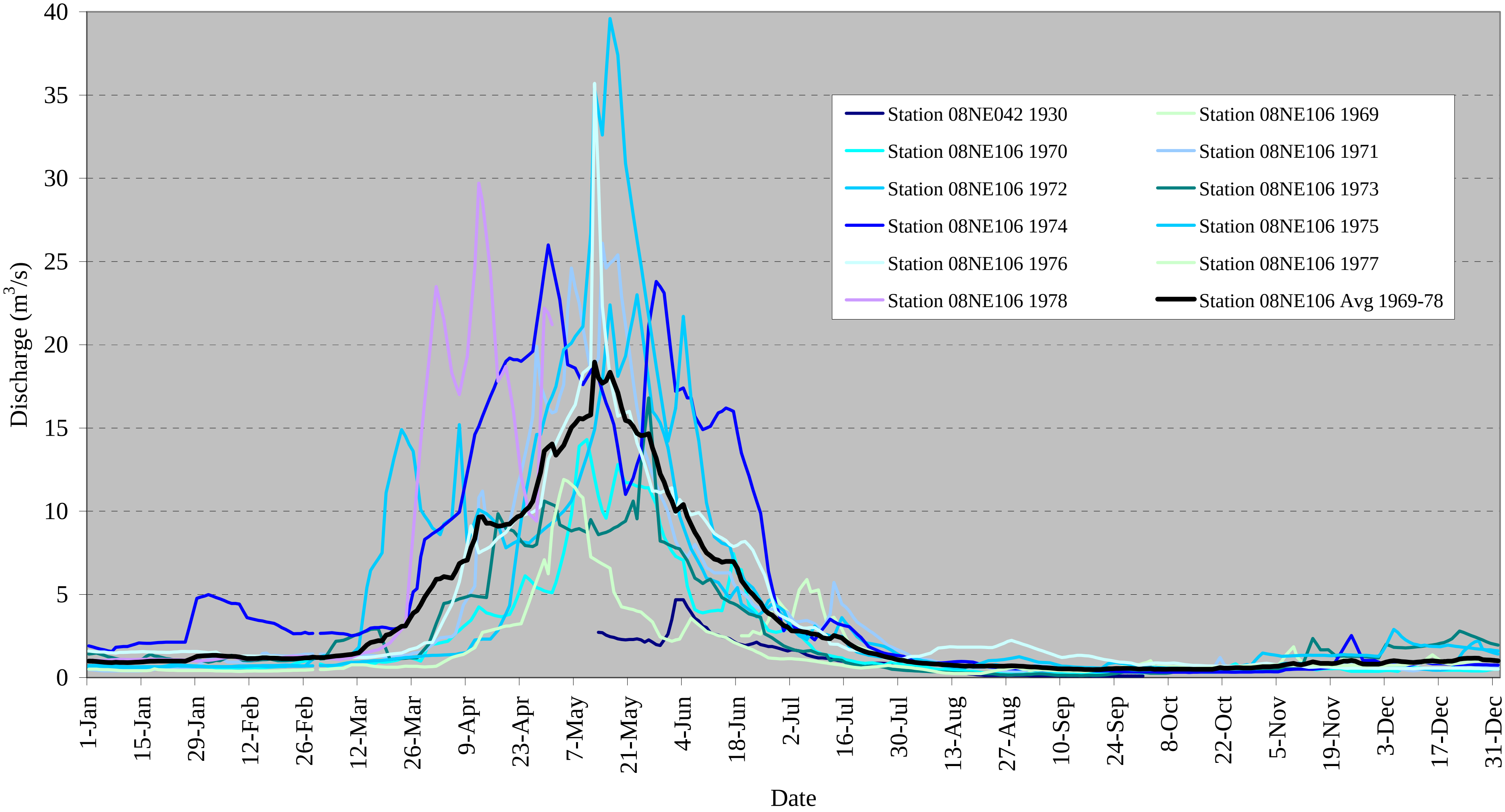


Figure 2.2 Discharge of Beaver Creek



3 BACKGROUND INFORMATION

Since June, 1965 the Village of Fruitvale has been discharging secondarily treated sewage to Beaver Creek under authorizations from WLAP. In 1995, major upgrades were completed at the Fruitvale STP in response to pollution concerns expressed by the ministry resulting from low dilution rates of the effluent and potential impacts on the water quality and health of Beaver Creek. The selected upgrades to the plant included a ground disposal system that incorporated primary and secondary aeration (Photo 8.1) with the addition of polyaluminum chloride as a flocculant, followed by further holding and settling of effluent, then finally discharging to the ground through rapid infiltration (RI) basins (Photos 8.2 & 8.3) (B. DeJong, pers. com., 2003).

Since Fruitvale's treated effluent was now to be discharged to the ground, disinfection and the dechlorination cell were no longer a regulatory requirement. As a result, one of the original four sewage treatment cells, previously used for dechlorination, was converted to an RI basin. In addition to the existing primary, secondary and holding cells, two additional RI basins were installed to provide the ability to rotate the use and efficacy of the RI basins and improve effluent quality prior to it reaching Beaver Creek (Gigliotti 1994). The original dechlorination cell was emptied, cleaned and scarified and all three RI cells were then lined with permeable material to allow the effluent to filter through the granular media. This effluent filtration process, used on a weekly rotating basis between the three RI cells, was thought to have the potential to remove 40 to 60% of the phosphorus from the effluent, depending on soil attenuating characteristics (Gigliotti 1994). Soils are known to attenuate bacteria or other pathogens and some phosphorus depending on the type and size of the soil particles.

The Fruitvale RI basins were tested in 1996 and the infiltration rates were found to be unsatisfactory for effluent disposal (Golder 1996). Further investigations indicated the presence of varying soils underlying the RI basins with an overall low hydraulic conductivity (soils with tightly packed particles and low permeability). As well, the water table was found to be near the bottom of the RI basin at the time of the investigation and was thought to also contribute to the low infiltration and permeability rates. As a result of this assessment, a series of underdrains were installed in the three RI basins in 1997, which collect the treated effluent approximately 0.6

m below the RI basin. The effluent flows through the underdrains to a 3 m cement outfall pipe, which discharges the effluent into Beaver Creek (Photos 8.4 & 8.5). At low creek levels, this discharge pipe is exposed and exists as a hanging outfall. This new system operates more effectively but somewhat reduces the attenuation performance of the “rapid infiltration to ground” means of effluent disposal. This disposal system is now considered a direct discharge to a surface water body, and is therefore subject to the *Municipal Sewage Regulation*.

Some historical ambient water quality data is available for two sites downstream of the Fruitvale STP as well as data for “end-of-pipe” STP effluent quality. General chemistry and metals for the Fruitvale STP have been analysed, but parameters have not been consistent among all studies in all years. Sites 0200154 Beaver Creek Below Fruitvale, and 0200002 Beaver Creek at the Mouth of the Columbia River, were sporadically sampled from 1980 to 1999. As well, compliance data for effluent quality of the STP was collected by the ministry sporadically between 1986 and 1999. However, the Village of Fruitvale routinely collects and submits limited effluent quality and flow volume data according to its requirements under Waste Management Act Permit Number PE 133. Effluent samples are collected by Village staff via the outfall pipe of the RI basin underdrains just prior to its discharge to Beaver Creek (G. Greive, pers. com., 2003).

4 METHODS

Water quality data was collected once a week for five weeks between September 1 and September 29, 1999, at six sample locations. On the last date of sampling (September 29, 1999) benthic invertebrate samples were also taken following the collection of water quality samples at five of the sites. Table 4.1 summarizes the sampling site location information. The sampling sites are mapped on Figure 2.1 and can be seen in Photos 8.7 to 8.12.

Table 4.1 1999 Beaver Creek Sampling Site Locations and Descriptions

EMS #	**Site Name**	**Site Description**
E238838	Beaver Creek at Meadows Road	Beaver Cr. on upstream side of Meadows Rd., near headwaters.
0200580	Beaver Creek at Marsh Creek Road	Beaver Cr. on upstream side of Marsh Cr. Rd bridge (12 km downstream from E238838).
E238839	Beaver Creek U/S Village of Fruitvale	Beaver Cr. approx. 20 m downstream of Hwy 3 bridge.
E238840	Beaver Creek U/S Fruitvale STP Outfall	Beaver Cr. approx. 100 m upstream of the Village of Fruitvale STP discharge.
E102209	Fruitvale (PE 133) STP Effluent	Village of Fruitvale STP outfall at the end of the pipe exiting the RI basin underdrains just prior to its discharge into Beaver Creek.
0200154	Beaver Creek D/S Village of Fruitvale	Beaver Cr. approx. 400 m downstream of the STP outfall at the Boy Scout camp.
0200002	Beaver Creek at Columbia River	Beaver Cr. approx. 200 m upstream of the confluence with the Columbia River.

The parameters measured at each of the six sites (excluding the STP effluent site) were:

- Site characteristics, including sediment particle size (visual assessment), riparian cover, stream morphology, instream vegetation, large woody debris and bank composition and stability

- Field measurements, including temperature, pH, dissolved oxygen and specific conductance

- Water quality sampling, including total ammonia, nitrate, nitrite, total nitrogen, total phosphorus, dissolved ortho-phosphate, metals, hardness, alkalinity, major anions (chloride, bromide, fluoride and sulphate), pH, non-filterable residue and conductivity

- Bacteriology sampling, including total coliforms, faecal coliforms, enterococci and *Escherichia coli* bacteria

- Benthic invertebrate sampling (with the exception of the Meadows Road site)

- Stream velocities and depths at the benthic invertebrate sampling sites

The STP effluent data consisted of water quality sampling for a similar suite of water quality parameters listed above.

4.1 Water Quality

The water quality and bacteriology samples taken from Beaver Creek were collected on five discrete sample dates over a 30 day period in September 1999 (September 1, 8, 15, 23 and 29) following standard procedures (Cavanagh *et al*. 1994a). This monitoring frequency was necessary to evaluate the attainment of B.C. Approved and Working Water Quality Guidelines (MELP 1998a, 1998b) for important physical and chemical water quality parameters.

Water chemistry analyses were carried out by the Pacific Environmental Science Centre (PESC), in North Vancouver B.C., which followed standard analytical protocols (Cavanagh *et al*. 1994 a and b). Bacteriological analyses were conducted by JR Laboratories in Vancouver B.C., also using methods outlined in Cavanagh *et al*. (1994b). Analytical results from PESC were downloaded and archived in the Environmental Monitoring System (EMS), the ministry's provincial environmental quality database.

The field data was collected using an Aqua-Check multi-variable meter, reported to PESC and loaded onto the EMS database at the laboratory.

Simple statistical analysis was conducted on certain subsets of the data, including nutrient and microbiological parameters, for data collected at the STP effluent and immediately (400 m) downstream of the Fruitvale STP. These parameters had the most complete datasets and similar (but not always equal) sample sizes, allowing the use of statistical tests to determine significant differences. The Student's t-test was used to determine if the water quality parameters for each site (STP effluent and downstream of the STP outfall) differed significantly over time (among 1990, 1993 and 1999 datasets). Statistical t-tests were also used to determine if the water quality parameters differed significantly between sites during the same time periods. For all tests, significance was determined at an alpha level of 0.05.

4.2 BENTHIC INVERTEBRATES

Benthic invertebrates were collected on September 29, 1999 at five sampling sites along Beaver Creek listed on Table 4.1. The Meadows Road site could not be sampled due to the small size of the creek, and the STP effluent itself could not be sampled for obvious reasons.

Because benthic invertebrate communities are closely linked to the physical, chemical and biological characteristics of the stream, generalized habitat characteristics were also collected from each of the five sites. Measurements included stream velocity and depth and a visual determination of sediment particle size, riparian cover, stream morphology, instream vegetation, large woody debris and bank composition and stability.

A Hess sampler (mesh size 210 μm with an area of 0.09 m^2) was used to quantitatively sample the stream bed for benthic invertebrates. At each stream location, five replicate sites were chosen and approached in an upstream manner, so as not to disturb the substrate and potentially lose invertebrates. Riffles with adequate flow and a gravel/cobble substrate were chosen. The five replicate samples were not composited into one, as dictated in the RIC protocol (Cavanagh *et al.*

1994b) but rather, left as individual replicates, in order to determine the variation inherent in the benthic habitats and to statistically analyse data between and within sites over time.

The samples were preserved with formalin (10% buffered formaldehyde) and processed at the laboratory at the University of Calgary, Alberta for counting and identification to the lowest possible level. The benthic invertebrate information was analyzed and interpreted using biometric analysis, which are measurements responsive to different types of anthropogenic impact, are robust to variations in sample size and have low variability both within a site and over time (Chessman and McEnvoy 1998; Fore *et al*. 1996). Biometric analyses included taxonomic richness, abundance, tolerance indices, feeding type and comparisons of dominant taxa to determine the health and state of the aquatic invertebrate community (Table 4.2). Data from these biometrics were ranked and judged on a scale ranging from unimpacted to severely impacted.

Hilsenhoff's Biotic Index (HBI) was used to calculate the pollution tolerance of each sample. Tolerance values have been previously determined in the literature for each taxon based on their relative presence/absence in areas of known levels of disturbance. A higher rating means a higher tolerance to pollution (Chessman and McEvoy 1998; Fore *et al*. 1996). Tolerances values for each taxon were obtained from U.S. EPA documents (Barbour *et al*. 1999) compiling information from several sources (Hilsenhoff 1988).

The taxa were also classified according to their functional feeding group (FFG), which categorizes invertebrates based on their feeding mode (Merritt and Cummins 1996; Cummins and Klug 1979) (Table 4.3). In contrast to other biometrics that measure the structure of the invertebrate community, FFG analysis measures its functioning.

Through the use of these functional feeding group definitions, the invertebrates present in the community indicate the type and relative amounts of different food sources being utilized. They also describe ongoing processes within the stream. Changes in the proportions of these functional feeding groups can indicate stressful conditions, as well as changes to the resource base.

Table 4.2 Summary of Biometric Analysis of Benthic Invertebrate Data (Barbour *et al*. 1999; Merritt and Cummins 1995).

Biometric	Measure	Indicator	Assessment/Rating
Abundance / Density	Production	Indicator of stream health, production of food for other organisms such as fish	Quantitative assessment allows spatial and temporal comparison
Total number of Taxa	Taxonomic richness	Indicates health of the community, reflects increasing water quality, habitat diversity and suitability	No impact- >26 taxa present Slight impact - 19-26 taxa Moderate impact- 11-18 taxa Severe impact- <11 taxa
Number of EPT Taxa	Taxonomic richness	Number of sensitive taxa (including mayflies (E), stoneflies (P) and caddisflies (T)), indicators of high water quality	No impact- >10 taxa present Slight impact - 6-10 taxa Moderate impact- 2-5 taxa Severe impact- <1 taxa
EPT/total Taxa	Taxonomic richness	Ratio of sensitive taxa (including mayflies (E), stoneflies (P) and caddisflies (T)) to total number of taxa	No impact- >40% Slight impact - 30-39% Moderate impact- 20-29% Severe impact- <20%
% Dominant Taxon	Composition	Indicates community balance, a community with only a few taxa indicates community stress	No impact- <20% Slight impact - 20-29% Moderate impact- 30-39% Severe impact- >40%
Hilsenhoff's Biotic Index (HBI)	Tolerance	Pollution tolerance, mainly organics	No impact- 0-3.5 Slight impact - 3.5-5.5 Moderate impact- 5.5-7.5 Severe impact- 7.5-10
EPT/(EPT+ Chironomid) Ratio	Tolerance	Measure of community balance, good biotic condition is reflected in communities with even distribution of all four groups	No impact- >75% Slight impact - 50-75% Moderate impact- 25-50% Severe impact- <25%
No. taxa by functional feeding group (FFG), and Percent functional feeding group	Trophic (feeding) status	Indicator of community food base, reflects the type of impact detected (Functional feeding groups include: predators, collector-gatherers collector-filterers, scrapers, shredders, parasites)	Descriptive assessment based on number of taxa in each group and relative proportions
Scraper / (Scraper+Collector-Filterer)	Dominant food resources	Indicates the condition of the periphyton community, availability of fine particulate organic matter and availability of attachment sites for filtering	Ratios of greater than 0.5 indicate that periphyton is the dominant food resource and ratios of less than 0.5 indicate that organic materials are the dominant resources available for macroinvertebrates
(Scraper + Collector-Filterer) / (Shredders + Collector-Gatherers)	Habitat Stability	Assessment of available surfaces for stable attachment and substrate stability	Ratios of greater than 0.5-0.6 indicate that stable substrates are not limiting, ratios of less than 0.5-0.6 indicate stable substrates are limiting

Table 4.3 Functional Feeding Group Classifications

Functional Feeding Group	Dominant Food	Feeding Mechanism
Predators	Living animal tissue	Attack prey, engulf or suck
Shredders	Living or dead CPOM [1]	Chewers (herbivores/detritivores)
Collector-Gatherers	Decomposing FPOM [2]	Detritivores or ingest sediments
Collector-Filterers	Decomposing FPOM	Suspension feeders
Scrapers	Periphyton	Graze surfaces
Parasites	Animal hosts	External/internal parasites

1 CPOM = coarse particulate organic matter

2 FPOM = fine particulate organic matter

Benthic invertebrates can be opportunistic and modify their feeding, and therefore, their FFG classification, based on the food availability. The FFG classification of aquatic insects can also change during development from early to late instars. For the purpose of this study, the taxa have been classified according to their primary feeding mode. When ambiguities about feeding ecology could not be resolved, taxa were identified as unknowns. Non-feeding stages such as pupae and non-aquatic adults were removed from the data set prior to the calculation of FFG analyses. The functional feeding group classifications for each taxon were obtained from U.S. EPA documents (Barbour *et al*. 1999) that compiled information from several sources (Merritt and Cummins 1996).

5 Results and Discussion

The water quality and ecological health of Beaver Creek were assessed for six sites located longitudinally throughout the drainage. The assessment included the determination of potential impacts on Beaver Creek and the potential sources of those impacts. The 1999 results were also compared to historical data to determine if improvements to the water quality of Beaver Creek have occurred since the latest upgrades to the Fruitvale STP. The data collected from the STP outfall itself were also assessed for improvements in effluent quality. Cumulative environmental impacts are discussed in the final section and relate to requirements under the *Municipal Sewage Regulation*, which the Village of Fruitvale STP discharge may be administered under in the future.

5.1 1999 Water Quality

The 1999 water quality data for all six sampling sites on Beaver Creek and the STP effluent are presented in Table 5.1 with the B.C. Approved and Working Water Quality Guidelines (MELP 1998a, 1998b) for drinking water, primary contact recreation and the protection of aquatic life noted at the bottom. Table 5.2 statistically compares the water quality of several variables for the two sites immediately upstream and downstream of the Fruitvale STP outfall. Several parameters are also graphed, starting with the uppermost sample site located at the headwaters of the Beaver Creek watershed and ending at the most downstream site near the junction with the Columbia River (Figures 5.1 to 5.9).

5.1.1 Nutrients

The inorganic forms of nitrogen measured in surface water and municipal effluent samples included ammonia (NH_3), nitrite (NO_2) and nitrate (NO_3). Ammonia is not typically found in high concentrations in pristine natural surface waters since it is formed during the degradation of organic compounds as, for example, during the sewage treatment process. Ammonia is an unstable form of inorganic nitrogen so is very quickly oxidized and transformed into nitrite and then nitrate under well-oxygenated conditions.

The 1999 data showed that total ammonia concentrations along Beaver Creek were fairly constant along the stream length, with the exception of a sharp increase downstream of the STP outfall (Figure 5.1). Ammonia concentrations at the site immediately downstream of the Fruitvale STP were significantly greater than the concentrations found just upstream of the STP outfall ($p=0.0080$) (Table 5.2), but dropped to background levels at the confluence site, much further downstream. It is reasonable to conclude that the source of this ammonia is the Fruitvale STP effluent. As treated sewage effluent is discharged and entrained downstream in Beaver Creek, the nitrification process continues, resulting in an increase in nitrate and consequently, a reduction in ammonia levels to near background concentrations further downstream.

With the exception of the Village of Fruitvale STP effluent discharge, concentrations of nitrite (NO_2) were at or below the analytical detection limit in all samples during the study. These nitrite results speak to the transient, short lived nature of the nitrite form of inorganic nitrogen. Conversely, the concentrations of nitrate increased along the stream length, with the greatest relative increase found at the site immediately downstream of the STP outfall (Figure 5.2). Significant differences ($p=0.0055$) in nitrate concentrations were found between the sites just upstream and 400 m downstream of the Fruitvale STP (Table 5.2), which strongly suggests that the STP is responsible for significant additional nitrate loadings to Beaver Creek.

Nitrate levels continued to rise further downstream, the opposite of the downstream trend displayed by ammonia. These results support the conclusion that the nitrification process continues along Beaver Creek, with the ammonia discharged from the STP effluent being transformed into nitrate along the stream length. Other sources of nitrate that may contribute to the progressive increase in its concentrations along Beaver Creek are agricultural land uses. The application of fertilizers and/or the presence of livestock adjacent to the creek may also result in the addition of nitrate.

Total nitrogen, which is a measure of all forms of nitrogen, both organic and inorganic, increased downstream of the STP outfall (Figure 5.3) with concentrations significantly greater than the site upstream ($p=0.0013$) (Table 5.2). Total nitrogen concentrations were consistently lower among the sites upstream of the outfall and higher among the sites downstream of the outfall. These results suggest that the STP effluent contributes significant total nitrogen to Beaver Creek.

Total phosphorus was relatively constant throughout the watershed, with the exception of a significant spike downstream of the STP outfall (Figure 5.4). Total phosphorus concentrations were significantly greater 400 m downstream of the outfall compared to the site just upstream ($p=0.004$) (Table 5.2). Total phosphorus concentrations dropped at the confluence with the Columbia River, likely the result of dilution from tributaries, and/or biological uptake, as compared to the site immediately downstream of the STP outfall.

Like total phosphorus, dissolved ortho-phosphate concentrations were relatively constant upstream of the STP, with a sharp increase just downstream of the STP, then falling again at the Columbia River confluence (Figure 5.5). Ortho-phosphate concentrations were significantly higher downstream of the outfall compared to the site upstream of the outfall ($p=0.004$) (Table 5.2). Ortho-phosphate is the dissolved component of the total phosphorus in the water and is highly available for uptake and growth of attached algae and phytoplankton in the creek.

In addition to higher concentrations of phosphorus occurring below the STP discharge, the form of phosphorus changes. Upstream of the STP outfall, ortho-phosphate comprised on average 10% of the total phosphorus values, indicating the majority of the phosphorus in these sections of Beaver Creek was suspended particulate and not immediately available for use by the biological communities in the stream. In contrast, ortho-phosphate comprised an average of 52% of the total phosphorus values downstream of the STP outfall, indicating a substantial increase in the availability of that phosphorus. The eventual drop in ortho-phosphate levels near the confluence with the Columbia River, may be explained by uptake and assimilation of the ortho-phosphate by the biota and dilution from other tributaries entering Beaver Creek.

These increases in nitrogen and phosphorus downstream of the STP outfall suggest that treated sewage effluent influences the overall pollutant loading and water quality of Beaver Creek. These increases are somewhat ameliorated further downstream, as a result of the combination of chemical reactions, dilution from tributaries and/or biological uptake.

Table 5.1 1999 Water Quality Data for Beaver Creek

EMS ID	SAMPLING DATE	Alkalinity	Ammonia-T	Bromide-D	Chlrid:D	Coli:Fec	Coli:Tot	Diss Oxy	E Coli	Entercoc	Fluoride-T	Hardness-T (Extr)
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(CFU/100mL)	(CFU/100mL)	(mg/L)	(CFU/100mL)	(CFU/100mL)	(mg/L)	(mg/L)
At Marsh Creek Road												
E238838	1-Sep-99	54	< 0.005	< 0.05	0.36	46	220	10	30	130	0.06	55
E238838	8-Sep-99	56	0.018	< 0.05	0.4	24	44	9.9	24	20	0.03	55.1
E238838	15-Sep-99	56.7	< 0.005	< 0.05	1.1	280	300		160	380	0.01	58
E238838	23-Sep-99	57.6	0.015	< 0.05	0.56	2700	5300		700	32	0.02	60.7
E238838	29-Sep-99	56.3	0.006	< 0.05	0.38	28	28		2	48	0.024	60.4
E238838	Mean	56.12	0.0098	< 0.05	0.56	615.6	1178.4	9.95	183.2	122	0.0288	57.84
E238838	Min	54	< 0.005	< 0.05	0.36	24	28	9.9	2	20	0.01	55
E238838	Max	57.6	0.018	< 0.05	1.1	2700	5300	10	700	380	0.06	60.7
At Meadows Road												
200580	1-Sep-99	69	< 0.005	< 0.05	4.8	66	530	9	66	46	0.06	73.1
200580	8-Sep-99	73	0.012	< 0.05	5.4	16	40	8.7	6	14	0.03	75.2
200580	15-Sep-99	74.5	< 0.005	< 0.05	6.2	16	22		10	18	0.03	80.8
200580	23-Sep-99	77.1	0.007	< 0.05	6.6	14	48		4	4	0.02	86.2
200580	29-Sep-99	76.4	0.007	< 0.05	6.7	600	500		250	4	0.03	91.3
200580	Mean	74	0.0072	< 0.05	5.94	142.4	228	8.85	67.2	17.2	0.034	81.32
200580	Min	69	< 0.005	< 0.05	4.8	14	22	8.7	4	4	0.02	73.1
200580	Max	77.1	0.012	< 0.05	6.7	600	530	9	250	46	0.06	91.3
U/S Village of Fruitvale												
E238839	1-Sep-99	74	< 0.005	< 0.05	5.5	310	450	10.5	160	18	0.06	79.5
E238839	8-Sep-99	78	0.006	< 0.05	5.6	14	190	10.2	10	4	0.05	81.4
E238839	15-Sep-99	79.8	< 0.005	< 0.05	6.6	8	230		14	8	0.03	86.4
E238839	23-Sep-99	83.6	0.008	< 0.05	6.9	10	210		< 2	12	0.03	< 0.4
E238839	29-Sep-99	82.3	< 0.005	< 0.05	7.1	8	370		2	4	0.03	93.5
E238839	Mean	79.54	0.0058	< 0.05	6.34	70	290	10.35	37.6	9.2	0.04	68.24
E238839	Min	74	< 0.005	< 0.05	5.5	8	190	10.2	< 2	4	0.03	< 0.4
E238839	Max	83.6	0.008	< 0.05	7.1	310	450	10.5	160	18	0.06	93.5
	BCALWQC	<10 acid sensitive	1.33 (30d) 6.92 (max)					9 (min) 11 (30d)			0.3 (max)	
	BC DWQC					0			0	0	1.0 (30d) 1.5 (max)	

Table 5.1 1999 Water Quality Data for Beaver Creek Cont.

EMS ID	SAMPLING DATE	Hardness-T (T)	Nitrate-D	Nitrate + Nitrite-D	Nitrogen - Nitrite-D	Nitrogen-T	Ortho-Phos-D	P--T	NFR	Specific Conductance	Sulfate:D	Temp	pH
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(uS/cm)	(mg/L)	(C)	(pH units)
At Marsh Creek Road													
E238838	1-Sep-99	41.0605	< 0.002	< 0.007	< 0.005	0.11	< 0.001	0.039	< 5	125	6.4	12.4	7.67
E238838	8-Sep-99	52.6957	< 0.002	< 0.007	< 0.005	0.08	0.004	0.017	< 5	127.5	6.7	13	7.79
E238838	15-Sep-99	54.4436	< 0.002	< 0.007	< 0.005	0.15	0.002	0.02	< 5	122	1.6		7.82
E238838	23-Sep-99	52.1087	0.007	0.012	< 0.005	0.17	0.003	0.022	< 5	132	7.1	17.5	7.72
E238838	29-Sep-99	56.4412	< 0.002	< 0.007	< 0.005	0.11	0.005	0.023	< 5	124	7.9		8.15
E238838	Mean	51.34994	0.003	0.008	< 0.005	0.124	0.003	0.0242	< 5	126.1	5.94	14.3	7.829
E238838	Min	41.0605	< 0.002	< 0.007	< 0.005	0.08	< 0.001	0.017	< 5	122	1.6	12.4	7.665
E238838	Max	56.4412	0.007	0.012	< 0.005	0.17	0.005	0.039	< 5	132	7.9	17.5	8.15
At Meadows Road													
200580	1-Sep-99	55.3548	0.026	0.031	< 0.005	0.11	0.002	0.016	< 5	174.5	8.1	10.2	7.47
200580	8-Sep-99	76.8773	0.031	0.036	< 0.005	0.09	0.003	0.017	< 5	187	8.7	9.5	7.62
200580	15-Sep-99	75.1294	0.032	0.037	< 0.005	0.11	0.002	0.019	< 5	178	9.6		7.63
200580	23-Sep-99	74.5424	0.035	0.04	< 0.005	0.16	0.005	0.023	< 5	190.5	9.9	11.9	7.65
200580	29-Sep-99	86.6901	0.037	0.042	< 0.005	0.11	0.003	0.021	< 5	184.5	10	10.2	7.20
200580	Mean	73.7188	0.0322	0.0372	< 0.005	0.116	0.003	0.0192	< 5	182.9	9.26	10.45	7.513
200580	Min	55.3548	0.026	0.031	< 0.005	0.09	0.002	0.016	< 5	174.5	8.1	9.5	7.2
200580	Max	86.6901	0.037	0.042	< 0.005	0.16	0.005	0.023	< 5	190.5	10	11.9	7.65
U/S Village of Fruitvale													
E238839	1-Sep-99	77.6264	0.034	0.039	< 0.005	0.16	0.002	0.016	< 5	195.5	8.8	11.9	7.41
E238839	8-Sep-99	80.7849	0.035	0.04	< 0.005	0.11	0.002	0.019	< 5	200	9.4	11	8.03
E238839	15-Sep-99	81.9458	0.025	0.03	< 0.005	0.12	0.001	0.019	< 5	190	10		8.02
E238839	23-Sep-99	81.7706	0.041	0.046	< 0.005	0.16	0.002	0.023	< 5	207	11	14	7.69
E238839	29-Sep-99	89.761	0.039	0.044	< 0.005	0.16	0.002	0.02	< 5	196	11	10.8	7.49
E238839	Mean	82.37774	0.0348	0.0398	< 0.005	0.142	0.0018	0.0194	< 5	197.7	10.04	11.925	7.726
E238839	Min	77.6264	0.025	0.03	< 0.005	0.11	0.001	0.016	< 5	190	8.8	10.8	7.405
E238839	Max	89.761	0.041	0.046	< 0.005	0.16	0.002	0.023	< 5	207	11	14	8.03
	BCALWQC		40 (30d) 200 (max)		0.08 (30d) 0.24 (max)				25 (24h) 5 (30d)		100 (max)		6.5-9.0
	BC DWQC		10 (max)		1 (max)						500		6.5-8.5

Table 5.1 1999 Water Quality Data for Beaver Creek Cont.

EMS ID	SAMPLING DATE	Alkalinity	Ammonia-T	Bromide-D	Chlrid:D	Coli:Fec	Coli:Tot	Diss Oxy	E Coli	Entercoc	Fluoride-T	Hardness-T (Extr)
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(CFU/100mL)	(CFU/100mL)	(mg/L)	(CFU/100mL)	(CFU/100mL)	(mg/L)	(mg/L)
U/S Fruitvale STP Outfall												
E238840	1-Sep-99	76	< 0.005	< 0.05	5.9	220	320	11.09	150	38	0.06	81
E238840	8-Sep-99	78	< 0.005	< 0.05	6.5	44	1600	10.6	24	94	0.04	81.5
E238840	15-Sep-99	81.4	< 0.005	< 0.05	7.3	66	2300		24	16	0.03	89.2
E238840	23-Sep-99	84.5	0.008	< 0.05	7.5	24	320		10	6	0.03	80.5
E238840	29-Sep-99	83.6	< 0.005	< 0.05	8.1	24	32		18	16	0.037	95.9
E238840	Mean	80.7	0.0056	< 0.05	7.06	75.6	914.4	10.845	45.2	34	0.0394	85.62
E238840	Min	76	< 0.005	< 0.05	5.9	24	32	10.6	10	6	0.03	80.5
E238840	Max	84.5	0.008	< 0.05	8.1	220	2300	11.09	150	94	0.06	95.9
Fruitvale STP Effluent												
E102209	1-Sep-99					4	12		4	18		
E102209	8-Sep-99	121	5.43	< 0.05	30	24	170		20	74	0.03	109
E102209	15-Sep-99	112	4.04	< 0.05	34	18	310		10	130	< 0.01	109
E102209	23-Sep-99	99.9	2.1	< 0.05	35	36	42		14	38	< 0.01	94.7
E102209	29-Sep-99	115	2.98	< 0.05	36	72	94		6	62	< 0.01	111
E102209	Mean	111.975	3.6375	< 0.05	33.75	30.8	125.6		10.8	64.4	0.015	105.925
E102209	Min	99.9	2.1	< 0.05	30	4	12	0	4	18	< 0.01	94.7
E102209	Max	121	5.43	< 0.05	36	72	310	0	20	130	0.03	111
D/S Village of Fruitvale												
200154	1-Sep-99	77	0.048	< 0.05	6.4	170	1700	10.5	82	100	0.06	81.9
200154	8-Sep-99	80	0.055	< 0.05	7	16	84	10.4	10	24	0.06	82.2
200154	15-Sep-99	82.2	0.028	< 0.05	7.3	10	70		14	24	0.04	89.8
200154	23-Sep-99	85.5	0.038	< 0.05	8.1	28	90		22	6	0.03	82.4
200154	29-Sep-99	84.4	0.037	< 0.05	8.7	28	40		20	10	0.03	95.3
200154	Mean	81.82	0.0412	< 0.05	7.5	50.4	396.8	10.45	29.6	32.8	0.044	86.32
200154	Min	77	0.028	< 0.05	6.4	10	40	10.4	10	6	0.03	81.9
200154	Max	85.5	0.055	< 0.05	8.7	170	1700	10.5	82	100	0.06	95.3
At Columbia River												
200002	1-Sep-99	85	< 0.005	< 0.05	6.5	150	1200	10.6	54	88	0.07	94.7
200002	8-Sep-99	88	< 0.005	< 0.05	7.4	10	430	11.8	8	32	0.04	94.8
200002	15-Sep-99	92.4	< 0.005	< 0.05	8.4	12	140		2	18	0.04	104
200002	23-Sep-99	95.8	0.011	< 0.05	8.7	4	20		2	2	0.04	21.1
200002	29-Sep-99	94.5	0.005	< 0.05	9.1	12	300		4	4	0.04	111
200002	Mean	91.14	0.0062	< 0.05	8.02	37.6	418	11.2	14	28.8	0.046	85.12
200002	Min	85	< 0.005	< 0.05	6.5	4	20	10.6	2	2	0.04	21.1
200002	Max	95.8	0.011	< 0.05	9.1	150	1200	11.8	54	88	0.07	111
	BCALWQC	<10 acid sensitive	1.33 (30d) 6.92 (max)					9 (min) 11 (30d)			0.3 (max)	
	BC DWQC					0			0	0	1.0 (30d) 1.5 (max)	

Table 5.1 1999 Water Quality Data for Beaver Creek Cont.

EMS ID	SAMPLING DATE	Hardness-T (T)	Nitrate-D	Nitrate + Nitrite-D	Nitrogen - Nitrite-D	Nitrogen-T	Ortho-Phos-D	P--T	NFR	Specific Conductance	Sulfate:D	Temp	pH
		(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(mg/L)	(uS/cm)	(mg/L)	(C)	(pH units)
U/S Fruitvale STP Outfall													
E238840	1-Sep-99	78.1258	0.054	0.059	< 0.005	0.2	< 0.001	0.011	< 5	227.5	9.2	11.3	7.63
E238840	8-Sep-99	83.1943	0.076	0.081	< 0.005	0.15	0.002	0.018	< 5	205	9.8	10.3	8.11
E238840	15-Sep-99	83.1067	0.065	0.07	< 0.005	0.18	< 0.001	0.017	< 5	195	11		8.12
E238840	23-Sep-99	81.1836	0.074	0.079	< 0.005	0.19	0.003	0.021	< 5	210.5	11	13.3	7.91
E238840	29-Sep-99	90.9219	0.077	0.082	< 0.005	0.19	0.002	0.019	< 5	206.5	11	9.8	7.65
E238840	Mean	83.30646	0.0692	0.0742	< 0.005	0.182	0.0018	0.0172	< 5	208.9	10.4	11.175	7.88
E238840	Min	78.1258	0.054	0.059	< 0.005	0.15	< 0.001	0.011	< 5	195	9.2	9.8	7.625
E238840	Max	90.9219	0.077	0.082	< 0.005	0.2	0.003	0.021	< 5	227.5	11	13.3	8.12
Fruitvale STP Effluent													
E102209	1-Sep-99												
E102209	8-Sep-99	104.603	2.38	2.609	0.229	9.1	1.1	1.335	< 5	433	28		7.40
E102209	15-Sep-99	104.3402	4.12	4.369	0.249	8.8	1.125	1.425	< 5	438	32		7.37
E102209	23-Sep-99	94.9392	4.78	5.227	0.447	8.4	1.275	1.4	< 5	430	33		7.36
E102209	29-Sep-99	109.9081	4.08	4.175	0.095	8.3	1.5	1.8	< 5	451	33		7.24
E102209	Mean	103.447625	3.84	4.095	0.255	8.65	1.25	1.49	< 5	438	31.5		7.3425
E102209	Min	94.9392	2.38	2.609	0.095	8.3	1.1	1.335	< 5	430	28	0	7.24
E102209	Max	109.9081	4.78	5.227	0.447	9.1	1.5	1.8	< 5	451	33	0	7.4
D/S Village of Fruitvale													
200154	1-Sep-99	81.6961	0.097	0.102	< 0.005	0.3	0.012	0.03	8	206.5	9.6	12	7.61
200154	8-Sep-99	83.1067	0.117	0.122	0.005	0.27	0.016	0.035	< 5	211.5	10.3	10	8.15
200154	15-Sep-99	84.3552	0.148	0.153	< 0.005	0.3	0.018	0.032	< 5	199	11		8.14
200154	23-Sep-99	85.503	0.167	0.172	< 0.005	0.39	0.025	0.043	< 5	211	11	12.5	7.73
200154	29-Sep-99	90.6722	0.166	0.171	< 0.005	0.34	0.03	0.052	< 5	209.5	12	9.7	7.67
200154	Mean	85.06664	0.139	0.144	0.005	0.32	0.0202	0.0384	5.6	207.5	10.78	11.05	7.86
200154	Min	81.6961	0.097	0.102	< 0.005	0.27	0.012	0.03	< 5	199	9.6	9.7	7.61
200154	Max	90.6722	0.167	0.172	0.005	0.39	0.03	0.052	8	211.5	12	12.5	8.15
At Columbia River													
200002	1-Sep-99	93.9928	0.19	0.195	< 0.005	0.31	0.007	0.022	7	224	12	11	7.86
200002	8-Sep-99	93.6555	0.226	0.231	< 0.005	0.31	0.008	0.027	< 5	240	13	9.6	8.08
200002	15-Sep-99	99.9725	0.249	0.254	< 0.005	0.34	0.009	0.024	< 5	227	15		8.26
200002	23-Sep-99	99.46	0.271	0.276	< 0.005	0.4	0.011	0.032	< 5	244.5	15	11.2	7.92
200002	29-Sep-99	105.041	0.25	0.255	< 0.005	0.35	0.011	0.03	< 5	237.5	16	9.3	8.01
200002	Mean	98.42436	0.2372	0.2422	< 0.005	0.342	0.0092	0.027	5.4	234.6	14.2	10.275	8.024
200002	Min	93.6555	0.19	0.195	< 0.005	0.31	0.007	0.022	< 5	224	12	9.3	7.86
200002	Max	105.041	0.271	0.276	< 0.005	0.4	0.011	0.032	7	244.5	16	11.2	8.26
	BCALWQC		40 (30d) 200 (max)		0.08 (30d) 0.24 (max)				25 (24h) 5 (30d)		100 (max)		6.5-9.0
	BC DWQC		10 (max)		1 (max)						500		6.5-8.5

Table 5.2 1999 Water Quality Data: Comparison of Sites Upstream and Downstream of the Fruitvale STP Outfall

Sampling Date	Nitrate (mg/L)	Nitrite (mg/L)	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Ortho-Phosphate (mg/L)	Total Ammonia (mg/L)	Total Coliforms (mg/L)	Faecal Coliforms (mg/L)	*E. coli* (cfu/100 mL)	Enterococ (cfu/100 mL)
U/S Fruitvale STP Outfall E2388840										
1-Sep-99	0.054	< 0.005	0.2	0.011	< 0.001	< 0.005	320	220	150	38
8-Sep-99	0.076	< 0.005	0.15	0.018	0.002	< 0.005	1600	44	94	24
15-Sep-99	0.065	< 0.005	0.18	0.017	< 0.001	< 0.005	2300	66	24	16
23-Sep-99	0.074	< 0.005	0.19	0.021	0.003	0.008	320	24	10	6
29-Sep-99	0.077	< 0.005	0.19	0.019	0.002	< 0.005	32	24	18	16
D/S Fruitvale 200154										
1-Sep-99	0.097	< 0.005	0.3	0.03	0.012	0.048	1700	170	82	100
8-Sep-99	0.117	0.005	0.27	0.035	0.016	0.055	84	16	10	24
15-Sep-99	0.148	< 0.005	0.3	0.032	0.018	0.028	70	10	14	24
23-Sep-99	0.167	< 0.005	0.39	0.043	0.025	0.038	90	28	22	6
29-Sep-99	0.166	< 0.005	0.34	0.052	0.03	0.037	40	28	20	10
Mean upstream	0.0692	0.005	0.182	0.0172	0.0018	0.0056	914.4	75.6	59.2	20
Mean downstream	0.139	0.005	0.32	0.0384	0.0202	0.04225	486	50.4	29.6	32.8
Ttest (p=0.05)	0.005467407	#DIV/0!	0.001309817	0.004006707	0.004442986	0.008004345	0.496988067	0.611750284	0.36726916	0.510215335
Is difference significant?	Yes	No	Yes	Yes	Yes	Yes	No	No	No	No

Figure 5.1 1999 Ammonia Concentrations in Beaver Creek

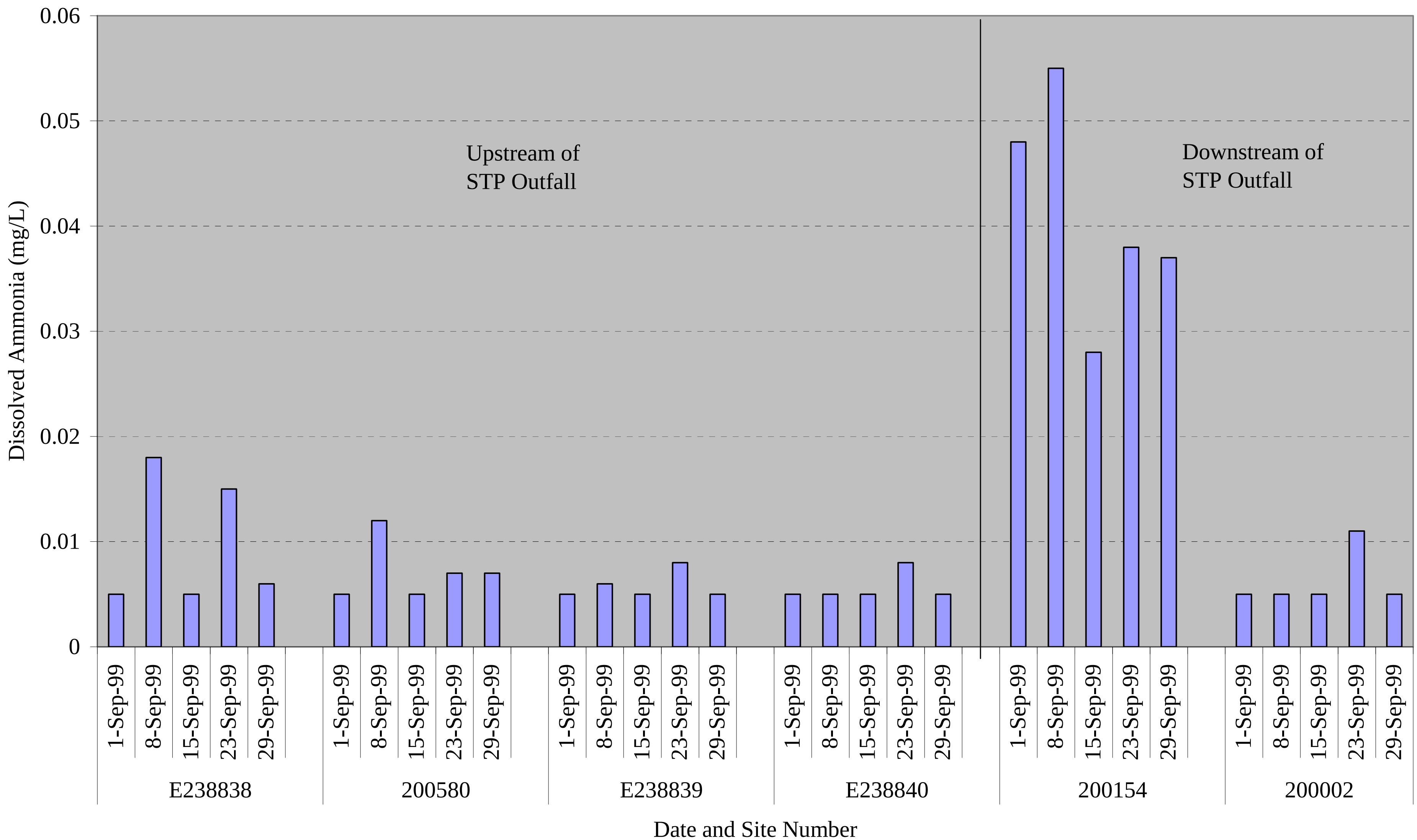


Figure 5.2 1999 Nitrate Concentrations in Beaver Creek

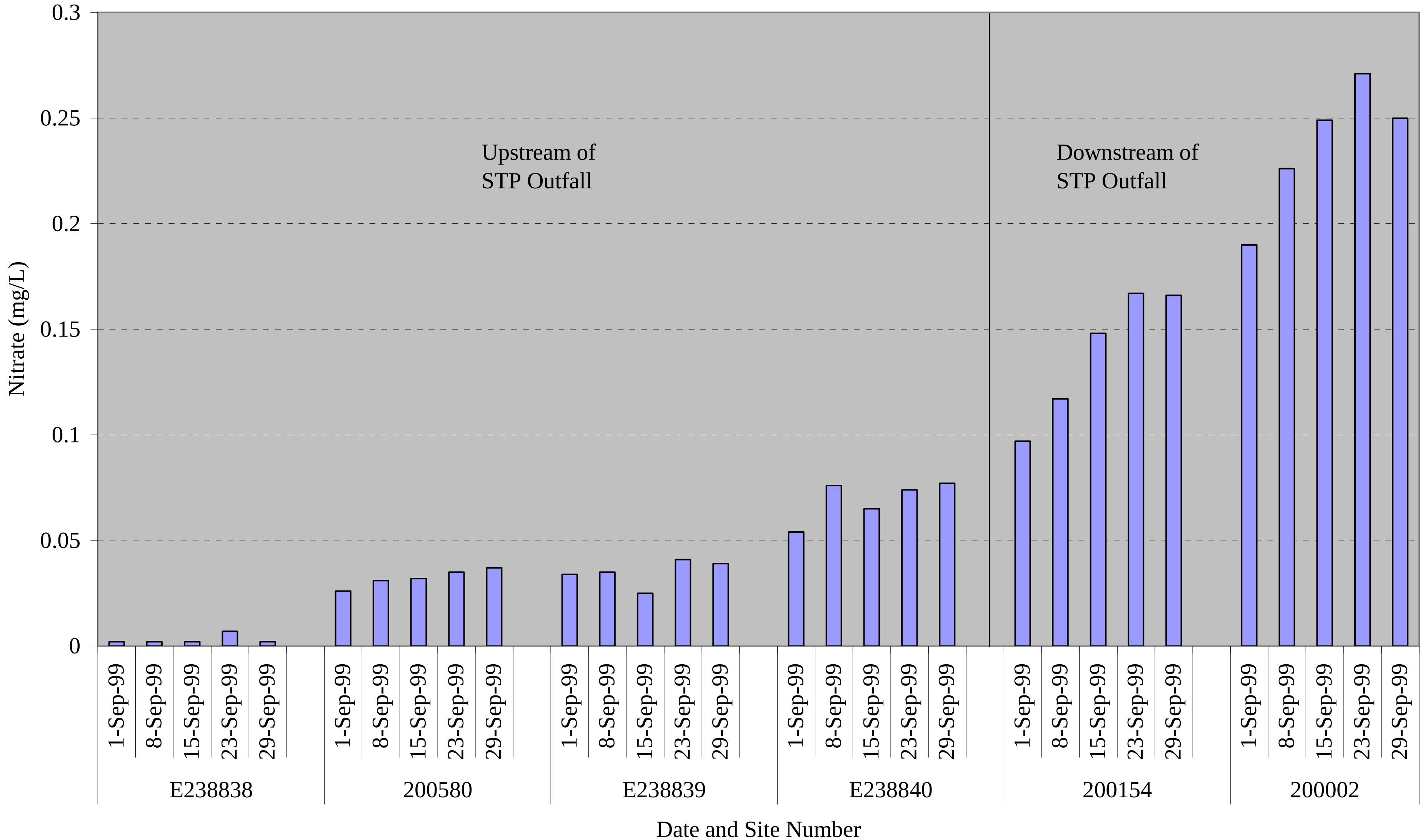


Figure 5.3 1999 Total Nitrogen Concentrations in Beaver Creek

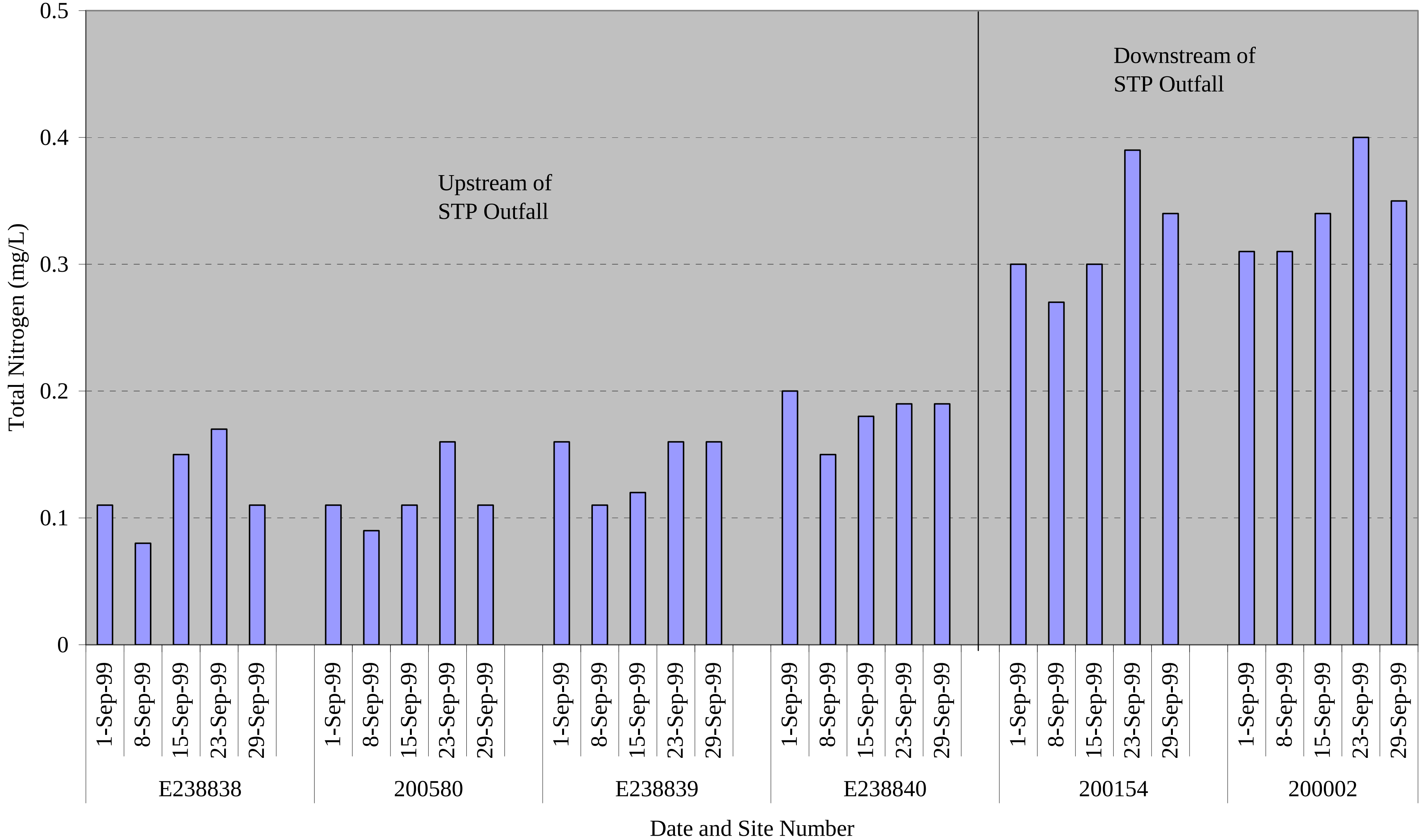


Figure 5.4 1999 Total Phosphorus Concentrations in Beaver Creek

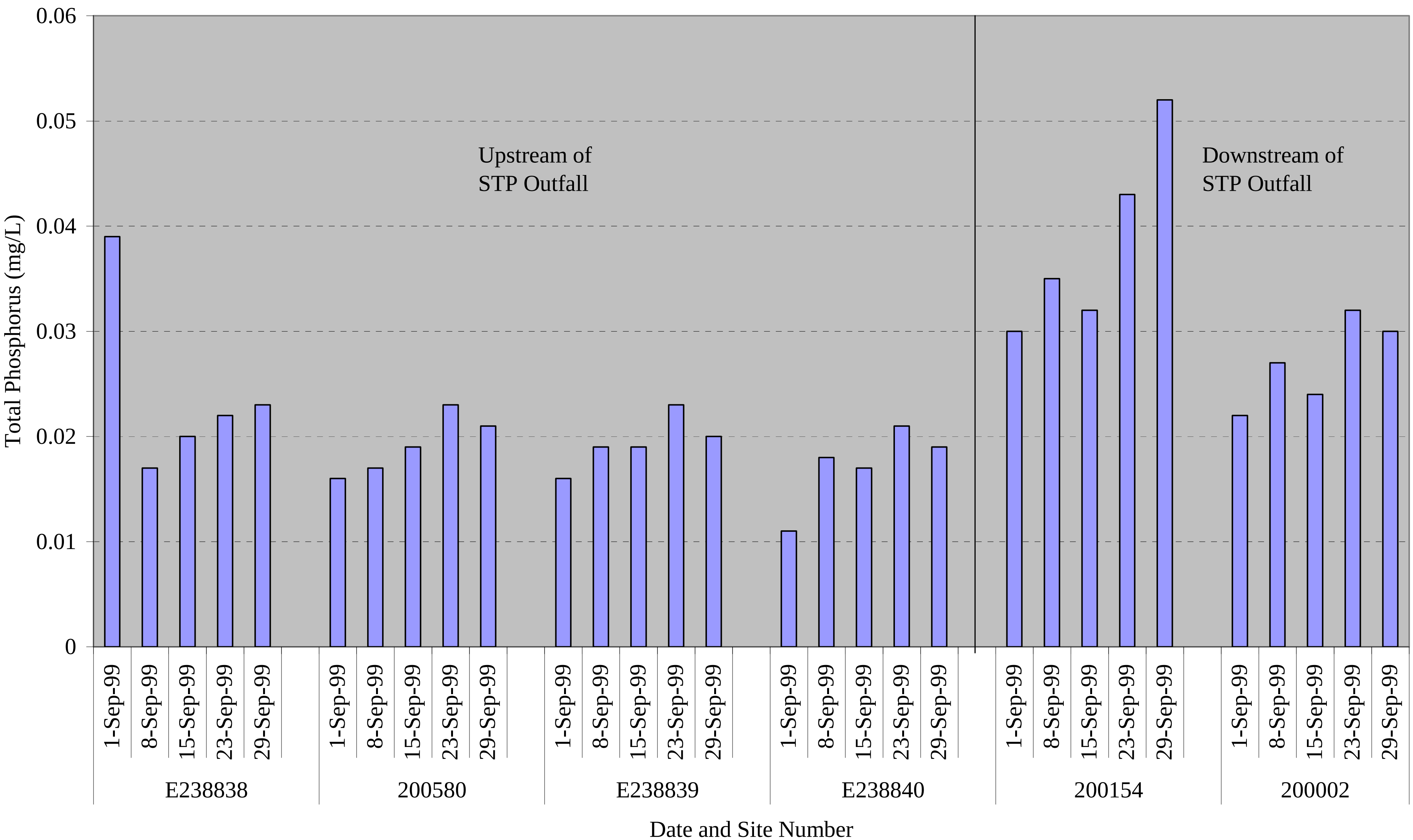
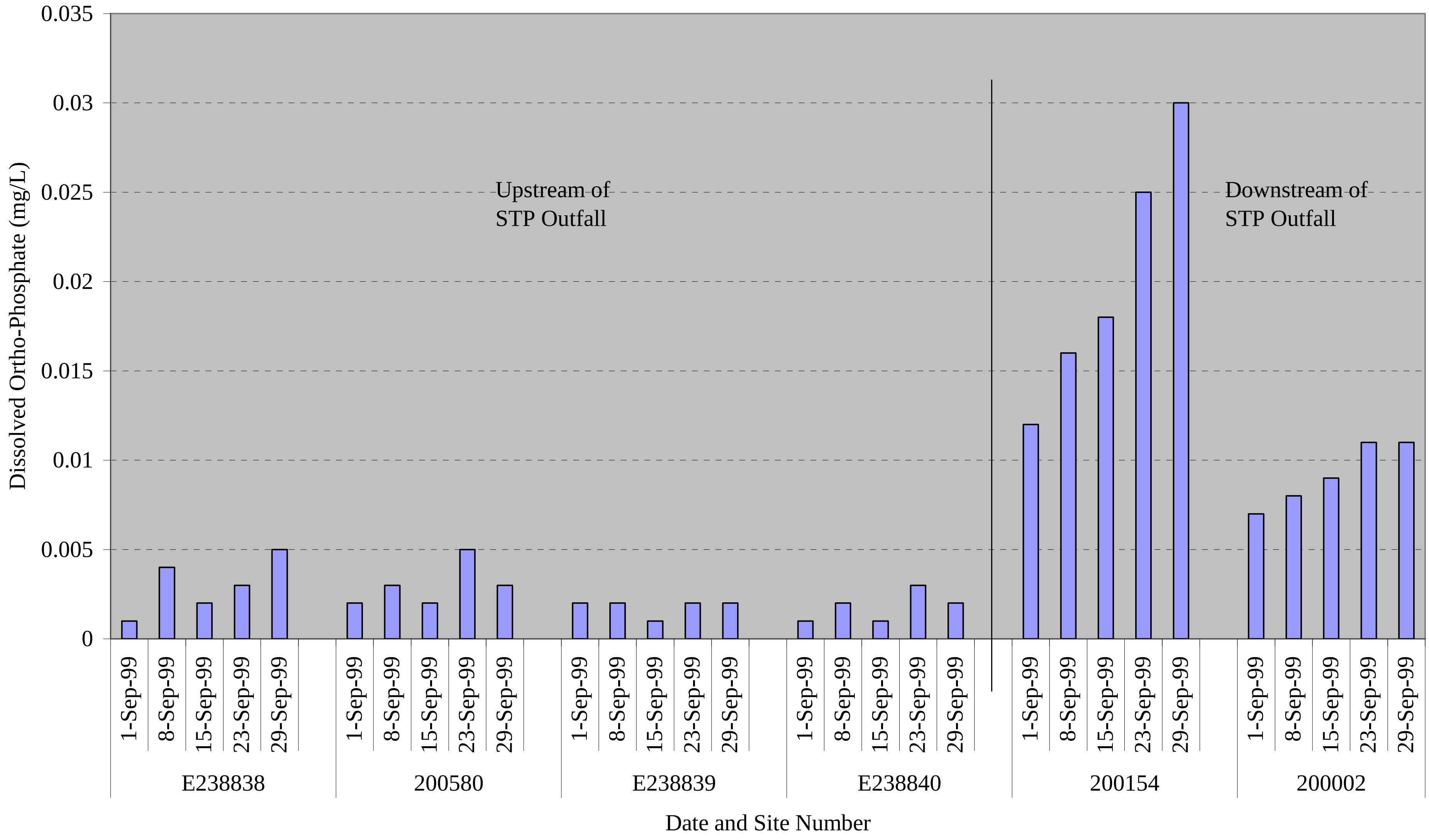


Figure 5.5 1999 Dissolved Ortho-phosphate Concentrations in Beaver Creek



5.1.2 BACTERIA

The 1999 bacteriology results for total coliform, faecal coliform, *E. coli* and enterococci bacteria are found in Table 5.1, with statistical comparisons of the sites upstream and downstream of the STP outfall found in Table 5.2. The results are also graphed along the stream length in Figures 5.6 to 5.9.

Bacterial concentrations in Beaver Creek were quite high, and likely reflect the various land uses in the watershed. Bacteria can enter the creek through surface water runoff or direct access of livestock or wildlife to the creek. While the survival of coliform bacteria is short-lived in surface waters like Beaver Creek that are shallow and turbulent, they may still survive for several days (Clark and Norris 2000), potentially impacting the water quality of the river for many kilometres downstream. Total coliforms originate from several sources, including soils and the wastes of mammals. Faecal coliform bacteria are a type of coliform bacteria that originate from the intestinal tract of mammals, including humans, livestock and wildlife. While coliform bacteria are not necessarily harmful to human health, faecal coliforms indicate the possible presence of other pathogenic organisms, including *E. coli*, *Giardia* and *Cryptosporidium*, which can have serious health implications. *E. coli* was measured in this study, as was enterococci bacteria, both of which can be pathogens and if present, indicate risks to human health if the water is used for drinking or recreational purposes.

There were no major differences for any of the microbial indicators along the length of Beaver Creek (Figures 5.6 to 5.9). However, the concentrations of all microbial indicators were generally highest in the upper part of the watershed, and on September 23, 1999, in particular. The uppermost site is located in an agricultural area where livestock (horses and cattle) have free access to the creek for watering. The bacterial concentrations at this site may be indicative of contamination from livestock. The wastes from domestic pets may also contribute to the creek's bacterial loadings via storm water runoff from the residential areas in the watershed.

There were no statistically significant differences in any of the bacterial data (total coliforms, faecal coliforms, *E. coli* and enterococci) between the two sites immediately upstream and downstream of the STP outfall (Table 5.2). These results, in addition to the relatively low bacterial concentrations in the STP effluent (Table 5.1), appear to indicate the efficiency with which bacteria are removed from the Fruitvale STP effluent prior to discharge into Beaver Creek. The rate of dilution of the STP effluent in the creek appears to be adequate in maintaining the bacterial concentrations immediately downstream of the STP outfall close to background levels higher up in the watershed.

The average concentrations of total and faecal coliform bacteria and *E. coli* in the STP effluent were consistently lower than those in the creek both upstream and downstream of the STP outfall (Table 5.1). Only enterococci bacteria were higher in the STP effluent compared to five of the sites along Beaver Creek. The site at Marsh Creek Road, near the beaver activity, had higher enterococci concentrations than any other site, including the STP effluent. These results show the effect of numerous non-point or point sources of bacteria which have not previously been identified throughout the Beaver Creek watershed, including wastes from wildlife, livestock and domestic animals.

Additional sources of bacteria to the creek may originate from septic systems, which service all rural residential lots outside of the Fruitvale service area. Seepage from these septic systems may result from old or improperly maintained systems, which could contribute bacteria as well as nutrients to the creek, depending on soil type, their proximity to groundwater and the levels of flows of the groundwater itself.

Figure 5.6 1999 Total Coliform Concentrations in Beaver Creek

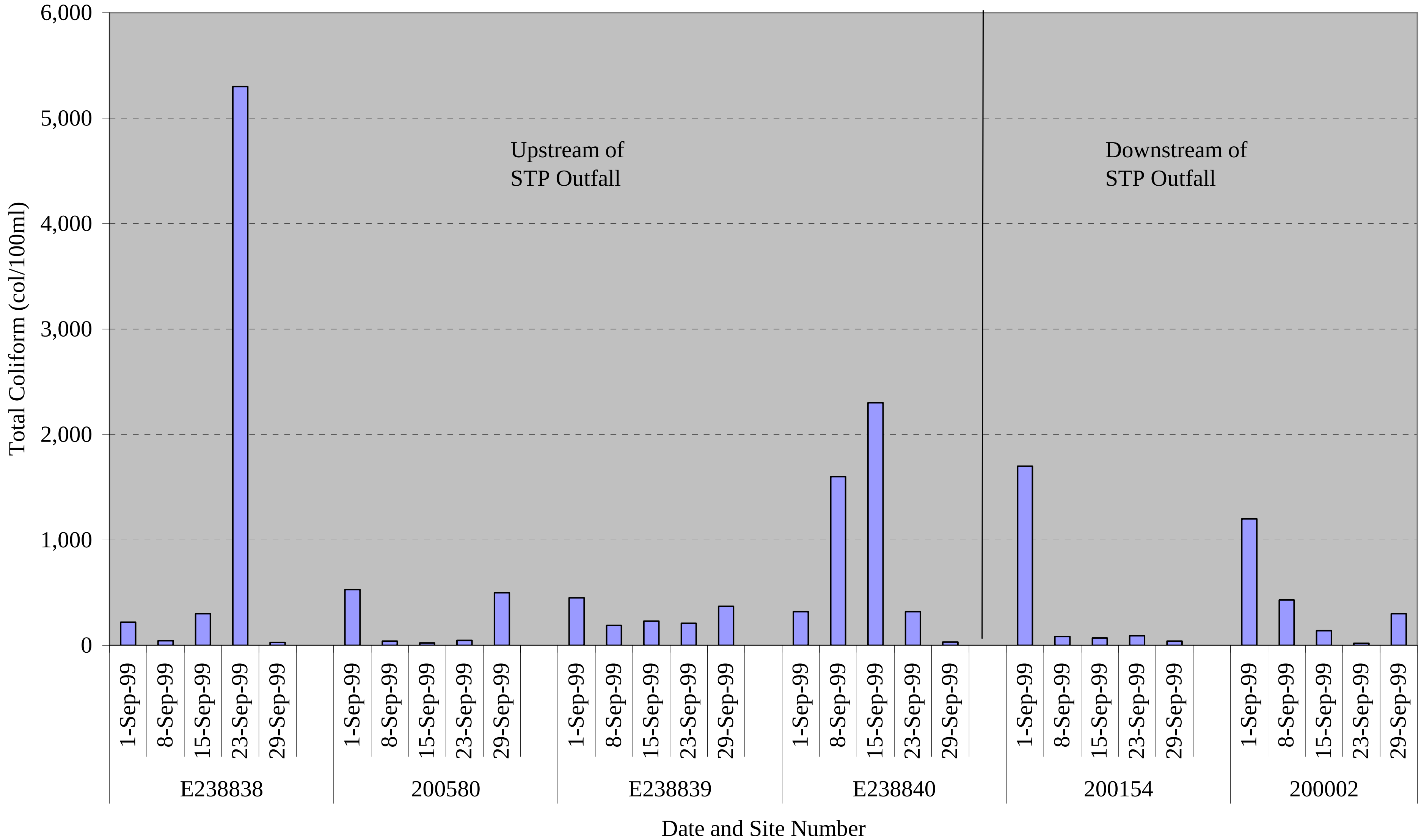


Figure 5.7 1999 Faecal Coliform Concentrations in Beaver Creek

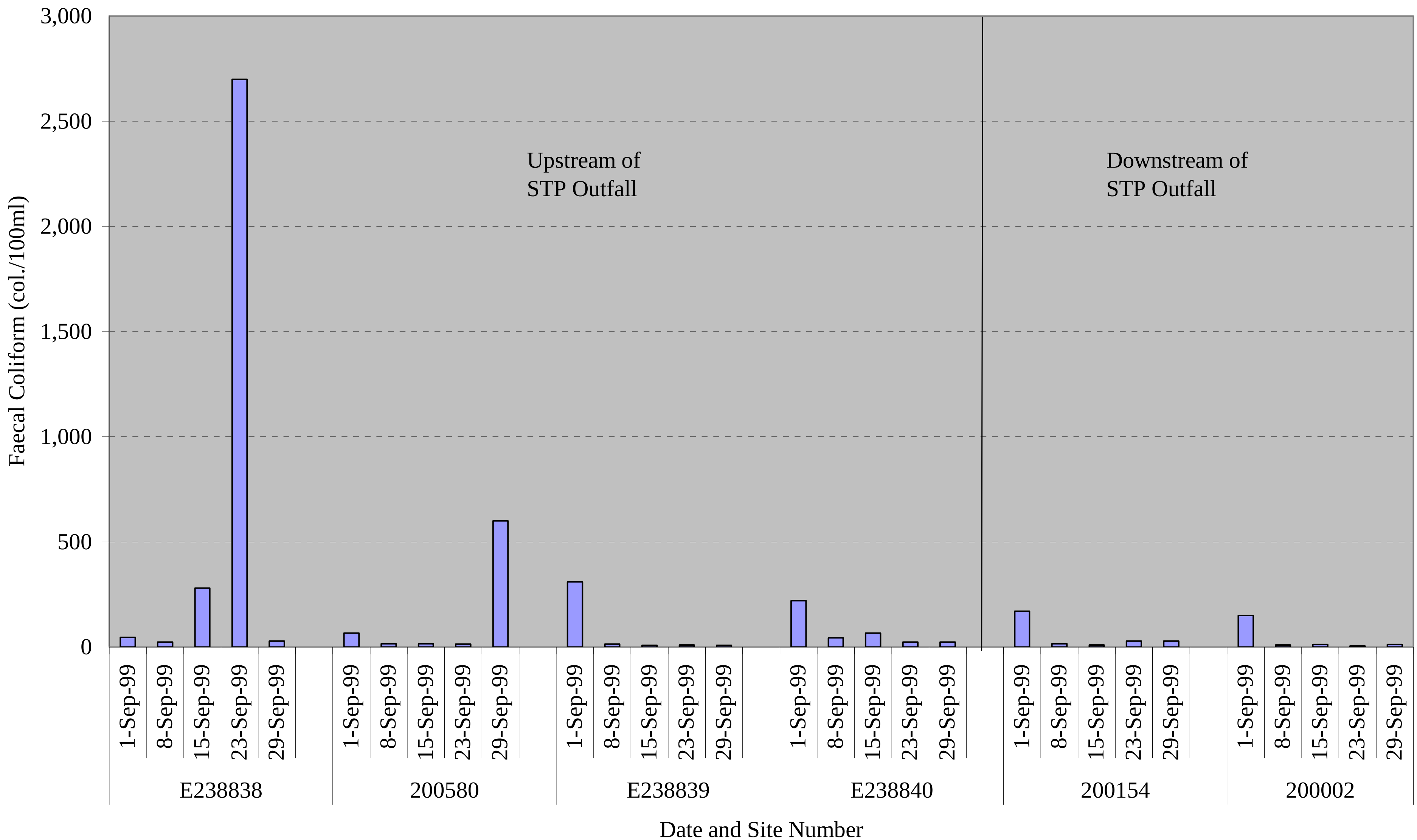


Figure 5.8 1999 *Escherichia coli* Concentrations in Beaver Creek

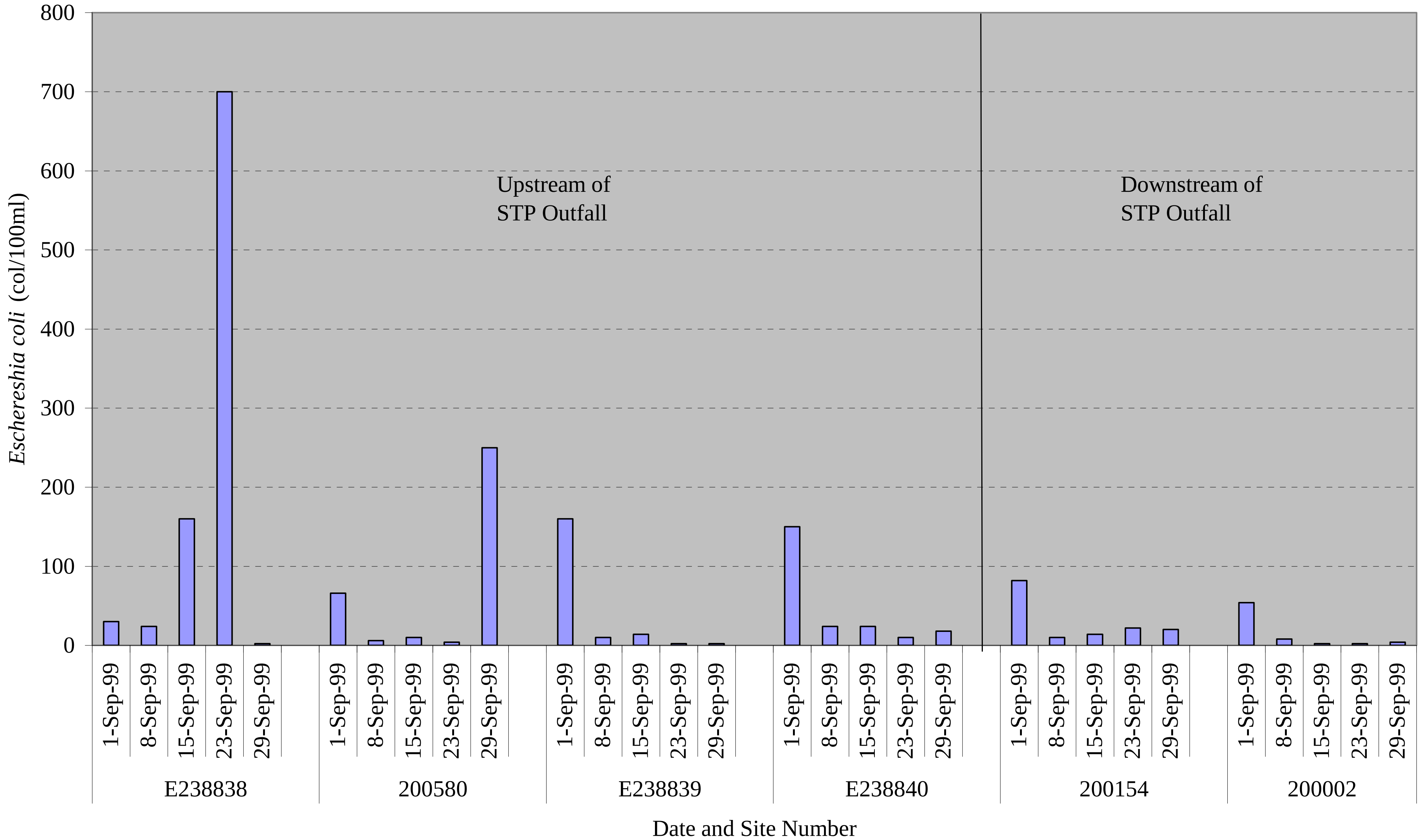
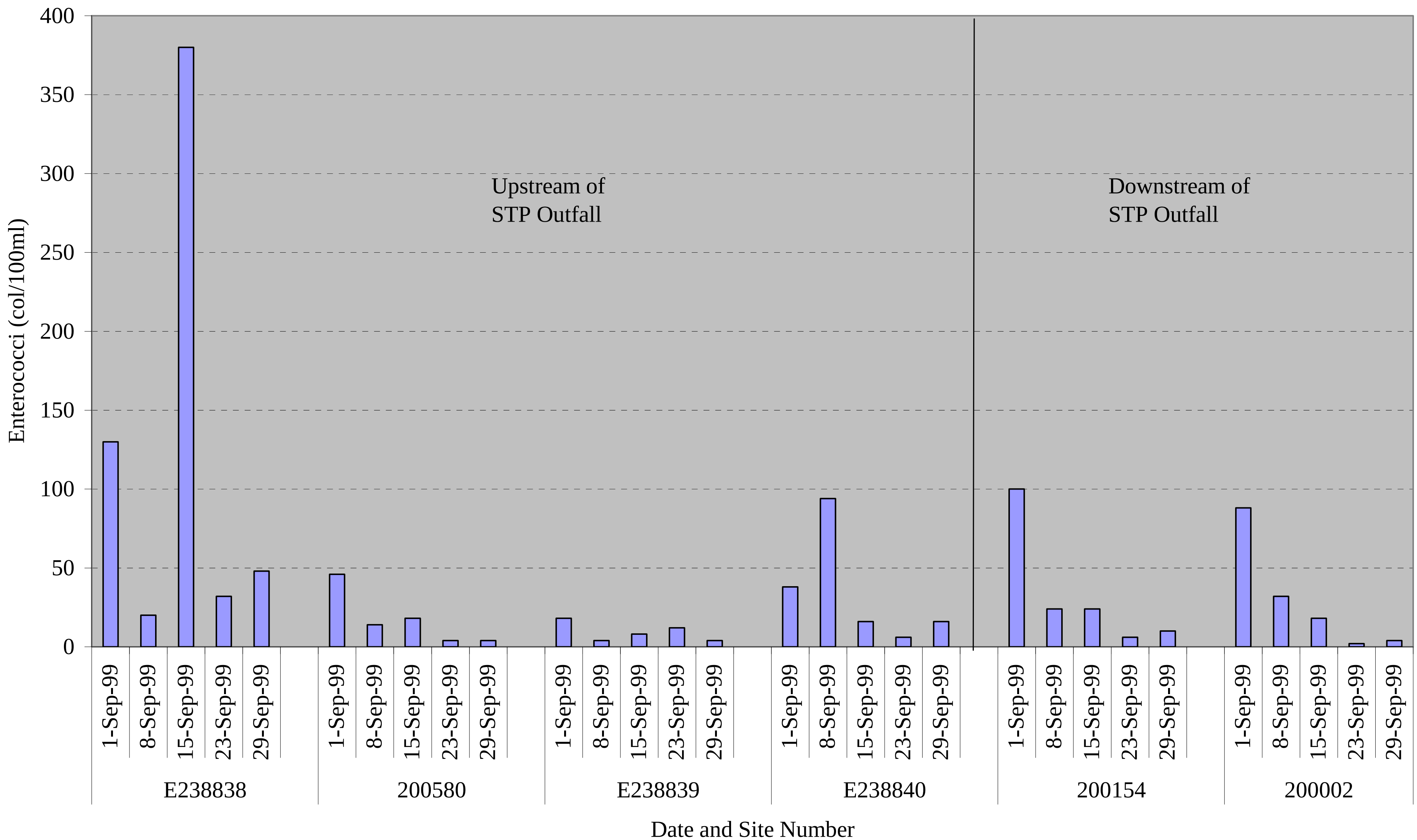


Figure 5.9 1999 Enterococci Bacteria Concentrations in Beaver Creek



5.2 Historical Water Quality Assessment

Historical water quality data for the STP effluent discharge and for Beaver Creek downstream of the Village of Fruitvale (the site downstream of the STP outfall) are presented in Tables 5.3 and 5.4. Water quality parameters such as total ammonia, nitrate+nitrite, total phosphorus and faecal coliforms for these two sites were graphically plotted over time (Figures 5.10 to 5.17). Results from earlier sampling (1990 and 1993) at these sites were compared to 1999 data to verify if significant improvements in the quality of the discharge and the receiving environment have occurred over time and since the upgrade of the STP facility (Tables 5.5 and 5.6).

5.2.1 STP Effluent

Data collected in 1999 and compared with similar data collected in 1990 and 1993 show that total ammonia concentrations in the Fruitvale STP effluent changed significantly over time. Total ammonia concentrations (averaged) in the STP effluent increased significantly from 7.4 mg/L in 1990 to 12.1 mg/L in 1993 ($p<0.0001$), but dropped to 3.6 mg/L in 1999. This drop was significant compared to both 1990 and 1993 levels ($p=0.00946$ and $p=0.00069$ respectively), indicating an improvement in ammonia concentrations from the effluent measured at the point of discharge or “end of pipe”. (Table 5.5, Figure 5.10). This improvement was likely brought about by an increase in the aeration of the lagoons, which enhances the aerobic process of oxidation of ammonia into nitrate.

This increased rate of conversion of ammonia in the effluent to nitrate is corroborated by the significant increase in the 1999 concentration of nitrate+nitrite (4.095 mg/L) in the STP effluent compared to 1990 and 1993 data ($p=0.00498$ and $p=0.00030$ respectively) (Table 5.5, Figure 5.11). No differences were found between the 1990 and 1993 nitrate+nitrite data, which were generally below the detection limit of <0.02 mg/L (Table 5.5).

The 1999 STP effluent data also demonstrate that total phosphorus concentrations decreased significantly to 1.46 mg/L, when compared to 1990 and 1993 concentrations ($p=0.00171$ and $p=0.00026$, respectively), suggesting that the flocculation and RI basins were effective at removing some of the phosphorus from the effluent (Table 5.5, Figure 5.12). This subsequent decrease in total phosphorus in 1999 is important, since concentrations initially increased from 2.29 mg/L in 1990 to 3.01 mg/L in 1993. According to the STP design, 40 to 60 % of the phosphorus in the raw sewage should be removed by the RI fields in addition to the flocculation process. The predicted phosphorus removal efficiency of the works has not been investigated nor confirmed, as influent quality data has never been collected.

The 1999 faecal coliform concentration of the STP effluent improved significantly since 1990 ($p=0.0023$) and also decreased an order of magnitude from 319 cfu/100 mL in 1993 to 31 cfu/100 mL in 1999 ($p=0.0918$). This data implies that the upgraded works conducted from 1995 to 1997 had a positive effect on the removal of bacteria within the effluent (Figure 5.13). While no significant decreases in the *E. coli* and enterococci concentrations were found from 1993 to 1999 ($p=0.0699$ and $p=0.1341$, respectively), the improvements were substantial: *E. coli* concentrations decreased from 300 cfu/100 mL in 1993 to 11 cfu/100 mL in 1999, while enterococci concentrations decreased from 199 cfu/100 mL in 1993 to 64 cfu/100 mL in 1999. These two kinds of bacteria were not measured in 1990, therefore, any changes in the effluent since this date could not be determined.

5.2.2 Beaver Creek Downstream of the STP Outfall

While all the nutrient and bacterial concentrations of the STP effluent discharge significantly improved between 1990 and 1999 (with the exception of nitrate+nitrite), these improvements were not always reflected in the water quality of Beaver Creek (Figures 5.14 to 5.17 and Table 5.6).

Average concentrations of the total inorganic forms of nitrogen (ammonia, nitrite and nitrate) in STP effluent increased between 1990 and 1993 but in 1999, returned to levels similar to those measured in 1990. This is likely the result of poor performance of the sewage treatment works during the 1993 period, but no real improvement in nitrogen removal overall following the STP plant upgrades in 1995 and 1997.

Ammonia concentrations in Beaver Creek were found to increase from 1990 to 1993, but then in 1999, decreased to 1990 levels. The increase in ammonia from 0.043 mg/L in 1990 to 0.080 mg/L in 1993 ($p=0.14091$) may indicate that during this time, the STP lagoons were not as effectively aerated, reducing the efficiency of the nitrification process. This temporary increase cannot be attributed to an increase in population and increased sewage inflows, as the population has decreased slightly in both Fruitvale and Montrose over the last few decades. The improvements to the aeration of the STP ponds and subsequent decreases in the ammonia levels from the STP over 1993 to 1999 were reflected in the ammonia concentrations downstream in Beaver Creek. While not statistically significant, average ammonia concentrations in the creek dropped substantially from 0.080 mg/L in 1993 to 0.041 mg/L in 1999 ($p=0.08929$).

It is important to note that the STP lagoons have experienced problems with duckweed growth on the surface of the pond, which may inhibit the nitrification process by creating an effective barrier to aerial oxygenation of the pond and reducing sunlight needed by the bacteria to break down ammonia (Photo 8.6). Duckweed growth on the polishing pond is an ongoing problem throughout the spring, summer and fall seasons. In an attempt to improve treatment and control the duckweed, the Village of Fruitvale Works Department uses a boat engine propeller on floats to keep an open area in the polishing pond (G. Greive, pers. com., 2003).

The increase in STP effluent nitrate+nitrite concentrations from 1990 to 1999 corresponded with an increase in the nitrate+nitrite concentrations in the creek during the same time period. While there was a significant decrease in nitrate+nitrite concentrations from 0.21 mg/L in 1990 to 0.09 mg/L in 1993 ($p=0.00459$), concentrations then increased to 0.14 mg/L in 1999 ($p=0.1080$). These results suggest that the improvements to the STP in 1995 and 1997 increased the conversion of ammonia to nitrate+nitrite, resulting in a slight increase in downstream nitrate+nitrite concentrations in Beaver Creek. The aquatic biota may be assimilating the increased nitrate+nitrite discharge as increased growth, removing this nutrient from the water column and decreasing its concentration.

While the STP effluent data indicated that phosphorus concentrations entering the creek decreased significantly over the 1990s, the total phosphorus measured in Beaver Creek downstream of the STP did not improve from 1990 to 1999. While there was a slight but insignificant increase in total phosphorus concentration from 0.032 mg/L in 1990 to 0.040 mg/L in 1993 ($p=0.1120$), concentrations then decreased slightly to 0.038 mg/L in 1999 ($p=0.7409$). These results may be due to a variety of reasons, including the possibility that portions of the effluent may be circumventing the RI basins through underlying soils and entering Beaver Creek via groundwater infiltration. In spite of the addition of the underdrains, these RI basins may not be performing as well as expected.

While the faecal coliforms, *E. coli* and enterococci bacteria in the STP effluent all decreased by an order of magnitude from 1993 to 1999, these same decreases were not seen in the water quality of Beaver Creek downstream of the STP site. While faecal coliforms did decrease significantly from 87 cfu/100 mL in 1990 to 20 cfu/100 mL in 1993 ($p=0.01237$), they increased again in 1999 to 50 cfu/100 mL ($p=0.3607$). Comparisons for *E. coli* and enterococci are available only for 1993 and 1999, and the data shows that they both increased over this time period as well ($p=0.4478$ and $p=5018$, respectively). *E. coli* increased from 18 cfu/100 mL in 1993 to 30 cfu/100 mL in 1999, while enterococci increased from 20 cfu/100 mL in 1993 to 33 cfu/100 mL in 1999.

These bacteriological results may suggest that effluent could be circumventing the RI basins and entering Beaver Creek without adequate treatment. It is possible that over time, the attenuation capacity of the RI basins may diminish since there is a very limited depth of gravels available for treatment of the effluent.

Overall, despite the upgrades to the STP and resulting improvements in its effluent quality from 1990 to 1999, there were no significant improvements in the water quality of Beaver Creek downstream of the STP outfall over the 1990s (ammonia concentrations improved, but not significantly). This could be due to several factors. One possibility is that undetermined performance problems at the sewage treatment system may be resulting in no substantial improvement in total loadings of nutrients and bacteria from the effluent to the river, despite the fact that the effluent quality, when measured from its outfall, has improved. It is possible that the RI basins are not performing as anticipated and the underdrains do not capture all the effluent, some of which may be lost directly to the shallow groundwater aquifer under the RI basins, and enter the creek through well established sub-surface soils.

Alternatively, the creek may not have had sufficient time to recover from past nutrient loading in order for improvements to be observed in its water quality. Nutrients can be tightly bound to particles and readily stored in sediments, from which they can be released slowly over time and mobilize to the water column. For this reason, accumulated nutrients may provide a long-term source for eutrophication, and it may take decades before the nutrient sink is depleted, nutrients concentrations drop and biological responses observed (Soziak 1990; Charlton and Bayne 1986).

While the concentrations of the effluent constituents are important to measure, it is really the total mass loading of these parameters to the stream that influence its biological response. The nutrient concentration refers to the amount of the nutrient in a defined volume of water (such as mg/L), while the nutrient load refers to the total amount of nitrogen or phosphorus entering the water during a given time (such as tonnes/year). The relationship between nutrient concentration and nutrient load can vary and depends on the flow, the volume of water in the creek and its watershed characteristics. An effluent may have high concentrations of nutrients, but if the discharge rate is low relative to the flow of the receiving stream, it may contribute minimally to the nutrient loading of the stream, with few implications for and responses from the biological community. Each aquatic system will have a certain capacity for assimilating nutrient loadings prior to the manifestation of biological responses outside normal variance.

Therefore, the inherent ability of the biota of Beaver Creek to assimilate the increased nutrients received from the STP outfall will be directly influenced by streamflow which changes seasonally and alters the stream's water quality. In western Canada, many smaller streams and creeks are often nutrient-limited, sometimes by both phosphorus and nitrogen. Nutrient enrichment, through the addition of fertilizers or sewage effluent, can lead to negative eutrophic conditions like undesirable increased aquatic plant growth. The negative impacts of nutrient enrichment are often not indicated by the actual nutrient concentrations found in the water, because the nutrients can be taken up immediately by the aquatic plants and stored as biomass, rather than remaining in the water. Even very small amounts of nutrient loading can result in increased aquatic plant growth, removing the nutrients from the water. As a result, the absolute concentrations of nutrients in the water are often poor indicators of productivity and actual nutrient loading of the system.

It is also important to note that all the water samples were taken in the summer and early fall, during the growing season, when there is increased biological uptake of nutrients by algae and aquatic plants. Had additional biological sampling been included in the analysis of Beaver Creek in 1990 and 1993, then comparisons could have been made with the 1999 benthic invertebrate data. This additional biological data may have shown changes in productivity and eutrophic condition, as benthic invertebrate data (Section 6.3) often tell a more complete story of nutrient levels and productivity.

In terms of the microbial content of Beaver Creek, it is not necessarily surprising that no decreases resulted from 1990 to 1999, despite the decrease in faecal coliforms of the STP effluent during this same time period. This lack of change in the creek may be due to the fact that faecal coliform bacteria do not live long in surface waters, particularly in shallow, cold and turbulent waters like those found in Beaver Creek. While bacteria can live for several days in slower, more laminar flow (Clark and Norris 2000), this would not be expected in Beaver Creek. This lack of change in bacteria concentrations may also be due to other non-point sources of bacteria being as important to the overall loading and/or some sewage not being effectively treated in the RI basins at the Fruitvale STP.

5.2.3 Water Quality Summary

After review of the data, the Fruitvale STP outfall appears to have an influence on the water quality of Beaver Creek. This influence is most apparent at the site immediately downstream of the STP outfall. The Fruitvale STP is the only major point source of pollution to this reach of Beaver Creek, including tributaries of the creek and other industrial and agricultural inputs, making it the major source of influence at the site downstream of the outfall. The degree to which the STP influences the sites further downstream is less clear.

The concentrations of water quality parameters such as ammonia, nitrate, total nitrogen, total phosphorus and ortho-phosphate measured at the site immediately downstream of the outfall were found to be significantly higher than the site immediately upstream. With the exception of nitrate, all the parameters had decreased at the next sampling site along the creek, likely the result of both dilution and the assimilation/biological uptake by the biotic components of the creek. The nitrate concentrations increased at each sampling site along Beaver Creek and may be a result of non-point source inputs from the landbase (surface runoff, either natural and/or anthropogenic) in addition to the influence of the STP effluent discharge and the conversion of ammonia to nitrate.

It is important to note that the effluent quality data collected from the Fruitvale STP is only descriptive of its concentration of water quality parameters. The data does not provide any information on the actual loadings (mass not concentration) of nutrients or bacteria entering Beaver Creek. Even if the concentrations of nutrients or bacteria decrease over time in the STP effluent, their total loadings to Beaver Creek may actually increase if the effluent volumes discharged to the creek increase disproportionately over the same time period. While the population of the Fruitvale community has decreased slightly, with effluent volumes remaining approximately constant over the last decade (G. Greive, pers. com., 2003), this flow information should be collected in the future for a complete assessment of the STP’s impact on Beaver Creek.

Table 5.3 Historical Water Quality Data for the Fruitvale STP Effluent

Sample	Ammonia	BOD	Bromide	Chloride	Diss. Oxy	Fluoride	Hardness Tot	Nitrate	Nitrate + Nitrite	Nitrogen-Nitrite	Total Nitrogen	Ortho-Phosphate	Total Phosphorus	Nonfilterable Residue
Date	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L CaCO3	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
8-Jul-86		13												24
19-May-87		20												35
1-Aug-90	7.12								0.04				2.02	
8-Aug-90	7.66								< 0.02			2.1	2.35	
16-Aug-90	8								< 0.02			2.2	2.49	
21-Aug-90	7.5								< 0.02			2.03	2.28	
28-Aug-90	6.5								< 0.02					
22-Jul-91		17												7
27-Apr-92		15												7
8-Jul-92		19												
5-Oct-92		17												2
25-Nov-92		35												21
5-Jan-93		9												4
14-Apr-93		8												13
8-Jul-93														5
15-Jul-93	10.5	14		29.6					< 0.02	< 0.005				5
21-Jul-93	10.2				0.8				< 0.02	0.007				
28-Jul-93	10.3	< 10		27.4	0.5				< 0.02	0.007				4
4-Aug-93	13.3				0.25				0.02	0.01				
11-Aug-93	12.8	< 10		29.8	0.15			0.94		0.02			3.04	8
18-Aug-93	12.1								< 0.02	0.005			3.14	
26-Aug-93	12	10		26.3	0.1				< 0.02	< 0.005			3.25	5
1-Sep-93	11.5			26.4					< 0.02	< 0.005	14.3	2.4	2.4	
8-Sep-93	11.9								< 0.02	0.008	13	2.59	3.55	
21-Oct-93		16												20
12-Jan-94														
19-Jan-94		8												5
12-Apr-94		7												6
29-Aug-94		12												14
9-Jan-95		< 5												9
5-Jul-95		9												5
1-Sep-99														
8-Sep-99	5.43		< 0.05	30		0.03	104.6	2.38	2.609		9.1	1.1	1.27	< 5
15-Sep-99	4.04		< 0.05	34		< 0.01	104.34	4.12	4.369		8.8	1.32	1.35	< 5
23-Sep-99	2.1		< 0.05	35		< 0.01	94.94	4.78	5.227		8.4	1.35	1.43	< 5
29-Sep-99	2.98		< 0.05	36		< 0.01	109.91	4.08	4.175		8.3	1.7	1.8	< 5
Mean	8.66	13.37	< 0.05	30.50	0.36	0.02	103.45	3.26	0.98	0.01	10.32	1.87	2.34	9.52
Min	2.1	< 5	< 0.05	26.3	0.1	< 0.01	94.94	0.94	< 0.02	< 0.005	8.3	1.1	1.27	2
Max	13.3	35	< 0.05	36	0.8	0.03	109.91	4.78	5.227	0.02	14.3	2.59	3.55	35
n	18	19	4	9	5	4	4	5	17	9	6	9	13	23
BCALWQC[1]	1.54 (30d) 10.7 (max)				9 (min) 11 (30d)	0.3 (max)		40 (30d) 200 (max)		0.08 (30d) 0.24 (max)				25 (24h) 5 (30d)
BC DWQC[2]						1.0 (30d) 1.5 (max)		10 (max)		1 (max)				

Table 5.3 Historical Water Quality Data for the Fruitvale STP Effluent Cont.

Sample	Specific Conductance	Sulphate	Temp	pH	Coli:Fec	Coli:Tot	E Coli	Entercoc
Date	uS/cm	mg/L	mg/L	pH Units	CFU/100mL	CFU/100mL	CFU/100mL	CFU/100mL
8-Jul-86	370			8.5				
19-May-87								
1-Aug-90					163			
8-Aug-90					110			
16-Aug-90					155			
21-Aug-90					249			
28-Aug-90					104			
22-Jul-91								
27-Apr-92					< 1			
8-Jul-92								
5-Oct-92					75			
25-Nov-92					100000			
5-Jan-93					74			
14-Apr-93					< 1			
8-Jul-93					250			
15-Jul-93		3.7			250	200	10	
21-Jul-93			16		750	830	480	
28-Jul-93			17		365		390	360
4-Aug-93			17		400		360	640
11-Aug-93		4.9	16		690		690	390
18-Aug-93					680		580	390
26-Aug-93			15.5		120		120	81
1-Sep-93			14.4		36		42	40
8-Sep-93		1.8	15.8		69		69	94
21-Oct-93					6			
12-Jan-94					5000			
19-Jan-94					< 1			
12-Apr-94								
29-Aug-94					10			
9-Jan-95					3			
5-Jul-95					700			
1-Sep-99					4	12	4	18
8-Sep-99	433		28	7.4	24	170	20	74
15-Sep-99	438	32		7.37	18	310	10	130
23-Sep-99	430	33		7.36	36	42	14	38
29-Sep-99	451	33		7.24	72	94	6	62
Mean	424.40	18.07	17.46	7.57	3561.81	236.86	199.64	193.08
Min	370	1.8	14.4	7.24	< 1	12	4	18
Max	451	33	28	8.5	100000	830	690	640
n	5	6	8	5	31	7	14	12
BCALWQC[1]		100 (max)						
BC DWQC[2]		500		6.5-8.5	0		0	0

Table 5.4 Historical Water Quality Data Downstream of the Fruitvale STP Outfall

Sample	Diss. Oxy	Temp	pH	Ammonia	BOD	Chloride	Coli:Fec	E Coli	Enterococ
Date	mg/L	mg/L	pH units	mg/L	mg/L	mg/L	CFU/100mL	CFU/100mL	CFU/100mL
31-Jan-80							6.5		
24-Apr-80							23		
7-Jul-80	8.4	17	8.4	0.012			2		
8-Jul-80	9.9	16	8.4	0.049			14.3		
9-Jul-80	9.8	18	8	0.04			176.3		
10-Jul-80	8.9	15	8.1	0.065			352.3		
27-Aug-80							37.3		
14-Jul-81							48		
5-Jul-83							26		
19-Jul-83							31		
1-Aug-90				< 0.005			65		
8-Aug-90				0.05			95		
16-Aug-90				0.055			120		
21-Aug-90				0.056			130		
28-Aug-90				0.049			26		
15-Jul-93		13		0.066	< 10	4.9	18	17	10
21-Jul-93	10.4	12		0.052			89	87	89
28-Jul-93	10.2	16		0.006	< 10	3.8	18	16	29
4-Aug-93	9.7	16		0.068			41	49	22
11-Aug-93	9.8	15.5		0.08	< 10	4.8	21	20	13
18-Aug-93				< 0.005			50	43	46
26-Aug-93	10.4	14		0.104		5.9	0	< 1	< 1
1-Sep-93		14.5		0.097		6	5	10	24
8-Sep-93		16.1		0.116			24	14	14
1-Sep-99	10.5	12	8.15	0.048			170	82	100
8-Sep-99	10.4	10	8.23	0.055			16	10	24
15-Sep-99			8.14	0.028			10	14	24
23-Sep-99		12.5	7.35	0.038			28	22	6
29-Sep-99		9.7	7.29	0.037			28	20	10
Mean	9.855	14.206	8.007	0.051	< 10.000	5.080	57.610	28.929	29.429
Min	8.4	9.7	7.29	< 0.005	< 10	3.8	0	< 1	< 1
Max	10.5	18	8.4	0.116	< 10	6	352.3	87	100
n	11	16	9	23	3	5	29	14	14
BCALWQC[1]	9 (min) 11 (30d)		6.5-9.0	1.1 (30d) 5.71 (max)					
BC DWQC[2]			6.5-8.5				0	0	0

[1]BCALWQC British Columbia Aquatic Life Water Quality Criteria

[2]BC DWQC British Columbia Drinking Water Quality Criteria

Table 5.4 Historical Water Quality Data Downstream of the Fruitvale STP Outfall Cont.

Sample	Nitrogen Total	Nitrate	Nitrate + Nitrite	Nitrogen-Nitrite	Ortho-Phosphate	Total Phosphorus	Non-filterable Residue	Specific Conductance	Sulphide Total
Date	mg/L		mg/L	mg/L	mg/L	mg/L	mg/L	uS/cm	mg/L
31-Jan-80									
24-Apr-80									
7-Jul-80			0.11		0.006	0.014		172	
8-Jul-80			0.14		0.012	0.021		175	
9-Jul-80			0.12		0.014	0.027		176	
10-Jul-80			0.13		0.015	0.027		178	
27-Aug-80									
14-Jul-81									
5-Jul-83									
19-Jul-83									
1-Aug-90			0.15			0.029			
8-Aug-90			0.2		0.021	0.031			
16-Aug-90			0.23		0.024	0.036			
21-Aug-90			0.22		0.027	0.038			
28-Aug-90			0.24			0.025			
15-Jul-93			0.08	0.006			4		0.5
21-Jul-93			0.06	0.005					
28-Jul-93			0.02	0.006			4		0.5
4-Aug-93			0.07	0.008					
11-Aug-93			0.06	0.007		0.031	4		0.5
18-Aug-93			0.02	0.005		0.036			
26-Aug-93		0.09	0.1	0.008		0.035	4		0.5
1-Sep-93	0.22		0.11	0.006	0.017	0.046			
8-Sep-93	0.27		0.17	0.015	0.033	0.054			0.5
1-Sep-99	0.3	0.097	0.102		0.012	0.03	8	187	
8-Sep-99	0.27	0.117	0.122		0.016	0.035	< 5	190	
15-Sep-99	0.3	0.148	0.153		0.018	0.032	< 5	199	
23-Sep-99	0.39	0.167	0.172		0.025	0.043	< 5	208	
29-Sep-99	0.34	0.166	0.171		0.03	0.052	< 5	212	
Mean	0.299	0.131	0.128	0.007	0.019	0.034	4.889	188.556	0.500
Min	0.22	0.09	0.02	0.005	0.006	0.014	4	172	0.5
Max	0.39	0.167	0.24	0.015	0.033	0.054	8	212	0.5
n	7	6	23	9	14	19	9	9	5
BCALWQC[1]		40 (30d) 200 (max)		0.08 (30d) 0.24 (max)			25 (24h) 5 (30d)		
BC DWQC[2]		10 (max)		1 (max)					

[1]BCALWQC British Columbia Aquatic Life Water Quality Criteria
[2]BC DWQC British Columbia Drinking Water Quality Criteria

Table 5.5 Data Comparisons between 1990, 1993 and 1999 for the Fruitvale STP Outfall

Sampling Dates	Nitrate + Nitrite	Ammonia	Total Inorganic Nitrogen	Total Nitrogen	Total Phosphorus	Coli:Fec	E Coli	Enterococ
1-Aug-90	0.04	7.12	7.16		2.02	163		
8-Aug-90	< 0.02	7.66	7.68		2.35	110		
16-Aug-90	< 0.02	8	8.02		2.49	155		
21-Aug-90	< 0.02	7.5	7.52		2.28	249		
28-Aug-90	< 0.02	6.5	6.52			104		
11-Aug-93		12.8	12.8		3.04	690	690	390
18-Aug-93	< 0.02	12.1	12.12		3.14	680	580	390
26-Aug-93	< 0.02	12	12.02		3.25	120	120	81
1-Sep-93	< 0.02	11.5	11.52	14.3	2.4	36	42	40
8-Sep-93	< 0.02	11.9	11.92	13	3.55	69	69	94
1-Sep-99						4	4	18
8-Sep-99	2.609	5.43	8.039	9.1	1.27	24	20	74
15-Sep-99	4.369	4.04	8.409	8.8	1.35	18	10	130
23-Sep-99	5.227	2.1	7.327	8.4	1.43	36	14	38
29-Sep-99	4.175	2.98	7.155	8.3	1.8	72	6	62
Mean 90	0.024	7.356	7.38		2.285	156.2		
Mean 93	0.02	12.06	12.076	13.65	3.076	319	300.2	199
Mean 99	4.095	3.6375	7.7325	8.65	1.4625	30.8	10.8	64.4
Data Comparison Between 1990 and 1993								
ttest (p=0.05)	0.373900966	6.03098E-07	0.000101858		0.010385572	0.31617034		
Is difference significant?	No	Yes	Yes		Yes	No		
Data Comparison Between 1990 and 1999								
ttest (p=0.05)	0.004980649	0.009455621	0.532183991		0.00170651	0.002256484		
Is difference significant?	Yes	Yes	No		Yes	Yes		
Data Comparison Between 1993 and 1999								
ttest (p=0.05)	0.000297043	0.000689938	0.51334518	0.06378745	0.000261181	0.0917679	0.069874736	0.134140186
Is difference significant?	Yes	Yes	No	No	Yes	No	No	No

Table 5.6 Data Comparisons between 1990, 1993 and 1999 for Beaver Creek below Fruitvale

Sampling Dates	Nitrate + Nitrite	Ammonia	Total Inorganic Nitrogen	Total Nitrogen	Total Phosphorus	Coli:Fec	E Coli	Enterococ
1-Aug-90	0.15	< 0.005	0.155		0.029	65		
8-Aug-90	0.2	0.05	0.25		0.031	95		
16-Aug-90	0.23	0.055	0.285		0.036	120		
21-Aug-90	0.22	0.056	0.276		0.038	130		
28-Aug-90	0.24	0.049	0.289		0.025	26		
11-Aug-93	0.06	0.08	0.14		0.031	21	20	13
18-Aug-93	0.02	< 0.005	0.025		0.036	50	43	46
26-Aug-93	0.1	0.104	0.204		0.035	0	< 1	< 1
1-Sep-93	0.11	0.097	0.207	0.22	0.046	5	10	24
8-Sep-93	0.17	0.116	0.286	0.27	0.054	24	14	14
1-Sep-99	0.102	0.048	0.15	0.3	0.03	170	82	100
8-Sep-99	0.122	0.055	0.177	0.27	0.035	16	10	24
15-Sep-99	0.153	0.028	0.181	0.3	0.032	10	14	24
23-Sep-99	0.172	0.038	0.21	0.39	0.043	28	22	6
29-Sep-99	0.171	0.037	0.208	0.34	0.052	28	20	10
Mean 90	0.208	0.043	0.251		0.0318	87.2		
Mean 93	0.092	0.0804	0.1724	0.245	0.0404	20	17.6	19.6
Mean 99	0.144	0.0412	0.1852	0.32	0.0384	50.4	29.6	32.8
Data Comparison Between 1990 and 1993								
ttest (p=0.05)	0.004591663	0.126657046	0.982027983		0.1120102	0.012368557		
Is difference significant?	Yes	No	No		No	Yes		
Data Comparison Between 1990 and 1999								
ttest (p=0.05)	0.016305742	0.870329609	0.45418918		0.197033158	0.33135275		
Is difference significant?	Yes	No	No		No	No		
Data Comparison Between 1993 and 1999								
ttest (p=0.05)	0.108022421	0.089289243	0.522457225	0.119630837	0.740876711	0.360698562	0.447802632	0.501842285
Is difference significant?	No	No	No	No	No	No	No	No

Figure 5.10 Ammonia Concentrations in the Fruitvale STP Effluent from 1986 to 1999

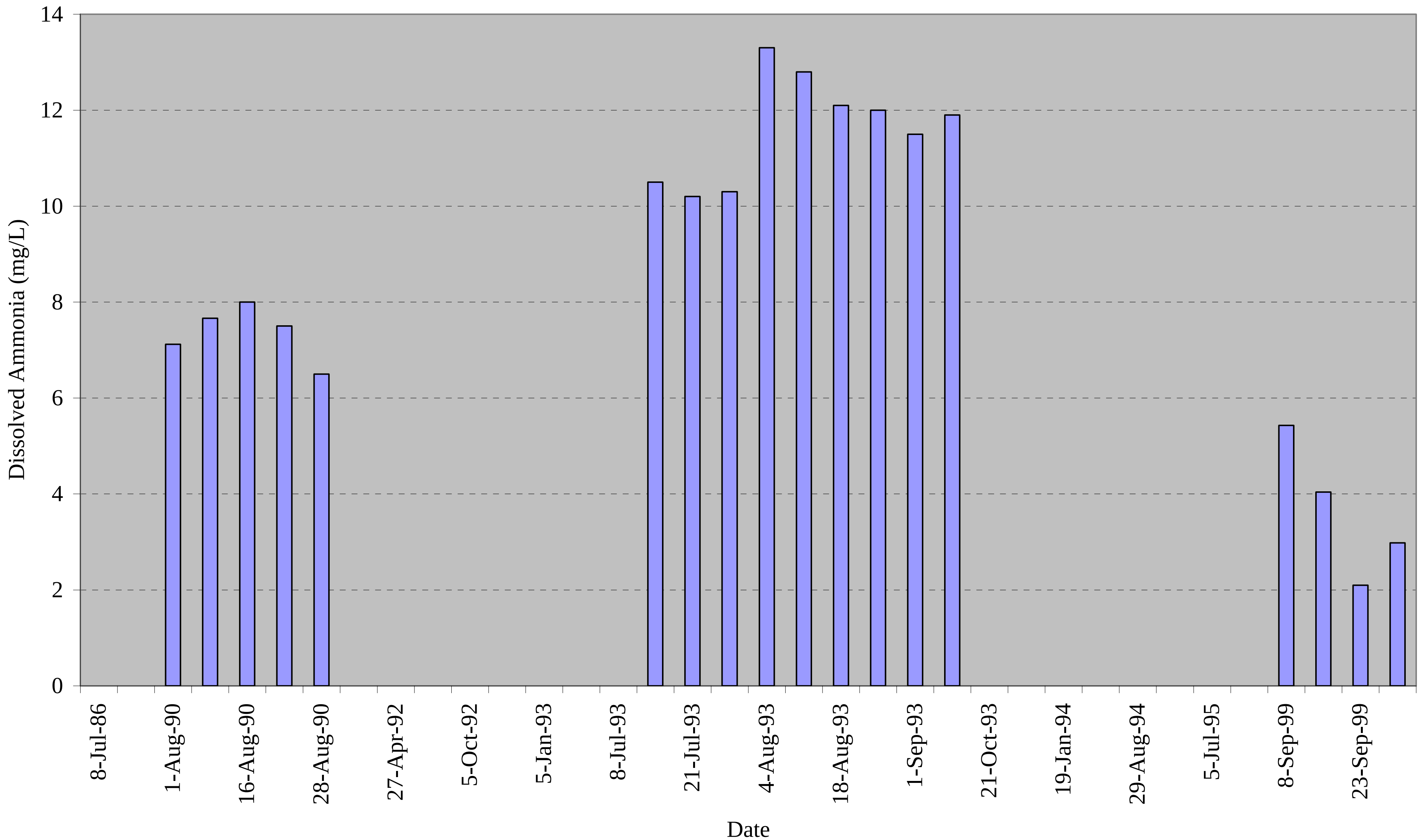


Figure 5.11 Nitrate+Nitrite Concentrations in the Fruitvale STP Effluent from 1986 to 1999

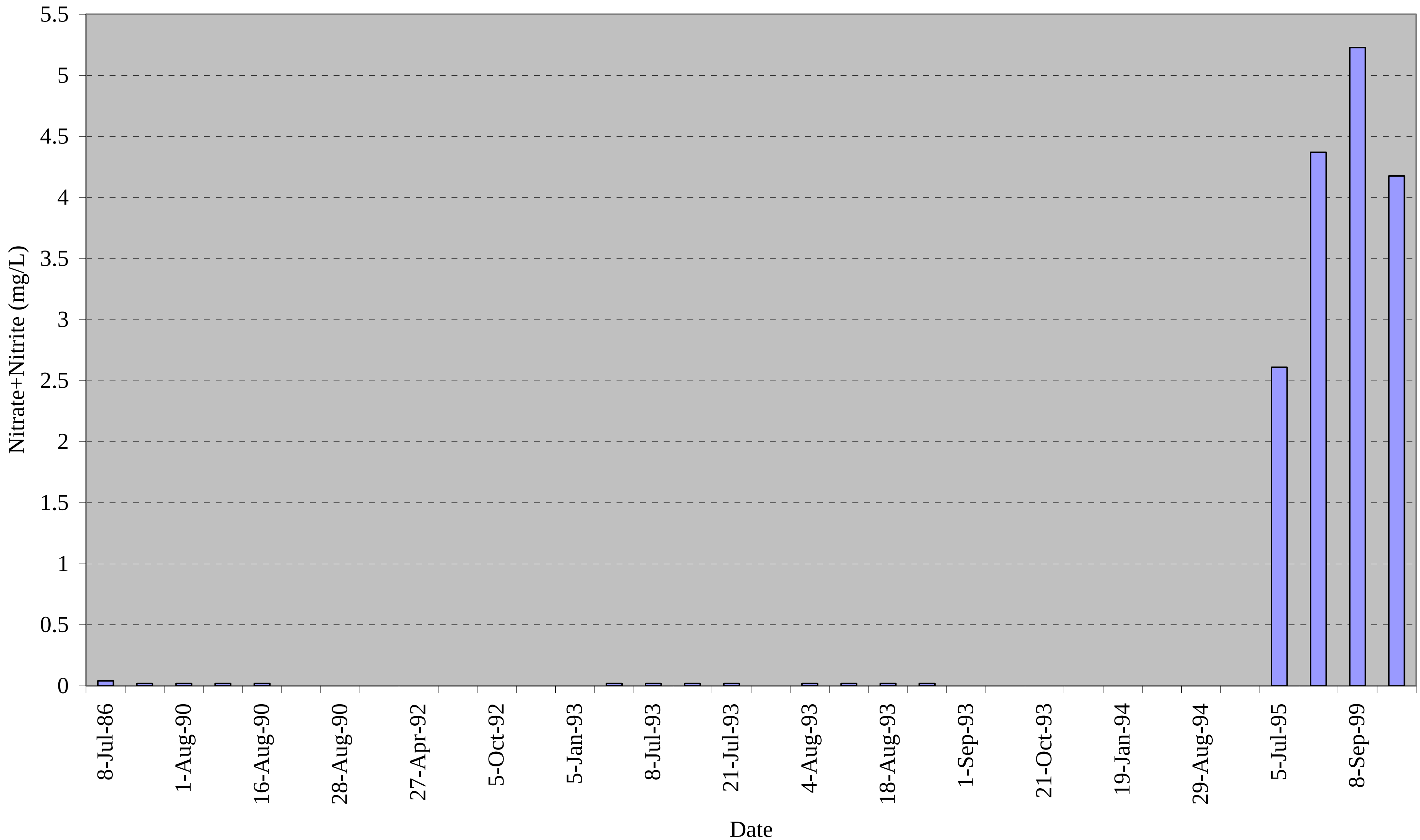


Figure 5.12 Total Phosphorus Concentrations in the Fruitvale STP Effluent from 1986 to 1999

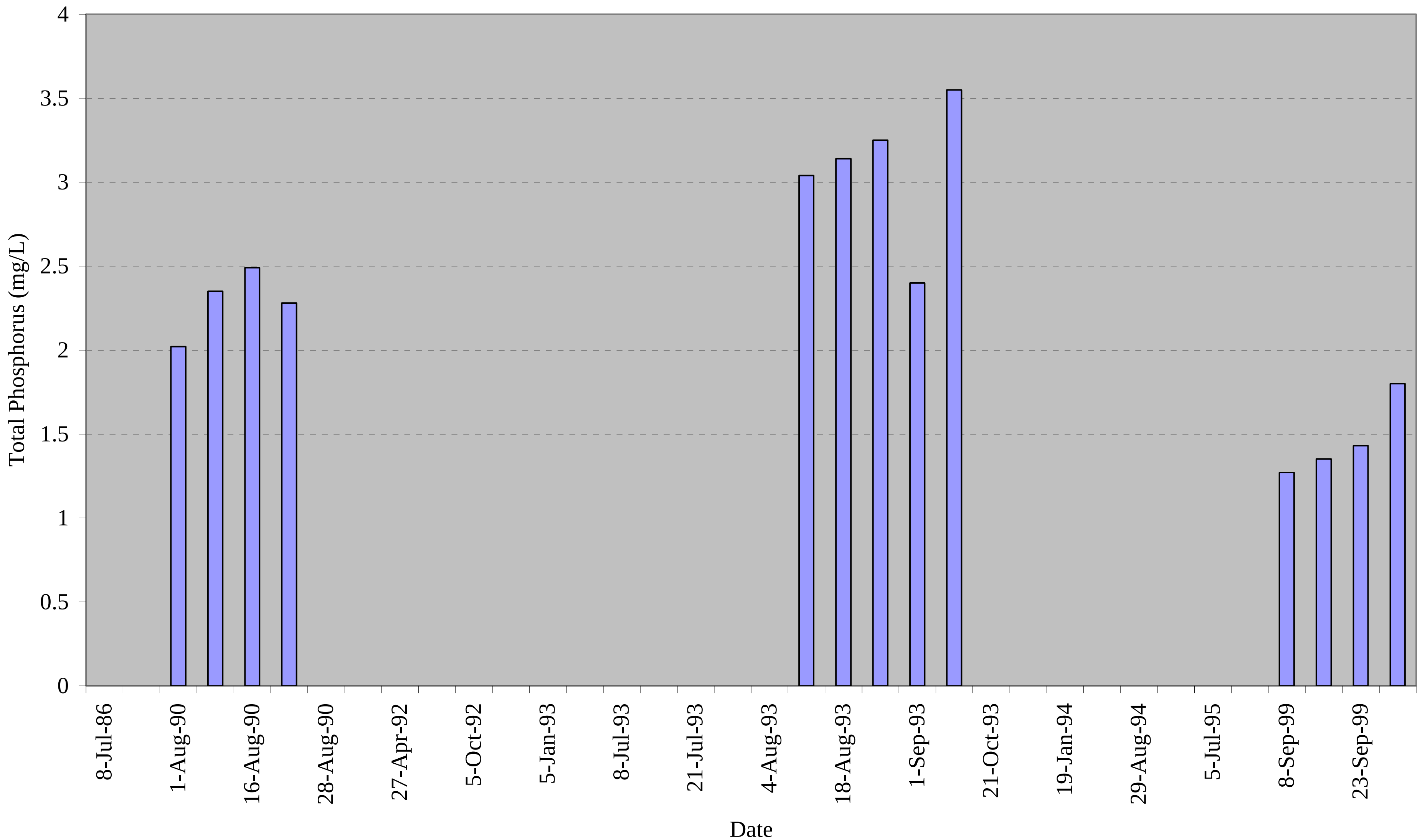


Figure 5.13 Faecal Coliform Concentrations in the Fruitvale STP Effluent from 1986 to 1999

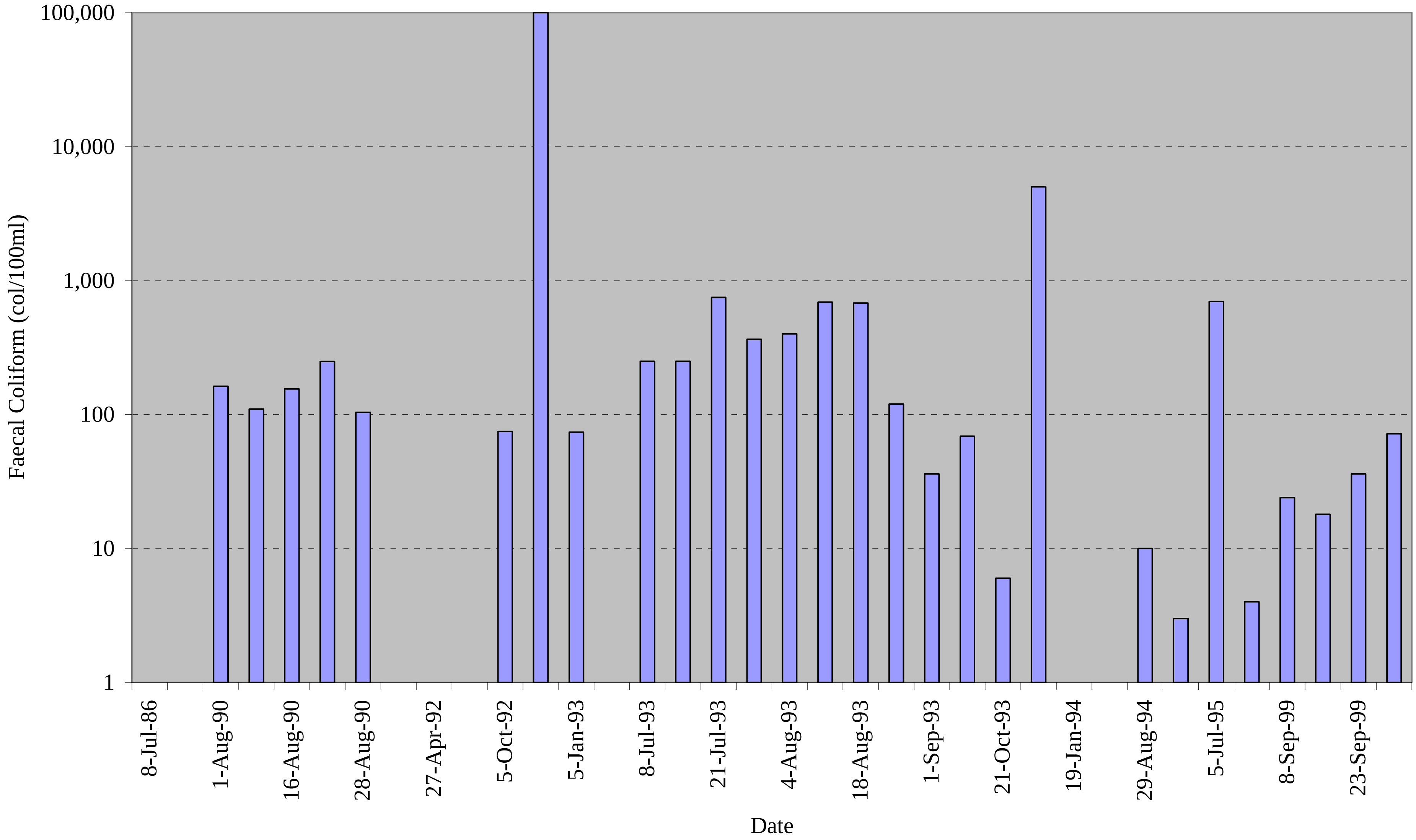


Figure 5.14 Ammonia Concentrations Downstream of the Fruitvale STP Outfall from 1980 to 1999

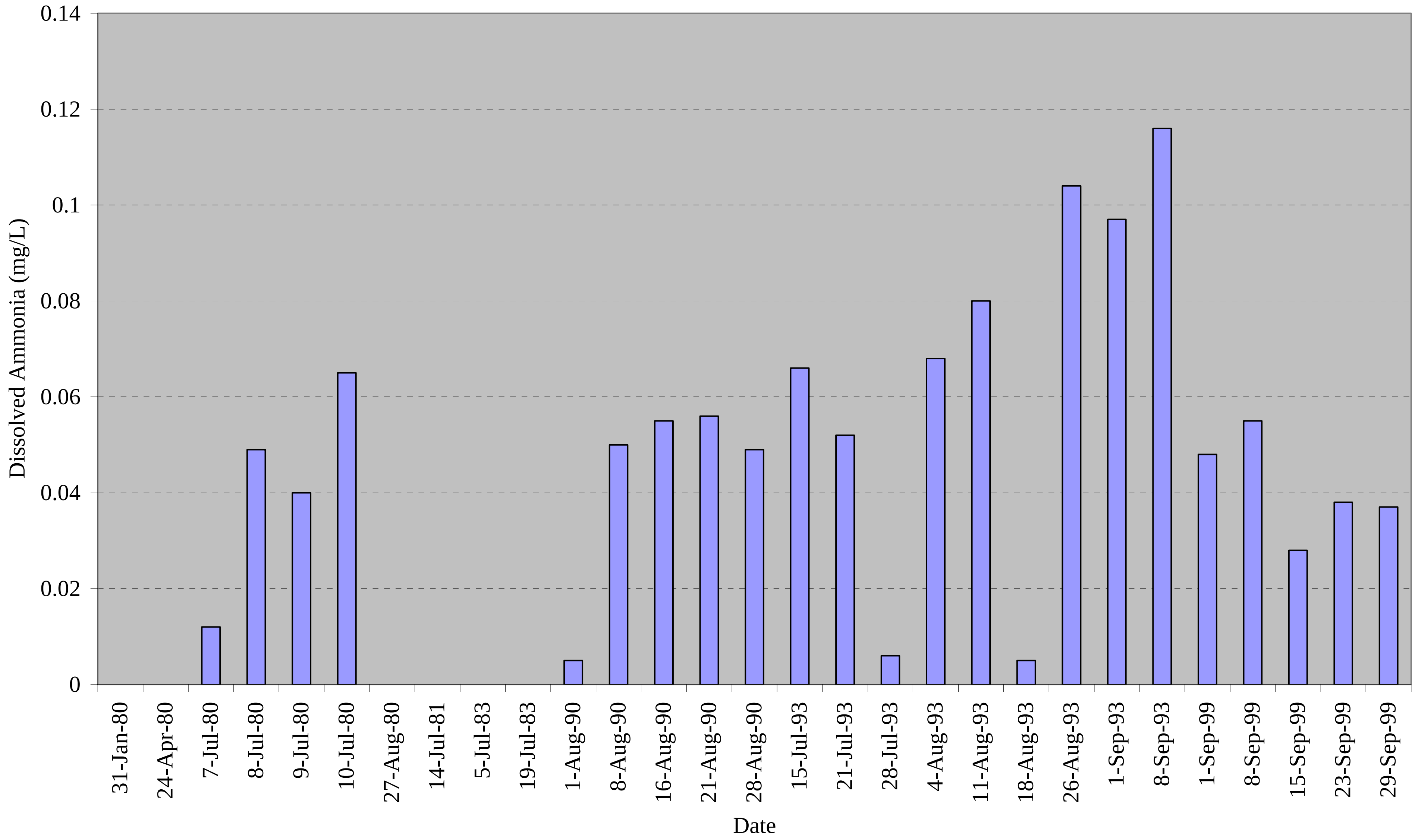


Figure 5.15 Nitrate+Nitrite Concentrations Downstream of the Fruitvale STP Outfall from 1980 to 1999

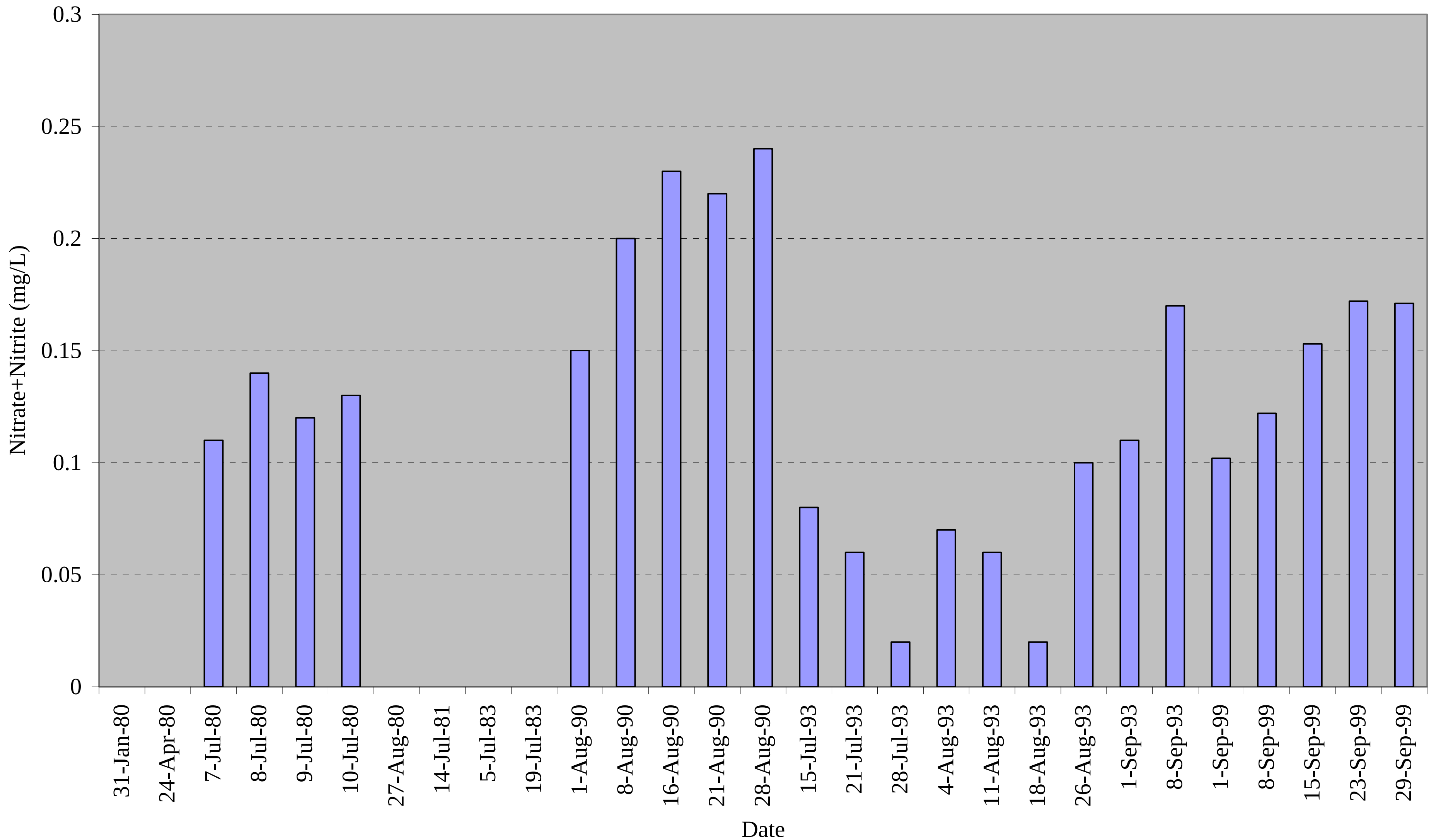


Figure 5.16 Total Phosphorus Concentrations Downstream of the Fruitvale STP Outfall from 1980 to 1999

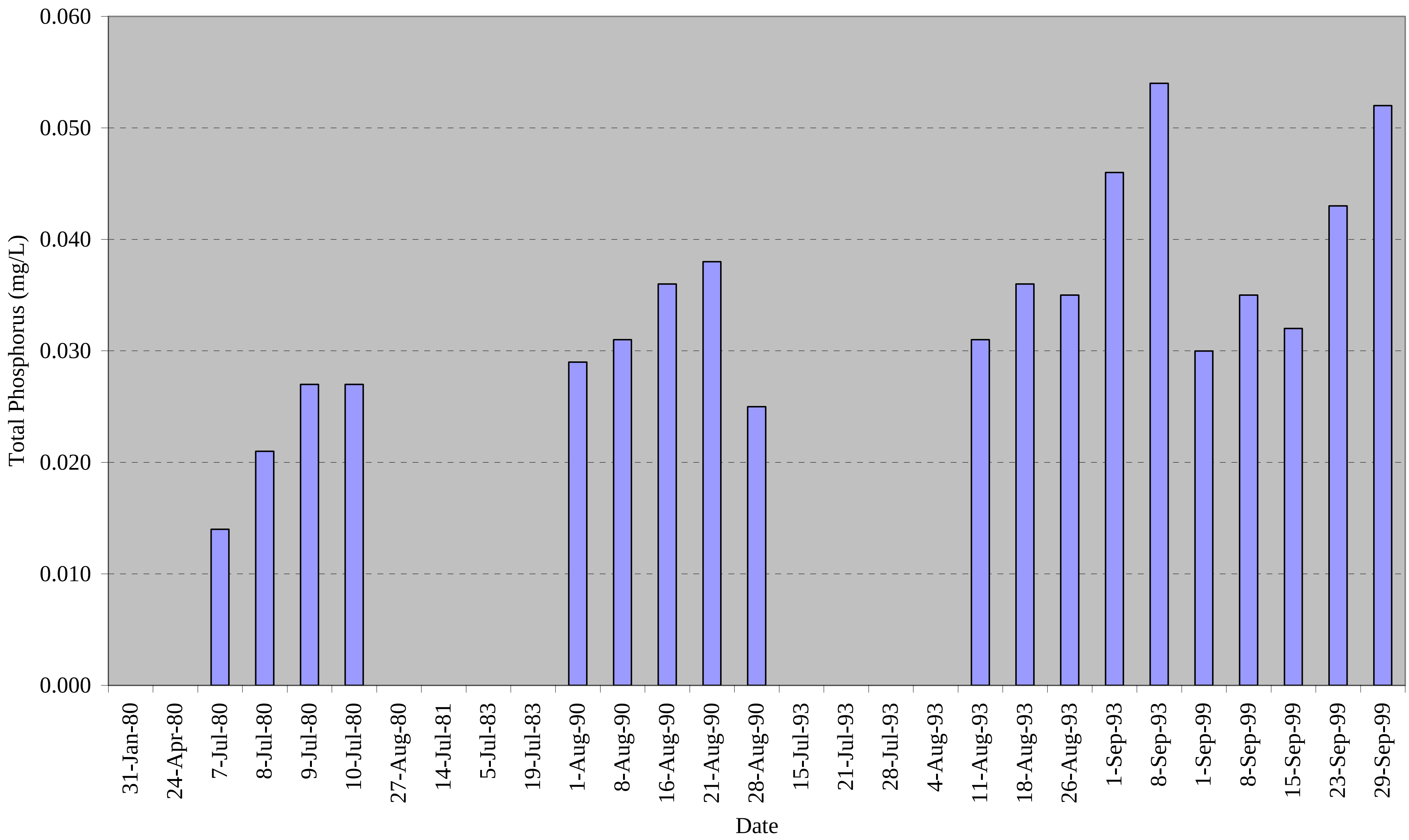
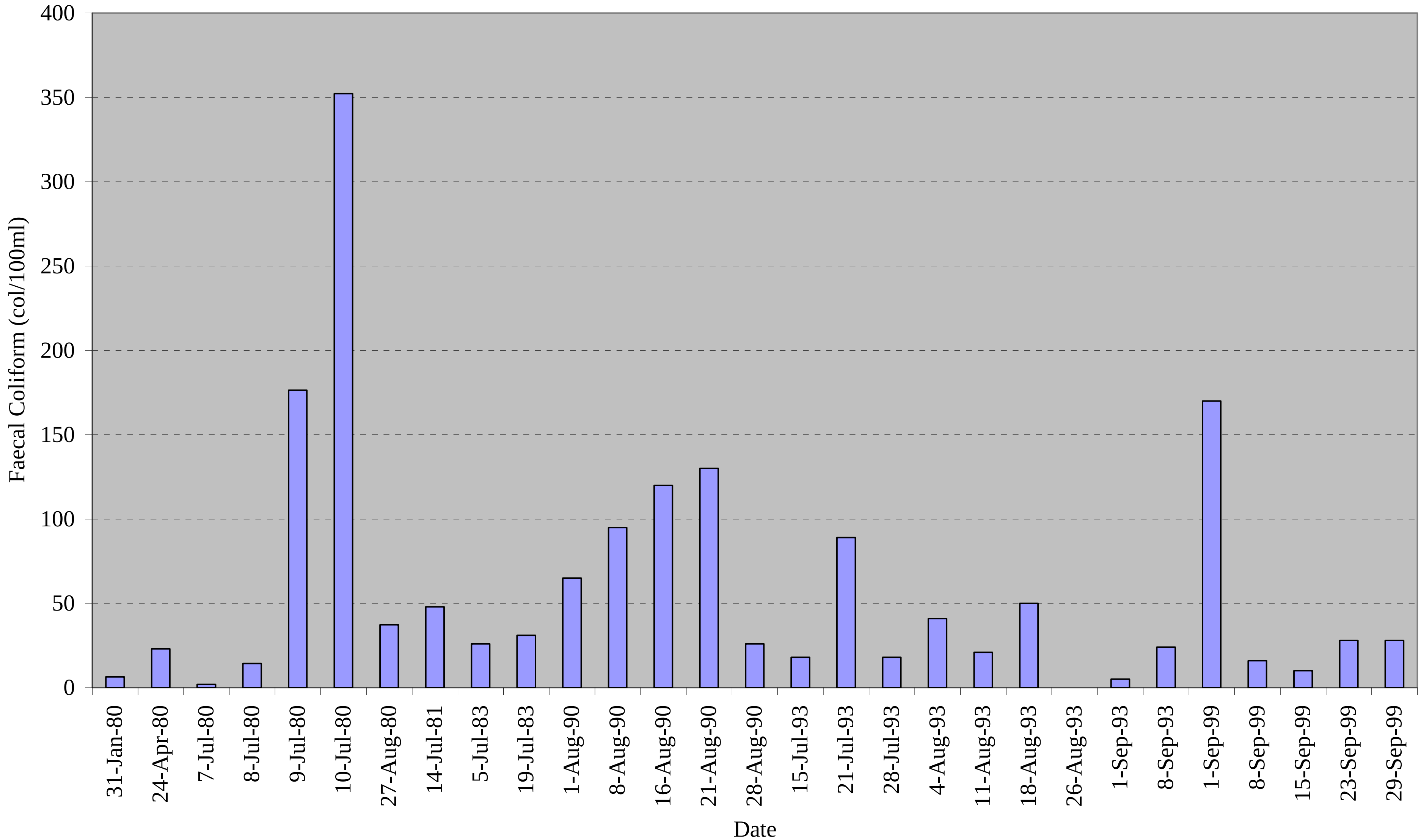


Figure 5.17 Faecal Coliform Concentrations Downstream of the Fruitvale STP Outfall from 1980 to 1999



5.3 REGULATORY ASSESSMENT

5.3.1 MUNICIPAL SEWAGE REGULATION

The *Municipal Sewage Regulation*, which was enacted in 1999, is intended to replace the Waste Management Permit system under which the Fruitvale STP currently operates. The operation of STPs requires that water quality meet certain standards in both the initial dilution zone (IDZ) and in the receiving environment itself. The IDZ is the three dimensional zone around the point of discharge that is designated for the mixing and dilution of an effluent by a receiving water body. By regulation, acute toxicity within the IDZ is not permitted but lower chronic levels of toxicity may be acceptable as long as certain water quality guidelines are met just outside the IDZ.

While the IDZ of the Fruitvale STP effluent was not directly measured in Beaver Creek, the location of the sampling site 400 m downstream of the outfall was chosen to represent water quality conditions in the creek outside the IDZ (which is at maximum, 100 m beyond the outfall) and after the effluent plume had been well mixed.

The *Municipal Sewage Regulation* also requires that the effluent pass an "end of pipe" 96 hour LC_{50} bioassay test, unless at least one of the following conditions is met:

(a) The discharge quality meets a maximum BOD not exceeding 10 mg/L and a maximum TSS not exceeding 10 mg/L;

(b) The discharge does not exceed a maximum daily flow of 5,000 m^3/d and the discharger demonstrates to the satisfaction of the manager that the discharge does not adversely affect the receiving environment;

(c) The discharge is diluted such that at the outside boundary of the IDZ, the dilution ratio exceeds 100:1 and the discharger demonstrates to the satisfaction of the manager that the discharge does not adversely affect the receiving environment; or

(d) The discharger demonstrates to the satisfaction of the manager that the discharge does not adversely affect the receiving environment.

If at least one of the above conditions are met, then the STP effluent is exempt from the acute toxicity requirements. The Fruitvale STP effluent discharge partially meets the second condition, since the maximum daily discharge rate for the STP must not exceed 1,425 m^3/d, according to their permit. However, with this discharge rate, the minimum dilution rate is not met during low water flows of Beaver Creek. The 7Q2 (lowest flows over seven days within a two year return period) for WSC site 08NE106 near the mouth of Beaver Creek was calculated as 0.286 m^3/s (24,710 m^3/d) (WSC 2003). By comparing the Beaver Creek 7Q2 discharge with the permitted maximum STP effluent discharge, the dilution ratio of the effluent in the creek is approximately 17.3:1, which is well below the minimum required dilution ratio of 100:1. This means that unless it can be demonstrated that the receiving environment will not be adversely affected, the STP effluent must pass the bioassay toxicity test. It is important to note that this ratio is calculated based on WSC data on Beaver Creek near the confluence with the Columbia River, not at the point of STP discharge, and therefore, includes all tributary contributions of flow between the STP outfall and the WSC sampling site. As a result, this 7Q2 ratio is not a conservative estimate, but rather, an overestimate, and the actual dilution ratio at the outfall site is likely to be much lower.

5.3.2 Water Quality Guidelines

In addition to meeting the requirements of the *Municipal Sewage Regulation*, the Fruitvale STP may not prevent Beaver Creek from meeting B.C. water quality guidelines (MELP 1998 a; 1998b). The majority of the water quality guidelines for both the protection of aquatic life and drinking water were met throughout the Beaver Creek sites during the 1999 sampling period. However, there were exceedances of both the drinking water and primary contact recreational guidelines for faecal and *E. coli* bacteria. The bacteriological data for Beaver Creek ranged from a high of 5,300 cfu total coliforms/100 mL to a low of <2 cfu *E. coli*/100 mL. Without appropriate treatment (filtration, disinfection or boiling), the presence of any faecal coliform bacteria or *E. coli* in surface waters means they are unsuitable for drinking purposes. As well, the numbers of faecal and *E. coli* bacteria measured on several occasions, present a risk to people using Beaver Creek for primary contact recreation like swimming and fishing.

While the nutrient loading to the Beaver Creek from the STP outfall did not exceed any water quality guidelines, there are few guidelines that apply specifically to the nutrient content of streams and to the nutrient parameters measured in this study. A discussion of the nutrient content of Beaver Creek and the potential effects of nitrate, nitrite and ammonia on the aquatic environment and human health follows.

High nitrate concentrations have been identified as a potential health problem, primarily for infants. Nitrate can be converted to nitrite, which combines with hemoglobin in blood to form methemoglobin, which does not absorb oxygen. The reduced capacity of the blood to absorb oxygen could result in death, in extreme cases (Nordin and Pommen 1986). An adequate level of protection for human health and recreational contact is provided when nitrate levels are less than 10 mg/L (MELP 1998a). Levels in the receiving environment were well below this level and ranged between a low of <0.002 mg/L at the upper end of the watershed and a maximum of 0.271 mg/L near the confluence with the Columbia River. Similarly, all nitrite concentrations in both the effluent and Beaver Creek were well below the maximum guideline of 1 mg/L (MELP 1998a). These results indicate that the nitrate and nitrate levels in Beaver Creek may not be a human health concern, but as mentioned previously, may contribute to negative responses in benthic invertebrate abundance and community diversity.

Ammonia toxicity to aquatic organisms is affected by the pH and temperature of the aquatic environment (Nordin and Pommen 1986). These parameters affect the amount of un-ionized ammonia (NH_3), which is the more toxic form, because it is a neutral molecule and thus is able to diffuse across the epithelial membranes of aquatic organisms much more readily than the charged ammonium ion (NH_4^+). Higher temperatures inhibit the ionization of ammonia from NH_3 to NH_4^+, increasing the toxicity of ammonia during the summer. The slightly alkaline pH of Beaver Creek may also contribute to a potentially higher toxicity of ammonia, since NH_3 is more prevalent at higher pH levels (Trussell 1972).

As a result, the higher the pH and the temperature, the higher is the potential toxicity of the total ammonia and the lower is the allowable concentration required to protect aquatic life. Downstream of the STP outfall, the pH and temperature of Beaver Creek averaged 7.86 pH units and 11.1 ºC respectively, during the 1999 sampling period. These specific conditions allow an average 30-day total ammonia concentration of 1.33 mg/L and a maximum total ammonia concentration of 6.92 mg/L for the protection of aquatic life of Beaver Creek. The ammonia concentration at the site downstream of the STP outfall ranged from 0.028 mg/L to 0.055 mg/L; well below both the 30-day average and maximum allowable total ammonia concentrations during the 4 week study period.

However, it is very important to note that because the downstream sampling site was located 300 m below the lower extent of the IDZ (maximum 100 metres below the point of discharge), and because this was a relatively short study over one 4 week period in the year, it is possible that the total ammonia guidelines are at times exceeded between 100 and 400 m downstream of the outfall. There may be potential risks for aquatic life, particularly on a chronic level for ammonia toxicity, since this assessment of the water quality of Beaver Creek for total ammonia is applicable only for the pH and temperatures measured during September 1999; the potential risks to aquatic life during other seasons, temperatures and pH levels have not been examined in this report.

5.4 BENTHIC INVERTEBRATES

The stream habitat characteristics of each site are summarized in Table 5.7. In general, the morphometric characteristics of Beaver Creek changed along its length, primarily in terms of size and observed (not measured) discharge volumes. The gradient of the creek was low throughout its drainage, with the exceptions of the falls noted previously. A summary of the benthic invertebrate results is found in Table 5.8. Figures 5.18 and 5.19 graph the community composition and functional feeding group results for each site. The taxonomic list, raw data and details from each sample replicate can be found in Appendix A. Photos of each site are found in Photos 8.7 to 8.12.

5.4.1 BEAVER CREEK AT MEADOWS ROAD

At the Meadows Creek Road site, Beaver Creek was relatively small, and meandered through a combination of marsh and an agricultural landbase (Photo 8.7). Its banks were predominantly grassed, and were somewhat incised, although access to the floodplain was maintained. Grazing activity and direct access to the stream for watering by cattle and horses may have influenced the stream and its banks, leading to some erosion and introduction of contaminants. Due to the lack of riparian vegetation, there was very little instream woody debris. The streambed and banks consisted primarily of gravels (Table 5.7). No benthic invertebrate data was collected at this site, due to the small size of the creek, which prevented the use of the sampling equipment.

Table 5.7 Stream Habitat Characteristics at Five Sites along Beaver Creek

Site	At Columbia River	d/s Fruitvale	u/s STP	u/s Fruitvale	At Marsh Creek Road	At Meadows Road
EMS Number	0200002	0200154	E238840	E238839	0200580	E238838
Time	10:05	11:05	12:19	13:30	14:40	16:00
Morphology/Pattern	• Riffle-pool • Cobbles • Sinuous	• Riffle-pool • Cobbles • Sinuous	• Riffle-pool • Cobbles • Sinuous	• Riffle-pool • Cobbles • Sinuous	• Riffle-pool • Gravels • Sinuous	• Riffle-pool • Gravels • Meandering
Islands/Bars	• No islands • Some side and mid channel bars	• No islands • Some side bars	• No islands • Some side and mid channel bars	• No islands • Some side bars	• No islands • No bars	• No islands • Some side and mid channel bars
Streambed Composition	15% Boulders 45% Cobbles 35% Gravels 5% Fines 0% Bedrock	1% Boulders 50% Cobbles 40% Gravels 9% Fines 0% Bedrock	0% Boulders 45% Cobbles 45% Gravels 10% Fines 0% Bedrock	1% Boulders 45% Cobbles 40% Gravels 14% Fines 0% Bedrock	0% Boulders 20% Cobbles 60% Gravels 20% Fines 0% Bedrock	0% Boulders 20% Cobbles 50% Gravels 30% Fines 0% Bedrock
Large Woody Debris/Distribution	• Few • Evenly distributed	• Few • Evenly distributed	• Few • Evenly distributed	• Abundant • Evenly distributed	• Abundant • Clumped distribution	• Few • Evenly distributed
Instream Vegetation	• Algae	• Algae	• Algae	• Algae	• Algae • Macrophytes	• None
Canopy Closure	1-20%	1-20%	0%	1-20%	1-20%	0%
Left Bank Riparian Vegetation/Stage	• Deciduous • Shrubs	• Mixed • Yearling forest	• Deciduous • Yearling forest	• Deciduous • Yearling forest	• Grass	• Grass
Right Bank Riparian Vegetation/Stage	• Deciduous shrubs	• Mixed • Yearling forest	• Shrubs	• Shrubs	• Shrubs	• Grass
Left Bank Composition	• Sloped • Gravels	• Sloped • Cobbles	• Overhanging • Cobbles	• Sloped • Gravels	• Undercut • Fines	• Undercut • Gravels
Right Bank Composition	• Sloped • Cobbles	• Sloped • Cobbles	• Sloped • Gravels	• Sloped • Fines	• Undercut • Fines	• Undercut • Gravels
Average Depth	• 0.24 m	• 0.31 m	• 0.17 m	• 0.28 m	• 0.33 m	• not measured
Average Velocity	• 3.48 m/s	• 3.43 m/s	• 4.57 m/s	• 6.05 m/s	• 4.09 m/s	• not measured

5.4.2 <u>BEAVER CREEK AT MARSH ROAD</u>

Beaver Creek at Marsh Road was considerably larger than the Meadows Road site, and was influenced by beaver activity, forming larger, slower moving run and some pool areas (Photo 8.8). Beaver activity also clumped the large woody debris within the stream. Riffles were abundant, and both algae and rooted macrophytes were found at this site, in comparison to only algae found at the other sites. The riparian area was well established, and consisted primarily of shrubs and grasses. The banks were undercut, providing instream refugia for fish (Table 5.7).

The biometric analysis of the invertebrate data indicated a healthy and diverse community unimpacted by pollution (Table 5.8). An average of 3,442 individuals was found in each sample. Species diversity was high, with an average of 43 different taxa found per sample. Only about one third of these taxa (15 different taxa) were represented by the more sensitive Ephemeroptera (mayflies), Plecoptera (stoneflies) and Trichoptera (caddisflies) orders, indicating that less sensitive taxa were more diverse than the more sensitive taxa.

Ephemeroptera overwhelmingly dominated this site on Beaver Creek (Figure 5.18), comprising over 66% of the samples, on average. Of the mayflies, the Ephemerellidae family was the most numerous taxon, and was also the most abundant taxon within the entire sample, comprising almost 61% of the total community. In general, an overwhelming dominance by just one taxon can indicate a stressed community, however, a closer look at the data leads us to modify this statement. The Ephemerellidae were extremely small, and could not be identified further. Had samples been taken later in the year, the instars would have developed more, and likely would have been differentiated into several genera. This family is also extremely sensitive to water pollution, requiring clean, swift moving water, and its strong dominance would not occur unless Beaver Creek were of good quality. Other common mayflies included *Baetis and Cinygmula sp.* Both these taxa are moderately to highly intolerant of water pollution and require swift flowing water to receive adequate oxygen.

The second most abundant taxon at this site on Beaver Creek was Elmidae, or riffle beetles. These beetles are so named because they are commonly found in swift moving water, using strong hooks and posterior prolegs to attach firmly to rough substrates. A wide diversity of different riffle beetle taxa was found, however, the most common was *Optioservus* sp.

Both the Plecopteran and Trichopteran orders were relatively rare, comprising just 2 and 2.3% of the samples, respectively. Dipterans were more common and comprised an average 10% of the samples. The dipteran community consisted primarily of chironomids. Unlike most insects, some chironomids contain haemoglobin, which enables their survival in low oxygenated areas. Because of this, their presence in high numbers is often one of the first signs of pollution and organic enrichment. At this site, chironomid numbers were low in comparison to the sensitive EPT taxa, and resulted in a high EPT/EPT+Chironomid ratio, indicating a non-polluted site. Because of the overwhelming dominance of the sensitive Ephemerellidae family, the HBI resulted in an unimpacted rating. While the extremely tolerant Hydracarina (water mites) and Oligochaeta were quite numerous in these samples, the vast majority of the community was composed of intolerant taxa that require clean and clear water.

The functional feeding group analysis demonstrated that this site was dominated by collector-gatherers, averaging 77% of the samples (Figure 5.19). This was due to the abundance of the Ephemerellidae family. The collector-gatherer group was also well represented by many of the chironomids found in the samples. Scrapers, shredders and collector-filterers were all less than 10% each. This structure indicated that primarily smaller particles of organic detritus are used as the resource base at this site.

Predators were not common and composed just 6% of the sample. While a large prey base has been established, predators have not responded in the numbers expected. The most common predator was Hydracarina, which may also function as a parasite [identification of water mites is very difficult, and does not aid in their functional feeding assignation (Clifford 1991)]. Had Hydracarina been classified as a parasite, then the proportion of predators would have dropped to 3.6% and parasites would have increased to 3.6% from 1.1%.

5.4.3 BEAVER CREEK UPSTREAM OF FRUITVALE

Upstream of the Village of Fruitvale, Beaver Creek was influenced by road and highway development, in addition to the agricultural practices further upstream in the watershed. Beaver

Creek was sampled just below where the highway crosses the creek, and its water quality may have been impacted by the road (Photo 8.9). The creek has been partially channelized in order to run beside the road, but in other respects, retained much of its natural structure and function. The streambed and banks were composed of larger cobble material in comparison to the gravels and fines of the upstream sites. A yearling forest of primarily deciduous vegetation was found on the left bank, while the right bank consisted of shrubs (Table 5.7).

The biometric analysis of the invertebrate data indicated a diverse community slightly impacted by pollution (Table 5.8). An average of 3,598 individuals was found in each sample. Species diversity was high, with an average of 47 different taxa found per sample. Over one third of these taxa (15 different taxa) were represented by the more sensitive EPT orders, indicating that less sensitive taxa were more diverse than the more sensitive taxa.

Like the Marsh Road site, Ephemeroptera overwhelmingly dominated this site (Figure 5.18) but to a lesser degree, comprising 54% of the samples, on average. The species composition of the mayfly order, however, was substantially different. The Heptageniidae family was the most numerous taxon, but the Ephemerellidae family, *Baetis* sp. and *Paraleptophlebia* sp. were also well represented. While both the Heptageniidae and *Baetis* sp. are slightly tolerant of pollution, the remainder of the mayflies are extremely sensitive.

A substantial increase in chironomid numbers led to an increased proportion of Dipterans, which made up 18% of the samples, suggesting a slight decrease in water quality. However, because of the abundance of mayflies, chironomid numbers were still low in comparison to the sensitive EPT taxa, and indicated a non-polluted site.

While Plecopteran numbers remained low, increases were seen for the Trichopteran order, which comprised 8% of the samples. Of these, *Hydropsyche* sp. was the most common. The remaining 18% of the samples was composed primarily of Elmidae, or riffle beetles, although Hydracarina were also common. Although sensitive taxa like Ephemerellidae and *Paraleptophlebia* were found in abundance at this site, because of the strong presence of slightly to moderately tolerant taxa (Heptageniidae, *Baetis*, Elmidae), the HBI resulted in a slightly impacted rating.

Due to the abundance of mayflies and chironomids, the majority of which were collector-gatherers, this group dominated this site on Beaver Creek, averaging 57% of the samples (Figure 5.19). Substantially more scrapers were found at this site, indicating the increasing importance of algae as a food resource. The predator community was small, and consisted primarily of Hydracarina.

5.4.4 Beaver Creek Upstream of the STP

Benthic invertebrates were sampled just upstream of the Fruitvale STP, where Beaver Creek was found to be a relatively wide, shallow and sinuous channel (Photo 8.10). The lower depth of the creek compared to other sites resulted in gravel exposure in some places, forming both mid channel and side bars. The left bank sloped steeply several metres up, while the right bank formed part of the creek's floodplain, on which the STP is located. The streambed and banks were composed primarily of cobble material, and algae were found to cover the surfaces of the rocks. Instream woody debris was rare, due to the lack of riparian vegetation (Table 5.7).

The invertebrate community along Beaver Creek was the most abundant upstream of the STP. The community was diverse, however, the biometric analysis indicated that it was slightly to moderately impacted by pollution (Table 5.8). Organic enrichment often results in an increased abundance of a few pollution-tolerant species, which is exactly what occurred at this site. An average of 6,151 individuals was found in each sample. Species diversity was high, with an average of 47 different taxa found per sample, however, only about one third of these taxa (18 different taxa) were represented by the more sensitive EPT orders. This indicated that less sensitive taxa were more diverse than the more sensitive taxa.

Unlike the previous two sites, Ephemeroptera did not dominate this site (Figure 5.18). Dipterans were the most common taxon and comprised an average 42% of the samples. Like the previous sites, the dipteran community consisted primarily of chironomids, and in particular, the *Cricotopus/Orthocladius* spp. This was the most common taxon within the samples, and the strong dominance of a pollution-tolerant species suggests a degradation of water quality. In addition, chironomid numbers had increased to a point where they were elevated in comparison to the sensitive EPT taxa, resulting in a low EPT/EPT+Chironomid ratio and indicating a moderately polluted site.

Mayflies were still abundant and comprised 26% of the samples. Although sensitive species like *Paraleptophlebidae* sp. were common, the most abundant mayflies were *Baetis* sp. and the Heptageniidae family, which are moderately tolerant of pollution. Both the Plecopteran and Trichopteran orders were relatively rare, comprising just 1 and 5% of the samples, respectively. The remaining 26% of the samples were composed primarily of Elmidae, Hydracarina and Oligochaeta. Because of the substantial increases in pollution-tolerant taxa (Chironomids, Hydracarina, Oligochaeta) at this site, the HBI increased to a slightly impacted rating.

The functional feeding group analysis demonstrated that collector-gatherers still dominated the samples, averaging 38%, however, shredders were also numerous at 25% of the samples (Figure 5.19). The shredder group was composed primarily of *Cricotopus/Orthocladius* spp., while a diverse group consisting of *Baetis* sp., *Paraleptophlebia* sp., Naididae, Elmidae and various chironomids contributed to the collector-gatherer population. Scrapers consisted primarily of the Heptageniidae family and composed 11% of the samples. This more complex structure indicated that both large and small pieces of organic detritus, as well as algae, were available and used as the resource base. The functional feeding group analysis also suggested that stable substrates were limiting to invertebrate production. The shallow gravels composing the streambeds may shift annually with the spring freshet, disturbing the habitat of aquatic invertebrates.

Predators were more common and composed over 12% of the sample, at first glance indicating a healthy population. However, this group was comprised almost exclusively of pollution-tolerant Hydracarina and Dipteran larvae, rather than sensitive Plecopterans.

5.4.5 BEAVER CREEK DOWNSTREAM OF FRUITVALE

Downstream of the Village of Fruitvale and its STP, Beaver Creek flowed through a more forested landbase (Photo 8.11). Both banks were vegetated by a yearling forest of mixed coniferous and deciduous trees, providing some canopy closure. Despite the riparian vegetation, instream woody debris was rare. Cobbles dominated both the streambed and banks of the creek, which sloped gently down to the margins of the creek (Table 5.7).

The invertebrate community decreased to its previous abundance prior to the STP. The community was diverse and biometric analysis indicated that it was slightly impacted by pollution (Table 5.8). An average of 3,679 individuals was found in each sample. Species diversity was high, with an average of 47 different taxa found per sample, with 40% of these taxa (19 different taxa) represented by the more sensitive EPT orders. This indicated that less sensitive taxa were slightly more diverse than the more sensitive taxa.

The community composition was also more similar to the two uppermost sites, in comparison to the previous site upstream of the STP. Ephemeroptera once again dominated this site, comprising 42% of the samples, on average (Figure 5.18). Of the mayflies, the Ephemerellidae family was the most numerous taxon. This was also the most abundant taxon found within the entire sample. Other common mayflies included *Baetis* sp. and the Heptageniidae family. Both these taxa are moderately tolerant of water pollution, while the Ephemerellidae are more sensitive.

Dipterans were also common and comprised an average 20% of the samples. Like all the previous samples, the dipteran community consisted primarily of chironomids, with the Tanytarsini family the most abundant. Relative to the sensitive EPT taxa, chironomid numbers were slightly elevated and resulted in a lowered EPT/EPT+Chironomid ratio, indicating a slightly polluted site.

While the Trichopteran order made up 9% of the samples, the Plecopteran order was relatively rare at this site, comprising just 2% of the samples. Elmidae were very common, however, and comprised the majority of the remaining orders and 27% of the samples. A wide diversity of different riffle beetle taxa was found, with *Optioservus* sp. the most common. Ostracods (small crustaceans), oligochaetes and water mites were also abundant, all of which are very tolerant of pollution and may indicate an impaired water quality.

Because of the strong presence of moderately to highly insensitive taxa, such as *Baetis*, Heptageniidae, Tanytarsini, Elmidae, Ostracoda, Oligochaeta and Hydracarina, the HBI resulted in a slightly impacted rating. However, because Ephemerellidae, which are sensitive to poor water quality, were the most abundant taxon, water quality cannot have degraded to a point where sensitive species cannot be supported.

The functional feeding group composition reverted back to that of the two uppermost sites, in which collector-gatherers dominated the samples. This group was composed primarily of Ephemerellidae, *Baetis*, Elmidae, Ostracoda and Oligochaeta and averaged 54% of the samples (Figure 5.19). Scrapers made up 17% of the samples and were comprised primarily of the Heptagneiidae family. Collector-filterers, consisting primarily of the Tanytarsini family, comprised 12% of the samples. Shredders made up only 8% of the community. This structure indicated that primarily smaller particles of organic detritus are used as the resource base. Once again, the predator group, which composed almost 9% of the samples, was represented primarily by the pollution-tolerant Hydracarina.

5.4.6 BEAVER CREEK AT THE COLUMBIA RIVER

Prior to its confluence with the Columbia River, the channel of Beaver Creek widened further (Photo 8.12). Its streambed composition also shifted, and was partially composed of boulders, which were absent at all other upstream sites. Like the three preceding sites, however, the streambed and banks were primarily composed of cobbles. The riparian vegetation had been cleared previously, such that only deciduous shrubs and small trees were present and little instream woody debris could be observed (Table 5.7).

The invertebrate community at this site was diverse, but the biometric analysis indicated that it was slightly to moderately impacted by pollution, or land use and clearing adjacent to the creek (Table 5.8). An average of 3,300 individuals was found in each sample. Species diversity was lower than the previous sites, but still high, with an average of 41 different taxa found per sample. Of all the sites along Beaver Creek, this site had the highest proportion of ETP taxa, at 46% (19 different taxa). Still, the less sensitive taxa were slightly more diverse than the more sensitive taxa.

Like the STP site, Ephemeroptera did not dominate this site (Figure 5.18). Dipterans were the most abundant taxon and comprised an average 48% of the samples. Like all the previous sites, the dipteran community consisted primarily of chironomids, and in particular, *Cricotopus/Orthocladius* spp. This was the most common taxon within the samples, and the strong dominance of a pollution-tolerant species indicates a degradation of water quality. In addition, chironomid numbers increased to a point where they were elevated in comparison to the sensitive EPT taxa, resulting in a low EPT/EPT+Chironomid ratio and indicating a moderately polluted site.

In contrast to all other sites, the Ephemeropteran order dropped substantially in abundance, comprising just 7% of the samples. The mayfly species composition remained similar to other sites, dominated by *Baetis* sp., Heptageniidae and Ephemerellidae. The Plecopteran order remained relatively rare and comprised just 2% of the samples. A substantial increase in Trichopteran numbers was another distinct characteristic of the invertebrate community at this site. Caddisflies comprised 22% of the samples, consisting primarily of the Hydropsychidae family.

The remaining 18% of the samples were composed primarily of Elmidae and Hydracarina, as found at previous sites. Because of the substantial increases in pollution-tolerant taxa (primarily chironomids) at this site, the HBI increased to a slightly impacted rating.

The functional feeding group analysis demonstrated that collector-gatherers no longer dominated the samples. Rather, dominance was shared by shredders (at 33%), collector-filterers (at 25%) and collector-gatherers (at 28%) (Figure 5.19). Scrapers composed 6% of the samples, and predators almost 8%. Once again, the predator population was composed almost entirely of Hydracarina. This community composition indicated that both large and small pieces of organic detritus, as well as algae, were available and used as the resource base.

Table 5.8 Summary of Benthic Invertebrate Results at Five Sites along Beaver Creek

Biometric	At Marsh	U/S Fruitvale	U/S STP	D/S Fruitvale	At Columbia
Mean abundance (± standard deviation)	3,442 (± 837)	3,598(± 621)	6,151 (± 578)	3,679 (±1,137)	3,300 (±1,581)
Mean density per m^2 (± standard deviation)	38,240 (± 9,297)	39,984 (± 56,906)	68,104 (± 6,351)	40,882 (± 12,365)	36,671 (± 17,571)
Total number of Taxa	No impact (43)	No impact (47)	No impact (47)	No impact (47)	No impact (41)
Number of EPT Taxa	No impact (15)	No impact (17)	No impact (18)	No impact (19)	No impact (19)
EPT/ Total Taxa	Slight impact (34%)	Slight impact (37%)	Slight impact (38%)	No impact (40%)	No impact (46%)
EPT / (EPT+ Chironomid) Ratio	No impact (89%)	No impact (79%)	Moderate impact (38%)	Slight impact (74%)	Moderate impact (41%)
% Dominant Taxon	Severe impact (62%)	No impact (20%)	Slight impact (23%)	No impact (18%)	Slight impact (27%)
Hilsenhoff Biotic Index	No impact (2.55)	Slight impact (4.01)	Slight impact (5.41)	Slight impact (4.15)	Slight impact (5.48)
Predators / Other FFG	Insufficient prey base	Insufficient prey base	Sufficient prey base	Sufficient prey base	Insufficient prey base
(Scraper + Collector-Filterer) / (Shredders + Collector-Gatherers)	Stable substrates not limiting	Stable substrates not limiting	Stable substrates limiting	Stable substrates not limiting	Stable substrates limiting

Figure 5.18 Change in Benthic Invertebrate Community Composition along Beaver Creek

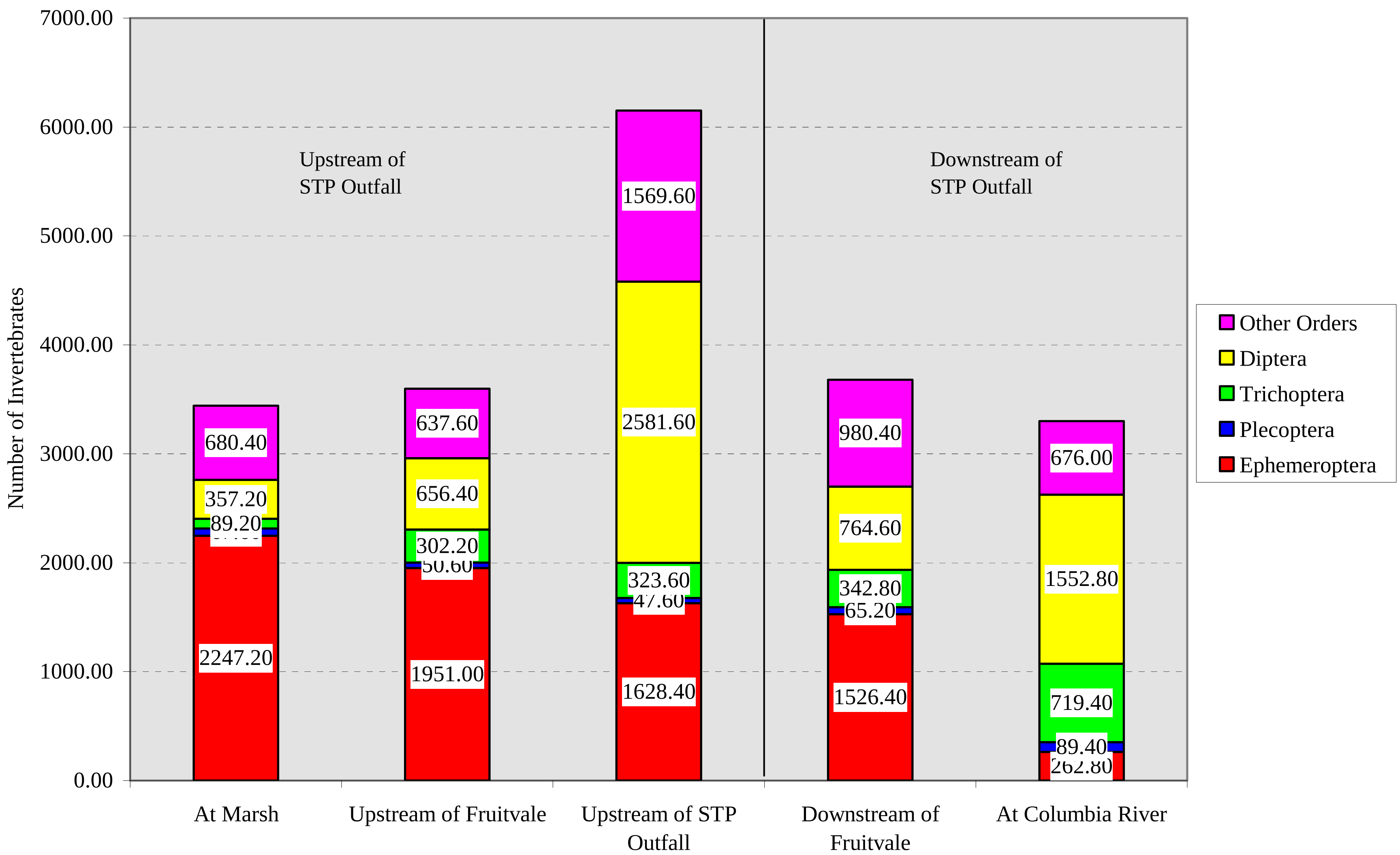
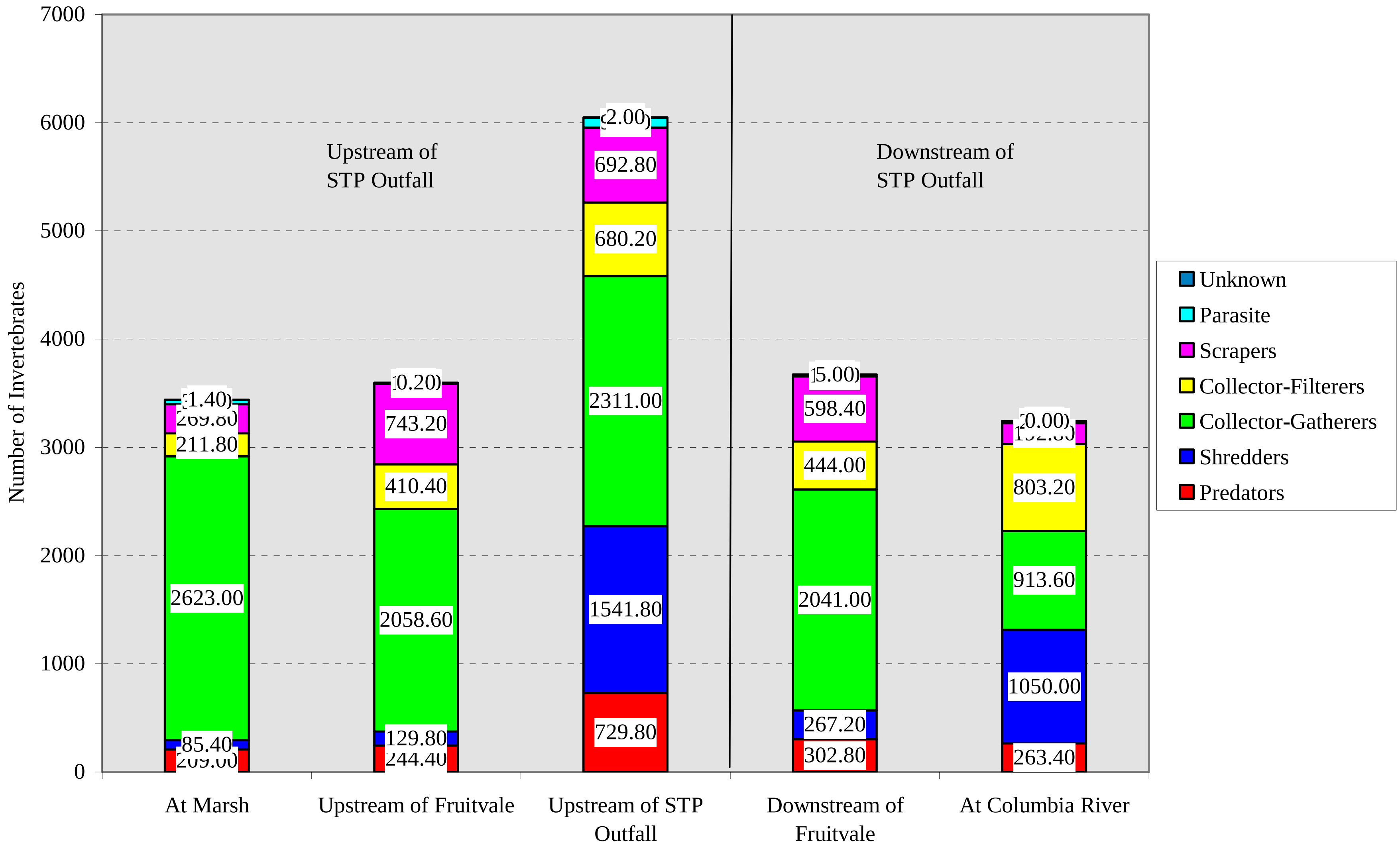


Figure 5.19 Change in Functional Feeding Group Composition along Beaver Creek



5.4.7 BENTHIC INVERTEBRATE SUMMARY

Because the complexity and size of streams increase along a downstream gradient, it would be expected that the increased food resources and habitats would result in increases in both the abundance and diversity of organisms at the downstream sites relative to the upstream sites. Although only viewed on a relatively small scale, this pattern was not entirely consistent with the data collected from the Beaver Creek sites. Rather, in comparison to the uppermost site, the invertebrate abundance and taxonomic diversity of the lowermost site decreased slightly.

The species composition of the community did change substantially along the length of Beaver Creek. Figure 5.18 clearly shows how mayfly numbers and proportions dropped consistently along the drainage, initially dominating samples at 66% at the Marsh Road site, but decreasing to just 7% at the Columbia River site. Conversely, a consistent increase in dipteran numbers, in particular, chironomids, occurred along the length of Beaver Creek. Dipterans initially comprised 10% of the samples at the Marsh Road site, but increased to 48% at the Columbia River site. A consistent increase in Trichoptera also occurred, from 2% to 22% of the samples along the length of the creek. The proportion and numbers of other groups, including Plecoptera, Elmidae, Oligochaeta and Hydracarina remained relatively stable. Overall, Beaver Creek changed from being dominated by mayflies, to being dominated by chironomids. Because mayflies are considered to be a more sensitive order, their decrease, coupled with the increase in the pollution-tolerant chironomids, indicates that the water quality of Beaver Creek had degraded somewhat along its length, despite increased dilution from tributary streams.

These species changes are somewhat reflected in the functional feeding group changes that occur along the creek. The FFG composition of Beaver Creek changed substantially from the headwaters to its confluence with the Columbia River (Figure 5.19). Initially dominated by collector-gatherers, Beaver Creek came to consist primarily of shredders. This shift indicated a change in resource use from smaller to larger particles of organic material. These changes in the FFG composition are inconsistent with those typically associated with longitudinal trends for mountain streams (Vannote *et al*. 1980): as larger organic material is broken down by the upstream shredders, smaller particles are available for the collector-filterers downstream. The River Continuum Concept, however, assumes that the landbase changes from being forested at the headwaters to being less influenced by riparian vegetation at its other extent (Vannote *et al*. 1980). This pattern is not the case for Beaver Creek. The riparian area adjacent to the headwaters of Beaver Creek has been cleared of vegetation to a large degree, to accommodate agriculture. The lower reaches of the creek, however, retain more of their riparian vegetation, allowing for more inputs of leaves and woody debris. This pattern results in a lesser reliance on riparian inputs at the headwaters, while these resources are utilized more further downstream. The functional feeding group composition and benthic invertebrate community reflect the resources available for use at the specific sites along the Beaver Creek watershed.

Alternatively, this functional feeding group shift could be explained by a decrease in water quality. The replacement of collector-gatherers by shredders and collector-filterers is largely due to the decreases in mayfly species and subsequent increases in chironomid species. The replacement of more pollution sensitive taxa (mayflies) by tolerant taxa (chironomids) suggests that an increase in downstream pollution may play a role in the structure of the invertebrate communities.

Overall, there was a paucity of stonefly taxa in Beaver Creek, which would not normally be expected for a small, cold mountain stream. Stonefly taxa traditionally make up a large portion of the predator community, and their absence may have contributed to the very high invertebrate abundances seen at these sites. Without stoneflies acting as predators, this role was left largely to the Hydracarina water mites, however, this classification is problematic, since they may actually belong to the parasite group. This indicates that a core functional feeding group is largely absent from this creek, the reasons for which may stem from water quality issues, since stoneflies require clean and cold running water. In addition, parasites are generally only established in communities that are stressed.

The attempt to attribute a causal relationship to the benthic invertebrate data along Beaver Creek is difficult, because anthropogenic activities have influences on natural conditions that are expected to change longitudinally. For example, nutrient and sediment loading are expected to increase as the landbase of the creek increases, but will also depend on the discharge and water quality of tributary streams. As a result, in the absence of information prior to human influence, it is extremely difficult to determine if changes stem from inherent processes or are influenced by human activity. In Beaver Creek, the abundance and composition of the benthic invertebrate community is likely the result of both.

In terms of the influence of the STP outfall, it appears that there is little immediate effect on the benthic invertebrate community within Beaver Creek. Common effects of treated sewage effluent on benthic invertebrate communities in mountain streams include excessive plant growth as a result of nutrient enrichment (Bowman 2001). Algae and macrophyte communities can shift toward a dominance by eutrophic species rather than clean-water species, and high rates of growth can produce unsightly “sewage mats” (Highwood 2001). These algae mats can impair the aesthetic appeal of the river and potentially pose a risk to aquatic life by decreasing the oxygen content of the water following their decomposition.

Plant production was not measured along Beaver Creek, therefore, it is not known how the algae and macrophyte communities responded to the STP outfall. However, complaints of “toilet paper” in Beaver Creek near Montrose have recently been received by the ministry (J. Beatty, pers. com., 2003). These long strands of attached algae on rocks within the water appear to be the nuisance algae *Didymosphenia geminata*, which could indicate eutrophication and excessive nutrient concentrations in Beaver Creek.

Increased aquatic plant productivity can lead to eutrophication of the entire system, including increased benthic invertebrate numbers and a shift in species (Highwood 2001; Bowman 2001). In Beaver Creek, however, the highest invertebrate abundance was found not downstream of the STP outfall, but at the site upstream of the STP outfall. The biological productivity at this site may have been high due to the open and shallow streambed, allowing higher light penetration and increased water temperatures that may stimulate primary production. This site is also downstream of agricultural lands and may be influenced by nutrient loadings from fertilizers and manure. The high light availability, in combination with the shallow, warm and nutrient-enriched waters would all contribute to increased productivity at this site, resulting in the highest benthic invertebrate populations along the creek. Benthic invertebrate abundance may have decreased at the two lower sites due to higher depths and a higher canopy cover, which could reduce the light availability and water temperature of the system and reduce its productivity.

In addition to increasing in abundance, benthic invertebrate communities often become less diverse downstream of STP outfalls. The community can shift from a diverse assemblage comprised of sensitive species to one that is more numerous, but dominated by just a few pollution-tolerant species, commonly oligochaetes and chironomids (Bowman 2001). In Beaver Creek, no dramatic shift in community composition was found at any one site, including the site downstream of the STP outfall. Rather, the community appeared to change at a gradual rate along the length of the creek, with incremental changes from a community dominated by Ephemeroptera to one dominated by Diptera and Trichoptera.

Community diversity was found to decrease slightly along the length of Beaver Creek. The greatest change in terms of invertebrate abundance occurred at the site upstream of the STP outfall, but the greatest change in terms of community composition occurred at the site near the Columbia River. This change toward pollution-tolerant species at the Columbia River site suggests that Beaver Creek has become organically enriched, to the point where more sensitive species are beginning to be replaced by tolerant ones. Whether this is the result of the discharge from the STP outfall, or a combination of natural and anthropogenic changes throughout the watershed, has yet to be determined. It is possible that the influence of the STP effluent is delayed through other physical, chemical and/or biological processes and is only manifested in Beaver Creek several kilometres downstream of the outfall.

6 SUMMARY AND CONCLUSIONS

Effluent discharged from STP outfalls can contribute significant amounts of sediment, nutrients, bacteria and organic material to surface waters, leading to changes in water quality and the health, abundance and composition of biological communities. The 1999 data collected and analysed in this report found that both the water quality and benthic invertebrates of Beaver Creek changed along the length of the creek, which may have been a result of effluent discharges from the Fruitvale STP as well as other non-point sources of pollution from agriculture, urban development and industry in the watershed.

Several water quality parameters increased significantly downstream of the STP outfall compared to upstream concentrations. The significant increases in ammonia, nitrate, total nitrogen, total phosphorus, and ortho-phosphate at the site downstream of the STP are believed to be the result of the Village of Fruitvale's effluent discharge to Beaver Creek.

Ammonia levels were found to increase downstream of the Fruitvale STP, but decreased to near background concentrations further downstream, likely the result of dilution and the nitrification process. Nitrate levels also increased downstream of the STP, and continued to increase along the length of the creek, due in part to the progressive nitrification of ammonia and perhaps inputs from fertilizers or other non-point nutrient sources in the downstream reaches. Total phosphorus and ortho-phosphate both increased significantly downstream of the STP site, but decreased near the confluence with the Columbia River, likely the result of increased biotic uptake, and/or increased dilution from tributaries. Downstream of the STP site, phosphorus was found to be substantially more bioavailable, which may have increased the productivity of the stream, although a resultant increase in the abundance of benthic invertebrates was not found until further downstream.

In contrast to the substantial changes in nutrient content along the length of Beaver Creek, no significant differences in microbial concentrations were found upstream and downstream of the STP outfall. With the exception of enterococci bacteria, the average concentrations of total and faecal coliform bacteria and *E. coli* in the STP effluent were consistently lower than those in the creek both upstream and downstream of the STP outfall. This indicates that the microbial loadings to the creek from the STP outfall were minimal. While the STP appears to effectively treat the microbial content in the effluent, other non-point sources of bacteria, including septic tanks, livestock and domestic and wild animals may be a greater contributor to bacteria within Beaver Creek.

The changes to the nutrient concentrations of Beaver Creek along its length may influence its benthic invertebrate communities. The abundance and diversity of benthic invertebrates decreased along the length of the creek, with more sensitive taxa being replaced by pollution-tolerant taxa. These results could represent impairments to the water quality of Beaver Creek. Changes in resource use from smaller to larger particles of organic material were also noted along the length of the creek, resulting from the increase in riparian vegetation from the headwaters to the confluence with the Columbia River.

Upgrades to the Fruitvale STP in 1995 and 1997 appeared to have been successful in significantly improving the effluent quality of the STP outfall from 1990 to 1999. The increased effectiveness of lagoon aeration appears to have resulted in a higher rate of conversion of ammonia into nitrate, with significant increases and decreases seen in the effluent's ammonia and nitrate concentrations, respectively. The drop in total phosphorus concentrations in the STP effluent was likely due to the combination of flocculant addition to the RI basins prior to settling and other improvements in the RI basins. Although not statistically significant, these 1995 and 1997 improvements also likely resulted in the effluent's microbial concentrations dropping by an order of magnitude.

These improvements to effluent quality did not result in similar improvements to the water quality of Beaver Creek at the site downstream of the STP outfall over the 1990 to 1999 period. Ammonia concentrations were found to decrease slightly from 1993 to 1999, while nitrate concentrations increased slightly. In contrast, however, total phosphorus concentrations were essentially unchanged throughout the 1990s, while the microbial concentrations of the creek at this site were actually found to increase from 1993 to 1999.

The lack of correspondence between effluent quality and water quality of Beaver Creek over the 1990s is difficult to interpret. While significant improvements in the effluent quality were noted between 1990 and 1999, the water quality of Beaver Creek was relatively unchanged, and actually decreased in quality for some parameters over this time. These results may indicate that while the RI basins are effective in treating the effluent flowing through them, they may not be treating all the effluent from the STP. It is possible that some effluent may leak out of the aeration or polishing basins into the underlying shallow aquifer, prior to discharge to the RI basins, resulting in partially treated effluent reaching the creek via the groundwater. It is also possible that the system has established sub-surface conduits through the soils in the RI basins, through which effluent may bypass the collection pipes and diminish the effectiveness of the treatment system. The possibility that sewage is somehow bypassing the system should be investigated, however, this should not dismiss the possibility that other non-point sources of pollution play an important role in impacting the water quality of Beaver Creek.

7 RECOMMENDATIONS

Implementation of the following recommendations should improve the understanding of Beaver Creek and assist in its protection for all water users. In particular, it is recommended that a watershed management plan be developed for the Beaver Creek watershed. This process typically involves all stakeholders, including land owners and provincial and municipal governments and represents the wide range of watershed users. A watershed management plan should first define the aquatic environment of Beaver Creek in terms of water quantity, quality, habitat and aquatic communities. The protection of Beaver Creek may then be achieved through the active management and co-ordination between jurisdictions as well as regulation of activities and water uses that affect the quality of groundwater and/or surface water.

An important step toward the initiation of a watershed management plan is the collection of additional information to ensure the aquatic resources of Beaver Creek and the land uses within the watershed have been fully described and analyzed. While this report has characterized the water quality and benthic invertebrate community of the creek at one point in time considered to be representative of a "worst case" dilution period, a more comprehensive understanding of the variability of Beaver Creek water quality is necessary, particularly since these characteristics can change greatly over the seasons.

In addition, further information is required to fully understand the various influences and sources of pollution to Beaver Creek. An inventory should be conducted of all land uses or activities that potentially contribute to point and non-point sources of pollution to the creek, including septic systems and livestock confined feeding areas. The locations of those septic systems in close proximity to the mainstem or tributary streams should be mapped and the depth to the underlying aquifer determined. This information will be essential in prioritizing a list of sites for further investigation and improvement, based their potential to impact the ecological health, recreational use or drinking water quality of Beaver Creek.

If future water quality sampling on Beaver Creek or its tributaries is conducted, the following recommendations should be implemented:

- Ensure that sampling dates and water quality analyses conducted for all sites are identical, including the Fruitvale STP effluent and Beaver Creek or tributary stream sites.

- Collect concurrent flow data from the Fruitvale STP (effluent flow volumes) and Beaver Creek. This will allow more accurate calculation of dilution ratios and total loadings (mass, not concentration) of nutrients entering Beaver Creek.

- Better define the zone and magnitude of impact just downstream of the Village of Fruitvale's treated sewage discharge.

- Implement a more comprehensive monitoring program to include an examination of seasonal variation in water quality of both Beaver Creek and the STP outfall.

- Implement a groundwater monitoring program to determine if the RI basins and underdrains are leaking to shallow aquifers and subsequently, to Beaver Creek

- Incorporate toxicological testing of the Village of Fruitvale effluent discharge in future monitoring and assessment programs.

- Collect attached algae (periphyton) samples for biomass and taxonomy. This information would help determine the presence of nuisance algae and the relative community composition of eutrophic and clean water species.

If implemented, these recommendations should assist in defining the influence of the STP discharge as well as other point and non-point sources of pollution on the water quality and aquatic health of Beaver Creek. The ministry advocates a watershed approach to best manage point and non-point source pollution and hopes to work with communities and various stakeholder groups to achieve this result.

PHOTOGRAPHS

Photo 9.1 Fruitvale STP aerated cell #1, Aug. 2003.

Photo 9.2 Fruitvale STP rapid infiltration basin #3, Aug. 2003.

Photo 9.3 Fruitvale STP rapid infiltration basin #4 (dry), Aug. 2003.

Photo 9.4 Fruitvale STP outfall discharging into Beaver Creek, Aug. 2003.

Photo 9.5 Fruitvale STP outfall discharging into Beaver Creek, Aug. 2003.

Photo 9.6 Duckweed growth on the Fruitvale STP lagoon, Aug. 2003.

Photo 9.7 Beaver Creek at Marsh Creek Road, Sept. 1999.

Photo 9.8 Beaver Creek at Meadows Road, Sept. 1999.

Photo 9.9 Beaver Creek upstream of the Village of Fruitvale, Sept. 1999.

Photo 9.10 Beaver Creek upstream of the Fruitvale STP Outfall, Sept. 1999.

Photo 9.11 Beaver Creek downstream of the Village of Fruitvale, Sept. 1999.

Photo 9.12 Beaver Creek upstream of the confluence with the Columbia River, Sept. 1999.

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ACRONYMS

7Q2	lowest seven day average flow over two years
96 hr LC_{50}	96 hour 50% lethal concentration
BOD	biochemical oxygen demand
CPOM	coarse particulate organic material
cfu/100 mL	colony forming units per 100 millilitres
DO	dissolved oxygen
D/S	downstream
EMS	environmental monitoring system
EPT	Ephemeroptera, Plecoptera and Tricoptera
E. coli	*Escherichia coli*
FFG	functional feeding group
FPOM	fine particulate organic material
HBI	Hilsenhoff biotic index
IDZ	initial dilution zone
km	kilometre
km^2	square kilometre
m	metre
m^2	square metre

ACRONYMS CONT.

mm	millimetre
m/s	metres per second
µm	micrometre
m^3/d	cubic metres per day
m^3/s	cubic metres per second
mg/L	milligrams per litre
mL	millilitre
MELP	Ministry of Environment, Lands and Parks
NFR	nonfilterable residue
NH_3	ammonia
NH_4^+	ammonium ion
NO_2	nitrite
NO_3	nitrate
RI	rapid infiltration
STP	sewage treatment plant
U/S	upstream
WLAP	(Ministry of) Water, Land and Air Protection
WSC	Water Survey of Canada

GLOSSARY

96 hr LC_{50}	A standard regulatory “acute lethality” test, often using rainbow trout, to estimate the concentration of effluent at which 50% of the test organisms die within the 96 hour test period.
abiotic	The physical and chemical characteristics of the environment.
acute toxicity	The ability of a toxic substance to cause severe adverse effects or death soon after a single or short-term exposure or dose.
aerobic decomposition	Digestion of organic material in the wastewater in the presence of oxygen. Bacteria oxidize the organic material to treatable solids, water and carbon dioxide.
algae	Single celled aquatic plants.
ammonia	A chemical found in human or animal waste that can be very toxic to aquatic organisms.
anthropogenic	Modified by human activities.
aquifer	A layer of gravel or sand or porous, fractured or cavernous rock that contains groundwater.
bacteria	Single-celled organisms that live in the air, soil, water, animals and humans.
benthic invertebrates	Aimals lacking a backbone found at the bottom of a stream, including worms, snails, water mites, leeches, small crustaceans, and insect larvae. Benthic invertebrates are an important food source for fish. They play a major role in the decomposition of organic material, and affect nutrient availability.

GLOSSARY CONT.

bioavailable	A form of a nutrient or element essential for plant growth that is easily absorbed and used.
biomass	The total mass of living organisms that comprise an area or biological community.
biometric	A measurable attribute of the biological assemblage (such as taxa richness or percentage of dominant species) that changes in some predictable way with increased human influence.
biotic	The biological (animal and plant life) characteristics of an environment.
Blue List	As defined by the B.C. Government, any indigenous species, subspecies or community considered to be Vulnerable (Special Concern) in British Columbia, but not Extirpated, Endangered or Threatened. They have characteristics that make them particularly sensitive to human activities or natural events.
chronic toxicity	The capacity of a toxic substance to cause long-term adverse health effects.
community	A group of different species sharing the same habitat.
confluence	The area where a smaller tributary joins with a larger river.
dechlorination cell	The component of a sewage treatment plant that removes the chlorine from wastewater.
decomposition	The breakdown of matter by bacteria and/or fungi, changing their chemical and physical characteristics.

GLOSSARY CONT.

discharge	(1) The volume of liquid flowing through a cross section per unit of time. (2) The release of an effluent to the receiving environment.
disinfection	A chemical or physical process that kills pathogenic organisms. Chlorine is often used to disinfect sewage treatment effluent.
dissolved	Molecules found in the ionised form in water.
dissolved oxygen (DO)	Oxygen dissolved in the water. Oxygen is essential for most aquatic life forms and chemical reactions within streams such that minimum concentrations are necessary for a functioning system. Dissolved oxygen concentration is a function of the temperature of the water. With increasing temperature, the solubility of oxygen decreases. At the same time, the respiratory requirements of aquatic organisms increase with increasing temperature, but there is less oxygen in the water to meet these increased needs, and death or impairment can result.
diversity	The variety of organisms in an ecosystem or habitat.
ecological integrity	The quality of a natural, unmanaged or managed ecosystem in which the natural ecological processes are sustained, with genetic, species, and ecosystem diversity assured for the future.
effluent	Water that is released into a river from a domestic or industrial purpose after it has been treated and cleaned.
eutrophic	A waterbody high in nutrients and with high productivity, either the result of natural or anthropogenic stimulation.

GLOSSARY CONT.

faecal coliforms	Coliform bacteria originating from the intestinal tract of mammals.
flocculant	The addition of a chemical to generate the formation of clumps of solids so they can be separated from the sewage.
functional feeding group (FFG)	A classification system based on the feeding mode of benthic invertebrates.
guideline	A limit on the amount of a substance in the environment to prevent adverse effects.
headwaters	The origin of a river.
herbivory	The action of feeding on plant material.
ion	A molecule dissolved in water.
mainstem	The major channel of a river, into which tributaries flow..
morphology	The form and structure of an object or organism.
nitrate	A common form of nitrogen found in the water. Nitrate is a nutrient essential for plant growth.
nitrification	The process by which ammonia in wastewater is oxidized to nitrite and then to nitrate by bacterial or chemical reactions.
nitrite	A form of nitrogen found in the water, which is generally quickly converted to nitrate through oxidation.

GLOSSARY CONT.

non-point source	A diffuse pollution source (i.e. without a single point of origin or not introduced into a receiving stream from a specific outlet). The pollutants are generally carried off the land by storm water. Common non-point sources are agriculture, forestry, urban, mining, construction, dams, channels, land disposal and city streets.
nutrients	Nitrogen and phosphorus are the two most important nutrients required for plant growth. Various chemical forms of these nutrients exist in the water and some are more important than others in determining how much primary production or plant growth will occur. Nitrate and phosphate are the more readily available forms and are most commonly measured. These nutrient levels need to be high enough to support a healthy plant community, which provides the basis of the food chain. Excessive amounts of nutrients, however, can also cause problems. A high amount of plant growth eventually leads to a high amount of dead plant material. Oxygen, required to decompose the organic material, can be significantly depleted to a point where aquatic organisms die.
ortho-phosphate	The amount of phosphorus in the water that is found in the ionized form. This is the easiest form of the nutrient for plants to use.
oxidization	The chemical addition of oxygen to break down pollutants or organic waste in sewage by bacterial and chemical means.

GLOSSARY CONT.

parameter	A variable, measurable property whose value is a determinant of the characteristics of a system.
particulate	Tiny particles found suspended in the water.
pathogen	An organism that can induce disease.
periphyton	Algae that grows on rocks within a stream. Algae are the primary producers in the stream and form the basis of the aquatic food web, providing food for benthic invertebrates and fish.
pH	The concentration of hydrogen ions in the water. The pH of water indicates how basic or neutral it is. A pH of 7 is neutral, above 7 is basic and below 7 is acidic. The pH also influences the toxicity of metals, especially aluminum and iron. At more acidic pH levels, these metals are significantly more toxic.
phosphorus	A nutrient essential for plant growth that is also found in fertilizers and human and animal waste.
phytoplankton	The portion of the plankton community that is comprised of microscopic plants (algae and diatoms).
piscivorous	An organism that eats fish.
point source	A stationary location or fixed facility from which pollutants are discharged, including pipes or ditches.
pollution	The harmful release of a chemical, whether man-made or natural, to the environment above certain amounts.

GLOSSARY CONT.

primary production	The plant growth in a system that is used as a food source for herbivorous animals such as benthic invertebrates and fish.
riffle	A fast flowing area within a stream that experiences turbulent water.
riparian vegetation	Vegetation that grows on the banks of streams, providing stability to the streambank. Riparian plants are terrestrial, not aquatic, however, their leaf litter contributes to the organic matter content of the stream and is often a major source of food for aquatic organisms.
runoff	The movement of water over the surface of the earth.
secondary treatment	Biological degradation of organic material through aerobic means. Dissolved and suspended organic material is removed from the wastewater.
sensitive	The relative likelihood of an organism not being capable of surviving adverse environmental conditions.
significant	A statistically-derived effect.
taxon	A level of identification or classification of plants or animals such as family, order, genera or species. Taxa is the plural form.
tolerant	The relative ability of an organism to survive adverse environmental conditions.
total coliforms	Coliform bacteria from all sources, including soils and mammal wastes.

GLOSSARY CONT.

toxic	A substance, that in high amounts, is harmful to plants or animals.
tributary	A smaller creek that joins with a larger river; considered part of the same river system.
turbulent	Non-laminar flow in a stream that results in the agitation and oxygenation of water.
watershed	The area of land that drains water, organic matter, dissolved nutrients and sediment into a waterbody.

APPENDIX A BENTHIC INVERTEBRATE DATASHEETS

Table A1 Benthic Invertebrates at Beaver Creek at Columbia River Site

Site Name		Beaver Creek @ Columbia River											
Sample Date		September 23, 1999											
Replicate #		1	2	3	4	5							
Water Velocity (m/s)		4.38	3.3	3.11	4.00	2.62							
Water Depth (m)		0.33	0.31	0.21	0.18	0.15							
Taxon	**stage**	**total organisms / sample**					**Total**	**Avg**	**Max**	**Min**	**St. Dev.**	**FFG**	**Tolerance**
Order : Ephemeroptera	nymph	0	4	4	8	0	16	3.2	8	0	3.34664011	CG	UN
Family : Baetidae													
Baetis sp.	nymph	36	46	153	237	119	591	118.2	237	36	82.6056899	CG	5
Family : Ephemerellidae (D)	nymph	48	20	117	0	76	261	52.2	117	0	46.2190437	CG	1
Drunella doddsi	nymph	5	0	8	72	11	96	19.2	72	0	29.7942948	SC	0
Family : Heptageniidae (D)	nymph	0	0	84	88	68	240	48	88	0	44.4522215	SC	4
Cinygmula sp.	nymph	0	0	0	1	1	2	0.4	1	0	0.54772256	SC	4
Epeorus sp.	nymph	1	4	0	1	4	10	2	4	0	1.87082869	SC	0
Heptagenia sp.	nymph	0	0	2	0	1	3	0.6	2	0	0.89442719	Sc	4
Rhithrogena sp.	nymph	0	0	0	0	1	1	0.2	1	0	0.4472136	SC	0
Family : Leptophlebiidae													
Paraleptophlebia sp.	nymph	0	4	54	20	16	94	18.8	54	0	21.3354166	CG	1
Order : Plecoptera (D)	nymph	0	8	8	0	4	20	4	8	0	4	PR	UN
Family : Capniidae	nymph	0	8	45	81	33	167	33.4	81	0	32.253682	SH	1
Family : Chloroperlidae (D)	nymph	12	4	28	20	4	68	13.6	28	4	10.4307238	PR	1
Sweltsa sp.	nymph	4	1	7	24	3	39	7.8	24	1	9.31128348	PR	1
Family : Leuctridae	nymph	0	0	0	0	1	1	0.2	1	0	0.4472136	SH	0
Family : Taeniopterygidae													
Taenionema sp.	nymph	0	0	4	0	0	4	0.8	4	0	1.78885438	SC	2
Family : Nemouridae													
Zapada sp.	nymph	0	0	14	84	25	123	24.6	84	0	34.8252782	SH	2
Family : Perlidae													
Acroneuria sp.	nymph	0	0	0	1	1	2	0.4	1	0	0.54772256	PR	1
Classenia sp.	nymph	0	0	0	1	1	2	0.4	1	0	0.54772256	PR	3
Family : Perlodidae (D)													
Skwala sp.	nymph	2	1	1	11	5	20	4	11	1	4.24264069	PR	2
Family : Pteronarcydae													
Pteronarcys sp.	nymph	0	0	0	0	1	1	0.2	1	0	0.4472136	SH	0
Order : Trichoptera (D)	pupae	1	3	5	3	4	16	3.2	5	1	1.4832397		
Family : Brachycentridae	larvae	4	0	8	0	0	12	2.4	8	0	3.57770876	CF	1
Family : Glossosomatidae	pupae	3	21	13	31	2	70	14	31	2	12.2882057		
Glossosoma sp.	larvae	0	1	0	1	0	2	0.4	1	0	0.54772256	SC	0
Family : Hydropsychidae (D)	larvae	542	337	329	1166	156	2530	506	1166	156	393.473633	CF	4
Hydropsyche sp.	larvae	126	103	114	387	41	771	154.2	387	41	134.203949	CF	4
Parapsyche sp.	larvae	1	0	2	7	1	11	2.2	7	0	2.77488739	PR	1
Lepidostomatidae													
Lepidostoma sp.	larvae	12	16	46	84	8	166	33.2	84	8	32.1123029	SH	1
Family : Rhyacophilidae	pupae	0	0	0	0	1	1	0.2	1	0	0.4472136		
Rhyacophila sp.	larvae	3	0	9	6	0	18	3.6	9	0	3.91152144	PR	0
Order : Diptera													
Family : Ceratopogonidae													
Probezzia sp.	larvae	1	1	0	0	0	2	0.4	1	0	0.54772256	PR	6
Family : Chironomidae	pupae	16	17	49	67	44	193	38.6	67	16	21.9157478		
Sub-family : Chironominae													
Tribe : Chironomini													
Polypedilum sp.	larvae	84	128	289	419	205	1125	225	419	84	133.624474	SH	6
Sub-family : Diamesinae	larvae	1	0	6	0	4	11	2.2	6	0	2.68328157	CG	1
Sub-family : Orthocladiinae	larvae	93	144	410	295	249	1191	238.2	410	93	125.314405	CG	6
Cricotopus/Orthocladius sp.	larvae	430	567	1578	495	589	3659	731.8	1578	430	477.169467	SH	7
Lopescladius sp.	larvae	40	140	140	260	0	580	116	260	0	101.390335	CG	6

Table A1 Benthic Invertebrates at Beaver Creek at Columbia River Site Cont.

Sub-family : Tanypodinae (D)													
Theinemannimyia sp.	larvae	0	8	17	4	4	33	6.6	17	0	6.46529195	PR	6
Sub-family : Tanytarsini (D)	larvae	44	72	76	342	123	657	131.4	342	44	121.098307	CF	6
Family : Empidiae													
Chelifera sp.	larvae	4	16	8	8	4	40	8	16	4	4.89897949	CG	6
Wiedemannia sp.	larvae	4	0	8	4	0	16	3.2	8	0	3.34664011	PR	6
Family : Simuliidae	larvae	0	0	0	28	4	32	6.4	28	0	12.1983605	CF	6
Simulium sp.	larvae	0	0	0	6	8	14	2.8	8	0	3.89871774	CF	6
Family : Tipulidae (D)	larvae	4	0	4	0	0	8	1.6	4	0	2.19089023	SH	3
Antocha sp.	larvae	16	12	47	13	24	112	22.4	47	12	14.5361618	CG	3
Dicranota sp.	larvae	1	4	12	0	0	17	3.4	12	0	5.07937004	PR	3
Hexatoma sp.	larvae	0	2	0	8	0	10	2	8	0	3.46410162	PR	2
Order : Coleoptera													
Family : Elmidae	adult	0	1	7	8	0	16	3.2	8	0	3.96232255	SC	4
Family : Elmidae (D)	larvae	56	88	216	156	96	612	122.4	216	56	63.5987421	CG	4
Heterlimnius sp.	larvae	0	4	1	0	0	5	1	4	0	1.73205081	CG	4
Optioservus sp.	larvae	66	81	152	141	150	590	118	152	66	41.1764496	SC	4
Zaitzevia sp.	larvae	17	4	13	32	8	74	14.8	32	4	10.8027774	CG	4
Class : Crustacea													
Sub-class : Copepoda		0	0	0	0	8	8	1.6	8	0	3.57770876	CG	8
Sub-class : Ostracoda		40	0	4	12	12	68	13.6	40	0	15.6460858	CG	8
Class : Arachnida													
Group : Hydracarina		126	60	276	372	225	1059	211.8	372	60	122.846245	PR	8
Phylum : Annelida													
Class : Oligochaeta													
Family : Enchytraeidae		0	24	12	120	42	198	39.6	120	0	47.5478706	CG	10
Family : Lumbriculidae		0	0	1	2	0	3	0.6	2	0	0.89442719	CG	8
Family : Naididae		52	44	141	229	170	636	127.2	229	44	78.9981012	CG	10
Phylum : Nematoda		16	8	30	31	22	107	21.4	31	8	9.68504001	PA	5
Phylum : Platyhelminthes													
Class : Turbellaria													
Polycelis coronata		0	0	4	0	0	4	0.8	4	0	1.78885438	CG	1
Total number of invertebrates found		1,935	2,022	4,568	5,394	2,583	16,502	3,300	5,394	1,935	1581.39631		
Density of invertebrates (#/m^2)		21,500	22,467	50,756	59,933	28,700	36,671	36,671	59,933	21,500	17571.0701		

D = extremely small or damaged individuals

Table A1 Benthic Invertebrates at Beaver Creek at Columbia River Site Cont.

Functional Feeding Group Analysis										
By Total Numbers	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	154	89	368	458	248	1317	263.4	458	89	151.187962
Shredders	530	719	1976	1163	862	5250	1050	1976	530	566.910487
Collector-Gatherers	427	566	1343	1400	832	4568	913.6	1400	427	443.066925
Collector-Filterers	716	512	527	1929	332	4016	803.2	1929	332	643.844469
Scrapers	72	87	257	312	236	964	192.8	312	72	107.218002
Parasite	16	8	30	31	22	107	21.4	31	8	9.68504001
Unknown	0	0	0	0	0	0	0	0	0	0
Total	1915	1981	4501	5293	2532	16222				
By Percentages	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	8.04	4.49	8.18	8.65	9.79	8.1181	7.83	9.79	4.49	1.98897274
Shredders	27.68	36.29	43.90	21.97	34.03	32.361	32.78	43.90	21.97	8.37339475
Collector-Gatherers	22.30	28.57	29.84	26.45	32.85	28.158	28.00	32.85	22.30	3.94053139
Collector-Filterers	37.39	25.85	11.71	36.44	13.11	24.755	24.90	37.39	11.71	12.2803992
Scrapers	3.76	4.39	5.71	5.89	9.32	5.9422	5.81	9.32	3.76	2.15238864
Parasite	0.8355	0.4038	0.666519	0.5857	0.8685	0.6596	0.67	0.87	0.40	0.19023301
Unknown	0	0	0	0.00	0	0	0.00	0.00	0.00	0
Total	100	100	100	100	100	100				

Biostatistical Metrics	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Total No. of Taxa	34	36	46	44	44	60	40.80	46.00	34.00	5.40370243
No. EPT Taxa	14	15	21	21	24	29	19.00	24.00	14.00	4.30116263
EPT/Total Taxa	41.18	41.67	45.65	47.73	54.55	48.33	46.15	54.55	41.18	5.43266704
EPT/EPT+Chironomid Ratio	52.22	34.73	29.05	55.26	32.49	41.628	40.75	55.26	29.05	12.0775269
% Dominant Taxa	28.01	28.04	34.54	21.62	22.80	22.173	27.00	34.54	21.62	5.13866666
SC / (SC+CF) Ratio	9.14	14.52	32.78	13.92	41.55	19.36	22.383	41.549	9.1371	14.0022801
(SC+CF) / (SH+CG) Ratio	82.34	46.61	23.62	87.44	33.53	50.72	54.709	87.437	23.622	28.7884247
% Ephemeroptera	4.65	3.86	9.24	7.92	11.50	7.9627	7.43	11.50	3.86	3.18358347
% Plecoptera	0.93	1.09	2.34	4.12	3.02	2.7088	2.30	4.12	0.93	1.33806428
% Trichoptera	35.76	23.79	11.51	31.24	8.25	21.797	22.11	35.76	8.25	12.0103079
% Diptera	39.38	55.74	58.14	36.28	48.86	47.049	47.68	58.14	36.28	9.67750852
% Other Orders	19.28	15.53	18.76	20.45	28.38	20.482	20.48	28.38	15.53	4.77732438
Hilsenhoff Biotic Index	5.30	5.50	5.63	5.20	5.76	5.4537	5.48	5.76	5.20	0.23042067

Biometric (based on average data)	**No Impact**	**Slight Impact**	**Mod. Impact**	**Severe Impact**
Total No. Taxa	X			
No. EPT Taxa	X			
EPT/Total Taxa	X			
EPT/EPT+Chironomid Ratio			X	
% Dominant Taxa		X		
HBI		X		

Table A2 Benthic Invertebrates at Beaver Creek d/s Fruitvale Site

Site Name		**Beaver Creek d/s Fruitvale**											
Sample Date		September 23, 1999											
Replicate #		1	2	3	4	5							
Water Velocity (m/s)		4.94	3.16	2.94	2.7	3.41							
Water Depth (m)		0.27	0.35	0.34	0.29	0.32							
Taxon	**stage**	**total organisms / sample**					**Total**	**Avg**	**Max**	**Min**	**St. Dev.**	**FFG**	**Tolerance**
Order : Ephemeroptera	nymph	0	0	12	0	0	12	2.4	12	0	5.366563	CG	UN
Family : Ameletidae													
Ameletus sp.	nymph	2	0	0	0	0	2	0.4	2	0	0.894427	CG	0
Family : Baetidae													
Baetis sp.	nymph	220	411	228	581	489	1929	385.8	581	220	159.5139	CG	5
Family : Ephemerellidae (D)	nymph	604	528	489	884	748	3253	650.6	884	489	163.7675	CG	1
Seratella sp.	nymph	7	2	2	5	2	18	3.6	7	2	2.302173	CG	2
Family : Heptageniidae	nymph	296	432	356	520	356	1960	392	520	296	86.3018	SC	4
Cinygmula sp.	nymph	3	2	1	1	0	7	1.4	3	0	1.140175	SC	4
Family : Leptophlebiidae													
Paraleptophlebia sp.	nymph	79	65	62	112	133	451	90.2	133	62	31.07571	CG	1
Order : Plecoptera	nymph	0	1	0	0	0	1	0.2	1	0	0.447214	PR	UN
Family : Capniidae	nymph	36	21	28	44	56	185	37	56	21	13.67479	SH	1
Family : Chloroperlidae	nymph	16	20	4	8	20	68	13.6	20	4	7.266361	PR	1
Sweltsa sp.	nymph	5	1	6	5	10	27	5.4	10	1	3.209361	PR	1
Family : Nemouridae													
Zapada sp.	nymph	0	0	1	8	8	17	3.4	8	0	4.219005	SH	2
Family : Perlidae	nymph	1	0	0	0	0	1	0.2	1	0	0.447214	PR	1
Claassenia sp.	nymph	2	0	0	0	0	2	0.4	2	0	0.894427	PR	3
Family : Perlodidae													
Skwala sp.	nymph	7	3	4	5	6	25	5	7	3	1.581139	PR	2
Order : Trichoptera	pupae	0	3	0	0	0	3	0.6	3	0	1.341641		
Family : Glossosomatidae	pupae	9	3	3	3	6	24	4.8	9	3	2.683282		
Glossosoma sp.	larvae	10	5	20	28	39	102	20.4	39	5	13.68576	SC	0
Family : Hydropsychidae	larvae	56	24	46	117	133	376	75.2	133	24	47.25146	CF	4
Hydropsyche sp.	larvae	46	39	61	119	40	305	61	119	39	33.59315	CF	4
Parapsyche sp.	larvae	7	1	2	1	0	11	2.2	7	0	2.774887	PR	1
Family : Lepidostomatidae													
Lepidostoma sp.	larvae	135	72	80	165	267	719	143.8	267	72	78.94745	SH	1
Family : Limnephilidae	larvae	3	3	0	0	0	6	1.2	3	0	1.643168	SH	4
Family : Rhyacophilidae													
Rhyacophila sp.	larvae	29	25	41	46	27	168	33.6	46	25	9.316652	PR	0
Order : Diptera													
Family : Athericidae	larvae	0	0	2	6	0	8	1.6	6	0	2.607681	UN	UN
Atherix sp.	larvae	0	0	1	0	0	1	0.2	1	0	0.447214	PR	2
Family : Ceratopogonidae	larvae	8	4	0	4	4	20	4	8	0	2.828427	PR	6
Probezzia sp.	larvae	0	0	1	1	1	3	0.6	1	0	0.547723	PR	6
Family : Chironomidae	pupae	21	32	44	61	41	199	39.8	61	21	14.85598	CG	6
Sub-family : Chironominae													
Tribe : Chironomini	larvae	0	5	4	0	4	13	2.6	5	0	2.408319	UN	UN
Polypedilum sp.	larvae	8	8	4	20	16	56	11.2	20	4	6.572671	SH	6
Sub-family : Diamesinae													
Pagastia sp.	larvae	0	0	0	0	1	1	0.2	1	0	0.447214	CG	1
Sub-family : Orthocladiinae	larvae	56	81	33	134	83	387	77.4	134	33	37.6736	CG	UN
Cricotopus/Orthocladius sp.	larvae	18	78	161	36	56	349	69.8	161	18	55.67944	SH	7
Lopescladius sp.	larvae	44	52	60	316	100	572	114.4	316	44	114.738	CG	6
Thienemanniella sp.	larvae	48	68	12	68	48	244	48.8	68	12	22.87357	CG	6
Sub-family : Tanypodinae (D)	larvae	0	0	0	4	0	4	0.8	4	0	1.788854	UN	UN
Theinemannimyia sp.	larvae	33	29	29	39	32	162	32.4	39	29	4.09878	PR	6
Sub-family : Tanytarsini (D)	larvae	184	239	244	528	344	1539	307.8	528	184	135.9493	CF	6
Family : Empidiae													

Table A2 Benthic Invertebrates at Beaver Creek d/s Fruitvale Site Cont.

Family : Psychodidae													
Pericoma sp.	larvae	0	1	0	8	4	13	2.6	8	0	3.435113	CG	4
Family : Simuliidae	pupae	0	0	1	0	0	1	0.2	1	0	0.447214		
Family : Tipulidae	larvae	0	4	0	0	0	4	0.8	4	0	1.788854	SH	3
Antocha sp.	larvae	12	9	38	12	41	112	22.4	41	9	15.69395	CG	3
Dicranota sp.	larvae	0	0	0	4	0	4	0.8	4	0	1.788854	PR	3
Hexatoma sp.	larvae	0	1	1	0	4	6	1.2	4	0	1.643168	PR	2
Order : Coleoptera													
Family : Elmidae	adult	17	9	10	15	8	59	11.8	17	8	3.962323	SC	4
Family : Elmidae	larvae	124	264	184	256	312	1140	228	312	124	73.97297	CG	4
Heterlimnius sp.	larvae	6	13	21	26	5	71	14.2	26	5	9.20326	CG	4
Optioservus sp.	larvae	213	185	119	120	221	858	171.6	221	119	49.40445	SC	4
Zaitzevia sp.	larvae	4	2	0	0	0	6	1.2	4	0	1.788854	CG	4
Order : Collembola		0	0	0	4	0	4	0.8	4	0	1.788854	CG	10
Class : Crustacea													
Sub-class : Copepoda		0	12	4	8	0	24	4.8	12	0	5.215362	CG	8
Sub-class : Ostracoda		157	164	112	292	164	889	177.8	292	112	67.42551	CG	8
Order : Gastropoda													
Family : Hydrobiidae		0	0	0	4	0	4	0.8	4	0	1.788854	SC	10
Family : Planorbidae		0	1	0	0	0	1	0.2	1	0	0.447214	SC	7
Family : Physidae													
Physa sp.		0	0	1	0	0	1	0.2	1	0	0.447214	SC	8
Class : Arachnida													
Group : Hydracarina		108	164	221	200	180	873	174.6	221	108	42.93949	PR	8
Phylum : Annelida													
Class : Oligochaeta													
Family : Enchytraeidae		26	4	65	516	68	679	135.8	516	4	214.2363	CG	10
Family : Lumbriculidae		1	4	1	6	3	15	3	6	1	2.12132	CG	8
Family : Naididae		8	28	28	60	36	160	32	60	8	18.76166	CG	10
Phylum : Nematoda		12	17	29	7	12	77	15.4	29	7	8.38451	PA	5
Phylum : Platyhelminthes													
Class : Turbellaria													
Polycelis coronata		6	2	1	11	4	24	4.8	11	1	3.962323	CG	1
Phylum : Cnidaria													
Hydra sp.		0	5	8	0	4	17	3.4	8	0	3.435113	PR	5
Total number of invertebrates found		2,707	3,170	2,902	5,446	4,172	18,397	3,679	5,446	2,707	1137.204		
Density of invertebrates (#/m^2)		30,078	35,222	32,244	60,511	46,356	40,882	40,882	60,511	30,078	12635.6		

D = extremely small or damaged individuals

Table A2 Benthic Invertebrates at Beaver Creek d/s Fruitvale Site Cont.

Functional Feeding Group Analysis										
By Total Numbers	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	236	278	335	341	324	1514	302.8	341	236	44.78504
Shredders	200	186	274	273	403	1336	267.2	403	186	86.068
Collector-Gatherers	1425	1742	1396	3360	2282	10205	2041	3360	1396	818.9512
Collector-Filterers	286	302	351	764	517	2220	444	764	286	200.939
Scrapers	539	634	507	688	624	2992	598.4	688	507	73.88031
Parasite	12	17	29	7	12	77	15.4	29	7	8.38451
Unknown	0	5	6	10	4	25	5	10	0	3.605551
Total	2698	3164	2898	5443	4166	18369				
By Percentages	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	8.75	8.79	11.56	6.26	7.78	8.24	8.63	11.56	6.26	1.932746
Shredders	7.41	5.88	9.45	5.02	9.67	7.27	7.49	9.67	5.02	2.082863
Collector-Gatherers	52.82	55.06	48.17	61.73	54.78	55.56	54.51	61.73	48.17	4.887632
Collector-Filterers	10.60	9.54	12.11	14.04	12.41	12.09	11.74	14.04	9.54	1.730433
Scrapers	19.98	20.04	17.49	12.64	14.98	16.29	17.03	20.04	12.64	3.218435
Parasite	0.4448	0.5373	1.0007	0.1286	0.288	0.42	0.48	1.00	0.2212	0.330139
Unknown	0	0.158	0.207	0.18	0.096	0.14	0.13	0.21	0	0.083151
Total	100	100	100	100	100	100				

Biostatistical Metrics	1	2	3	4	5	Total	Avg	Max	Min	St. Dev.
Total No. of Taxa	44	50	49	48	44	65	47.00	50.00	44.00	2.828427
No. EPT Taxa	21	20	19	18	16	25	18.80	21.00	16.00	1.923538
EPT/Total Taxa	47.73	40.00	38.78	37.50	36.36	38.46	40.07	47.73	36.36	4.490446
EPT/EPT+Chironomid Ratio	79.24	73.72	70.99	68.74	76.35	73.28	73.81	79.24	68.74	4.172609
% Dominant Taxa	22.31	16.66	16.85	16.23	17.93	17.68	18.00	22.31	16.23	2.492774
SC / (SC+CF) Ratio	65.33	67.74	59.09	47.38	54.69	57.41	58.846	67.735	47.383	8.213472
(SC+CF) / (SH+CG) Ratio	50.77	48.55	51.38	39.97	42.50	45.16	46.631	51.377	39.967	5.119535
% Ephemeroptera	44.74	45.43	39.63	38.62	41.42	41.49	41.96	45.43	38.62	3.02634
% Plecoptera	2.48	1.45	1.48	1.29	2.40	1.77	1.82	2.48	1.29	0.569715
% Trichoptera	10.90	5.52	8.72	8.80	12.27	9.32	9.24	12.27	5.52	2.561606
% Diptera	16.70	20.03	22.47	23.30	19.53	20.78	20.41	23.30	16.70	2.61175
% Other Orders	25.19	27.57	27.71	28.00	24.38	26.65	26.57	28.00	24.38	1.661711
Hilsenhoff Biotic Index	3.69	4.16	4.33	4.68	3.88	4.21	4.15	4.68	3.69	0.388817

Biometric (based on average data)	**No Impact**	**Slight Impact**	**Mod. Impact**	**Severe Impact**
Total No. Taxa	X			
No. EPT Taxa	X			
EPT/Total Taxa	X			
EPT/EPT+Chironomid Ratio		X		
% Dominant Taxa	X			
HBI		X		

Table A3 Benthic Invertebrates at Beaver Creek u/s STP Outfall Site

Site Name		**Beaver Creek u/s STP Outfall**											
Sample Date		September 23, 1999											
Replicate #		1	2	3	4	5							
Water Velocity (m/s)		3.08	4.77	5.13	4.83	5.03							
Water Depth (m)		0.16	0.13	0.16	0.21	0.21							
Taxon	**stage**	**total organisms / sample**					**Total**	**Avg**	**Max**	**Min**	**St. Dev.**	**FFG**	**Tolerance**
Order : Ephemeroptera (D)	nymph	0	56	24	56	112	248	49.6	112	0	42.1046	CG	UN
Family : Baetidae													
Baetis sp.	nymph	495	579	485	224	695	2478	495.6	695	224	173.634	CG	5
Family : Ephemerellidae (D)	nymph	40	32	65	40	72	249	49.8	72	32	17.5556	CG	1
Attenella sp.	nymph	0	0	4	1	27	32	6.4	27	0	11.6319	CG	3
Drunella grandis	nymph	1	0	0	0	0	1	0.2	1	0	0.44721	CG	1
Seratella sp.	nymph	176	233	124	141	129	803	160.6	233	124	45.2802	CG	2
Family : Heptageniidae (D)	nymph	452	616	568	496	296	2428	485.6	616	296	123.47	SC	4
Heptagenia sp.	nymph	1	2	0	2	3	8	1.6	3	0	1.14018	SC	4
Family : Leptophlebiidae													
Paraleptophlebia sp.	nymph	193	220	248	200	1034	1895	379	1034	193	366.778	CG	1
Order : Plecoptera (D)	nymph	4	0	0	0	0	4	0.8	4	0	1.78885	PR	UN
Family : Capniidae	nymph	12	8	33	10	24	87	17.4	33	8	10.7145	SH	1
Family : Chloroperlidae													
Sweltsa sp.	nymph	0	1	5	2	1	9	1.8	5	0	1.92354	PR	1
Family : Nemouridae													
Zapada sp.	nymph	10	16	17	16	19	78	15.6	19	10	3.36155	SH	2
Family : Perlodidae													
Skwala sp.	nymph	8	9	8	17	12	54	10.8	17	8	3.83406	PR	2
Family : Pteronarcydae													
Pteronarcys sp.	nymph	0	1	0	1	4	6	1.2	4	0	1.64317	SH	0
Order : Trichoptera													
Family : Glossosomatidae	pupae	0	0	1	0	0	1	0.2	1	0	0.44721		
Glossosoma sp.	larvae	0	0	0	0	9	9	1.8	9	0	4.02492	SC	0
Family : Hydropsychidae (D)	larvae	105	88	0	71	336	600	120	336	0	127.187	CF	4
Hydropsyche sp.	larvae	103	77	91	23	193	487	97.4	193	23	61.5695	CF	4
Parapsyche sp.	larvae	1	0	1	0	2	4	0.8	2	0	0.83666	PR	1
Family : Hydroptilidae													
Ochrotrichia sp.	larvae	0	0	0	8	0	8	1.6	8	0	3.57771	PR/C(	4
Family : Lepidostomatidae													
Lepidostoma sp.	larvae	114	65	57	73	104	413	82.6	114	57	25.006	SH	1
Family : Rhyacophilidae	pupae	0	0	0	0	4	4	0.8	4	0	1.78885		
Rhyacophila sp.	larvae	13	27	8	11	33	92	18.4	33	8	10.9453	PR	0
Order : Diptera													
Family : Athericidae													
Atherix sp.	larvae	3	6	3	5	10	27	5.4	10	3	2.88097	PR	2
Family : Ceratopogonidae (D)	larvae	4	0	0	0	8	12	2.4	8	0	3.57771	PR	6
Probezzia sp.	larvae	1	1	1	1	0	4	0.8	1	0	0.44721	PR	6
Family : Chironomidae	pupae	70	100	105	109	120	504	100.8	120	70	18.727		
Sub-family : Chironominae													
Tribe : Chironomini	larvae	0	0	0	2	0	2	0.4	2	0	0.89443	UN	6
Polypedilum sp.	larvae	12	16	16	32	48	124	24.8	48	12	15.0732	SH	6
Sub-family : Diamesinae	larvae	3	0	10	5	0	18	3.6	10	0	4.15933	CG	1
Sub-family : Orthocladiinae	larvae	152	306	320	228	209	1215	243	320	152	69.9285	CG	6
Cricotopus/Orthocladius sp.	larvae	1729	1312	1339	1493	1127	7000	1400	1729	1127	225.213	SH	7
Lopescladius sp.	larvae	84	16	8	8	8	124	24.8	84	8	33.2746	CG	6
Thienemanniella sp.	larvae	32	72	56	56	112	328	65.6	112	32	29.6108	CG	6
Sub-family : Tanypodinae													
Procladius sp.	larvae	0	0	8	0	0	8	1.6	8	0	3.57771	PR	9
Theinemannimyia sp.	larvae	190	227	138	315	107	977	195.4	315	107	81.3038	PR	6
Sub-family : Tanytarsini	larvae	341	442	273	677	562	2295	459	677	273	163.51	CF	6

Table A3 Benthic Invertebrates at Beaver Creek u/s STP Outfall Site Cont.

Family : Pelecorhynchidae	pupae	0	1	0	0	0	1	0.2	1	0	0.44721		
Glutops sp.	larvae	1	16	0	0	0	17	3.4	16	0	7.05691	PR	3
Family : Psychodidae													
Pericoma sp.	larvae	0	0	0	2	0	2	0.4	2	0	0.89443	CG	4
Family : Simuliidae	pupae	2	1	0	0	1	4	0.8	2	0	0.83666		
Family : Simuliidae (D)	larvae	0	8	0	0	8	16	3.2	8	0	4.38178	CF	6
Family : Tipulidae													
Sub-family : Limoniinae (D)	larvae	0	8	0	0	0	8	1.6	8	0	3.57771	UN	UN
Antocha sp.	larvae	24	36	47	4	65	176	35.2	65	4	23.0586	CG	3
Dicranota sp.	larvae	1	0	0	0	0	1	0.2	1	0	0.44721	PR	3
Hexatoma sp.	larvae	1	1	2	1	0	5	1	2	0	0.70711	PR	2
Order : Coleoptera													
Family : Elmidae	adult	7	8	4	9	8	36	7.2	9	4	1.92354	SC	4
Family : Elmidae (D)	larvae	208	440	296	408	376	1728	345.6	440	208	93.7059	CG	4
Heterlimnius sp.	larvae	1	0	2	2	0	5	1	2	0	1	CG	4
Lara sp.	larvae	1	0	0	0	0	1	0.2	1	0	0.44721	SH	4
Narpus sp.	larvae	0	0	0	0	1	1	0.2	1	0	0.44721	CG	4
Optioservus sp.	larvae	169	195	179	215	210	968	193.6	215	169	19.6672	SC	4
Zaitzevia sp.	larvae	7	11	11	35	16	80	16	35	7	11.0905	CG	4
Family : Dytiscidae													
Hydrovatus sp.	larvae	1	0	0	0	0	1	0.2	1	0	0.44721	PR	5
Order : Pelecypoda													
Family : Sphaeriidae													
Pisidium sp.		0	1	2	0	0	3	0.6	2	0	0.89443	CF	8
Order : Gastropoda													
Family : Hydrobiidae		0	0	0	0	1	1	0.2	1	0	0.44721	SC	10
Family : Planorbidae		1	0	1	10	0	12	2.4	10	0	4.27785	SC	7
Family : Physidae													
Physa sp.		0	0	0	1	1	2	0.4	1	0	0.54772	SC	8
Class : Crustacea													
Sub-class : Copepoda		0	16	24	8	0	48	9.6	24	0	10.4307	CG	8
Class : Arachnida													
Group : Hydracarina		516	474	416	545	411	2362	472.4	545	411	59.4247	PR	8
Phylum : Annelida													
Class : Oligochaeta													
Family : Enchytraeidae		17	246	208	163	66	700	140	246	17	96.1691	CG	10
Family : Lumbriculidae		0	0	0	1	0	1	0.2	1	0	0.44721	CG	8
Family : Naididae		9	336	440	420	184	1389	277.8	440	9	180.948	CG	10
Phylum : Nematoda		94	138	74	65	81	452	90.4	138	65	28.6409	PA	5
Phylum : Platyhelminthes													
Class : Turbellaria													
Polycelis coronata		1	7	0	1	9	18	3.6	9	0	4.09878	CG	1
Phylum : Cnidaria													
Hydra sp.		0	8	8	16	8	40	8	16	0	5.65685	PR	5
Total number of invertebrates found		5,418	6,495	5,746	6,229	6,866	30,754	6,151	6,866	5,418	578.135		
Density of invertebrates (#/m^2)		60,178	72,333	63,578	68,589	75,844	68,104	68,104	75,844	60,178	6351.15		

D = extremely small or damaged individuals

Table A3 Benthic Invertebrates at Beaver Creek u/s STP Outfall Site Cont.

Functional Feeding Group Analysis										
By Total Numbers	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	748	786	606	917	592	3649	729.8	917	592	134.953
Shredders	1878	1418	1462	1625	1326	7709	1541.8	1878	1326	216.92
Collector-Gatherers	1447	2606	2380	2007	3115	11555	2311	3115	1447	627.916
Collector-Filterers	549	616	366	771	1099	3671	680.2	1099	366	275.543
Scrapers	630	821	752	733	528	3464	692.8	821	528	114.738
Parasite	94	138	74	65	81	452	90.4	138	65	28.6409
Unknown	0	8	0	2	0	10	2	8	0	3.4641
Total	5346	6393	5640	6120	6741	30510				
By Percentages	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	13.99	12.29	10.74	14.98	8.78	12.067	12.159	14.984	8.7821	2.48797
Shredders	35.11	21.43	24.91	25.77	18.13	24.64	25.069	35.11	18.128	6.37899
Collector-Gatherers	27.07	40.76	42.20	32.79	46.21	38.211	37.807	46.21	27.067	7.73158
Collector-Filterers	10.29	10.39	7.50	13.38	17.85	12.1	11.881	17.846	7.5	3.93065
Scrapers	11.78	12.84	13.33	11.98	7.83	11.455	11.554	13.333	7.8327	2.17405
Parasite	1.75832	2.1586	1.3121	1.0621	1.2016	1.4947	1.4985	2.1586	1.0621	0.45183
Unknown	0	0.1251	0	0.03	0	0.0331	0.0316	0.1251	0	0.05419
Total	100	100	100	100	100	100				

Biostatistical Metrics	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Total No. of Taxa	49	47	45	49	46	70	47.2	49	45	1.78885
No. EPT Taxa	17	17	16	19	20	25	17.8	20	16	1.64317
EPT/Total Taxa	34.69	36.17	35.56	38.78	43.48	35.71	37.735	43.478	34.694	3.55368
EPT/EPT+Chironomid Ratio	39.81	44.90	43.34	32.24	57.55	44.253	43.57	57.553	32.245	9.21642
% Dominant Taxa	31.91	20.20	23.30	23.97	16.41	22.761	23.16	31.912	16.414	5.73456
SC / (SC+CF) Ratio	53.44	57.13	67.26	48.74	32.45	48.55	51.804	67.263	32.452	12.786
(SC+CF) / (SH+CG) Ratio	35.46	35.71	29.10	41.41	36.64	37.04	35.663	41.41	29.099	4.3902
% Ephemeroptera	25.06	26.76	26.42	18.62	34.49	26.475	26.271	34.489	18.623	5.65123
% Plecoptera	0.63	0.54	1.10	0.74	0.87	0.7739	0.775	1.0964	0.5389	0.21904
% Trichoptera	6.20	3.96	2.75	2.99	9.92	5.2611	5.1625	9.9184	2.7497	2.98791
% Diptera	49.06	39.80	40.76	47.17	34.74	41.972	42.304	49.059	34.736	5.81371
% Other Orders	19.05	28.95	28.98	30.49	19.98	25.519	25.488	30.486	19.048	5.49766
Hilsenhoff Biotic Index	5.44	5.53	5.70	5.78	4.60	5.39	5.4112	5.7826	4.6031	0.47182

Biometric (based on average data)	**No Impact**	**Slight Impact**	**Mod. Impact**	**Severe Impact**
Total No. Taxa	X			
No. EPT Taxa	X			
EPT/Total Taxa		X		
EPT/EPT+Chironomid Ratio			X	
% Dominant Taxa		X		
HBI		X		

Table A4 Benthic Invertebrates at Beaver Creek u/s Fruitvale Site

Site Name		**Beaver Creek u/s Fruitvale**											
Sample Date		September 23, 1999											
Replicate #		1	2	3	4	5							
Water Velocity (m/s)		5.94	6.39	6.78	5.22	5.91							
Water Depth (m)		0.29	0.27	0.28	0.27	0.31							
Taxon	**stage**	**total organisms / sample**					**Total**	**Avg**	**Max**	**Min**	**St. Dev.**	**FFG**	**Tolerance**
Order : Ephemeroptera	nymph	20	0	28	0	0	48	9.6	28	0	13.4462	CG	UN
Family : Baetidae													
Acentrella sp.	nymph	5	3	6	0	8	22	4.4	8	0	3.04959	CG	4
Baetis sp.	nymph	620	719	786	245	583	2953	590.6	786	245	209.182	CG	5
Family : Ephemerellidae (D)	nymph	444	448	284	208	300	1684	336.8	448	208	105.58	CG	1
Drunella grandis	nymph	0	0	2	0	0	2	0.4	2	0	0.89443	CG	1
Seratella sp.	nymph	16	24	14	19	22	95	19	24	14	4.12311	CG	2
Family : Heptageniidae (D)	nymph	364	612	753	552	856	3137	627.4	856	364	189.298	SC	4
Family : Leptophlebiidae													
Paraleptophlebia sp.	nymph	246	356	454	304	454	1814	362.8	454	246	91.8978	CG	1
Order : Plecoptera													
Family : Capniidae	nymph	40	57	1	28	28	154	30.8	57	1	20.4622	SH	1
Family : Chloroperlidae	nymph	0	8	0	0	12	20	4	12	0	5.65685	PR	1
Sweltsa sp.	nymph	9	2	3	3	4	21	4.2	9	2	2.77489	PR	1
Family : Nemouridae													
Zapada sp.	nymph	0	1	0	0	1	2	0.4	1	0	0.54772	SH	2
Family : Perlidae													
Claassenia sp.	nymph	0	2	0	0	0	2	0.4	2	0	0.89443	PR	3
Family : Perlodidae													
Skwala sp.	nymph	4	8	7	10	7	36	7.2	10	4	2.16795	PR	2
Family : Pteronarcydae													
Pteronarcys sp.	nymph	2	3	10	0	3	18	3.6	10	0	3.78153	SH	0
Order : Trichoptera													
Family : Glossosomatidae	pupae	1	1	3	0	0	5	1	3	0	1.22474		
Glossosoma sp.	larvae	2	0	5	1	2	10	2	5	0	1.87083	SC	0
Family : Hydropsychidae	larvae	84	132	180	16	80	492	98.4	180	16	61.4882	CF	4
Hydropsyche sp.	larvae	114	169	248	24	75	630	126	248	24	86.4321	CF	4
Parapsyche sp.	larvae	4	6	9	0	3	22	4.4	9	0	3.36155	PR	1
Family : Lepidostomatidae													
Lepidostoma sp.	larvae	108	12	40	52	64	276	55.2	108	12	35.259	SH	1
Family : Rhyacophilidae													
Rhyacophila sp.	larvae	16	18	18	9	15	76	15.2	18	9	3.70135	PR	0
Order : Diptera													
Family : Athericidae	pupae	3	1	0	0	2	6	1.2	3	0	1.30384		
Atherix sp.	larvae	4	3	5	1	1	14	2.8	5	1	1.78885	PR	2
Family : Ceratopogonidae													
Probezzia sp.	larvae	0	1	0	0	0	1	0.2	1	0	0.44721	PR	6
Family : Chironomidae	pupae	20	16	16	4	20	76	15.2	20	4	6.57267	CG	6
Sub-family : Chironominae													
Tribe : Chironomini													
Polypedilum sp.	larvae	28	4	0	8	0	40	8	28	0	11.6619	SH	6
Sub-family : Orthocladiinae	larvae	68	77	97	108	41	391	78.2	108	41	26.1285	CG	UN
Cricotopus/Orthocladius sp.	larvae	24	20	8	76	21	149	29.8	76	8	26.5368	SH	7
Lopescladius sp.	larvae	148	625	116	228	172	1289	257.8	625	116	209.314	CG	6
Thienemanniella sp.	larvae	44	40	28	32	41	185	37	44	28	6.7082	CG	6
Sub-family : Tanypodinae (D)													
Theinemannimyia sp.	larvae	4	8	13	25	6	56	11.2	25	4	8.40833	PR	6
Sub-family : Tanytarsini (D)	larvae	108	333	148	189	116	894	178.8	333	108	91.9059	CF	6
Family : Empidiae	larvae												
Chelifera sp.	larvae	4	9	8	8	1	30	6	9	1	3.39116	CG	6

Table A4 Benthic Invertebrates at Beaver Creek u/s Fruitvale Site Cont.

Family : Simuliidae	pupae	0	1	0	0	0	1	0.2	1	0	0.44721		
Family : Simuliidae	larvae	16	0	16	0	0	32	6.4	16	0	8.76356	CF	6
Family : Tipulidae	larvae	0	0	0	4	0	4	0.8	4	0	1.78885	SH	3
Sub-family : Limoniinae	larvae	0	0	1	0	0	1	0.2	1	0	0.44721	UN	UN
Antocha sp.	larvae	5	11	9	13	1	39	7.8	13	1	4.81664	CG	3
Dicranota sp.	larvae	3	1	5	1	0	10	2	5	0	2	PR	3
Hexatoma sp.	larvae	0	0	0	1	0	1	0.2	1	0	0.44721	PR	2
Order : Coleoptera													
Family : Elmidae	adult	28	11	19	8	11	77	15.4	28	8	8.14248	SC	4
Family : Elmidae	larvae	144	252	192	208	300	1096	219.2	300	144	59.4239	CG	4
Heterlimnius sp.	larvae	8	1	0	12	21	42	8.4	21	0	8.61974	CG	4
Narpus sp.	larvae	1	0	0	2	1	4	0.8	2	0	0.83666	CG	4
Optioservus sp.	larvae	74	91	55	176	91	487	97.4	176	55	46.3821	SC	4
Zaitzevia sp.	larvae	1	5	1	0	1	8	1.6	5	0	1.94936	CG	4
Class : Crustacea													
Sub-class : Copepoda		0	4	0	0	8	12	2.4	8	0	3.57771	CG	8
Sub-class : Ostracoda		8	4	4	0	8	24	4.8	8	0	3.34664	CG	8
Order : Pelecypoda													
Family : Sphaeriidae													
Pisidium sp.		0	4	0	0	0	4	0.8	4	0	1.78885	CF	8
Order : Gastropoda													
Family : Hydrobiidae		1	0	0	0	0	1	0.2	1	0	0.44721	SC	10
Family : Planorbidae		4	0	0	0	0	4	0.8	4	0	1.78885	SC	7
Class : Arachnida													
Group : Hydracarina		197	164	100	196	212	869	173.8	212	100	44.8129	PR	8
Phylum : Annelida													
Class : Oligochaeta (D)													
Family : Enchytraeidae		48	76	32	36	125	317	63.4	125	32	38.4942	CG	10
Family : Lumbriculidae		1	0	2	0	1	4	0.8	2	0	0.83666	CG	8
Family : Naididae		20	28	24	20	20	112	22.4	28	20	3.57771	CG	10
Phylum : Nematoda		14	8	8	4	16	50	10	16	4	4.89898	PA	5
Phylum : Platyhelminthes													
Class : Turbellaria (D)		8	4	8	0	0	20	4	8	0	4	PR	4
Polycelis coronata		5	14	3	6	4	32	6.4	14	3	4.39318	CG	1
Dugesia sp.		1	9	4	0	3	17	3.4	9	0	3.50714	PR	4
Phylum : Cnidaria													
Hydra sp.		0	4	4	0	0	8	1.6	4	0	2.19089	PR	5
Total number of invertebrates found		3,148	4,440	3,794	2,845	3,762	17,989	3,598	4,440	2,845	621.25		
Density of invertebrates (#/m^2)		34,978	49,333	42,200	31,611	41,800	39,976	39,984	49,333	31,611	6,906.27		

D = extremely small or damaged individuals

Table A4 Benthic Invertebrates at Beaver Creek u/s Fruitvale Site Cont.

Functional Feeding Group Analysis										
By Total Numbers	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	255	268	189	246	264	1222	244.4	268	189	32.1139
Shredders	205	98	59	168	119	649	129.8	205	59	57.5647
Collector-Gatherers	1878	2712	2110	1461	2132	10293	2058.6	2712	1461	454.066
Collector-Filterers	322	638	592	229	271	2052	410.4	638	229	190.35
Scrapers	473	714	832	737	960	3716	743.2	960	473	179.434
Parasite	14	8	8	4	16	50	10	16	4	4.89898
Unknown	0	0	1	0	0	1	0.2	1	0	0.44721
Total	3147	4438	3791	2845	3762	17983				
By Percentages	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	8.10	6.04	4.99	8.65	7.02	6.80	6.96	8.65	4.99	1.49182
Shredders	6.51	2.21	1.56	5.91	3.16	3.61	3.87	6.51	1.56	2.2219
Collector-Gatherers	59.68	61.11	55.66	51.35	56.67	57.24	56.89	61.11	51.35	3.8006
Collector-Filterers	10.23	14.38	15.62	8.05	7.20	11.41	11.10	15.62	7.20	3.75391
Scrapers	15.03	16.09	21.95	25.91	25.52	20.66	20.90	25.91	15.03	5.12549
Parasite	0.44	0.18	0.21	0.14	0.43	0.28	0.28	0.44	0.14	0.14356
Unknown	0.00	0.00	0.03	0.00	0.00	0.01	0.01	0.03	0.00	0.0118
Total	100	100	100	100	100	100				

Biostatistical Metrics	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Total No. of Taxa	51	51	48	38	45	63	46.6	51	38	5.41295
No. EPT Taxa	18	19	19	13	18	22	17.4	19	13	2.50998
EPT/Total Taxa	35.29	37.25	39.58	34.21	40.00	34.92	37.27	40.00	34.21	2.5529
EPT/EPT+Chironomid Ratio	82.54	69.68	87.00	68.71	85.79	78.90	78.74	87.00	68.71	8.87517
% Dominant Taxa	19.70	16.19	20.72	19.40	22.75	17.44	19.75	22.75	16.19	2.38376
SC / (SC+CF) Ratio	59.50	52.81	58.43	76.29	77.99	64.42	65.003	77.985	52.811	11.3825
(SC+CF) / (SH+CG) Ratio	38.17	48.11	65.65	59.30	54.69	52.71	53.184	65.652	38.166	10.5637
% Ephemeroptera	54.48	48.69	61.33	46.68	59.09	54.23	54.06	61.33	46.68	6.35762
% Plecoptera	1.75	1.82	0.55	1.44	1.46	1.41	1.41	1.82	0.55	0.50559
% Trichoptera	10.45	7.61	13.26	3.59	6.35	8.40	8.25	13.26	3.59	3.7312
% Diptera	15.44	26.58	12.84	24.82	11.24	18.24	18.18	26.58	11.24	7.0483
% Other Orders	17.88	15.29	12.02	23.48	21.85	17.72	18.11	23.48	12.02	4.68804
Hilsenhoff Biotic Index	3.89	4.24	3.79	4.08	4.06	4.02	4.01	4.24	3.79	0.17627

Biometric (based on average data)	**No Impact**	**Slight Impact**	**Mod. Impact**	**Severe Impact**
Total No. Taxa	X			
No. EPT Taxa	X			
EPT/Total Taxa		X		
EPT/EPT+Chironomid Ratio	X			
% Dominant Taxa	X			
HBI		X		

Table A5 Benthic Invertebrates at Beaver Creek at Marsh Site

Site Name		**Beaver Creek @ Marsh**											
Sample Date		September 23, 1999											
Replicate #		1	2	3	4	5							
Water Velocity (m/s)		4.04	4.75	4.68	3.58	3.38							
Water Depth (m)		0.43	0.36	0.33	0.27	0.28							
Taxon	**stage**	**total organisms / sample**					**Total**	**Avg**	**Max**	**Min**	**St. Dev.**	**FFG**	**Tolerance**
Order : Ephemeroptera													
Family : Ameletidae													
Ameletus sp.	nymph	1	4	0	5	0	10	2	5	0	2.34520788	CG	0
Family : Baetidae													
Baetis sp.	nymph	48	77	20	65	78	288	57.6	78	20	24.2548964	CG	5
Family : Ephemerellidae (D)	nymph	2206	2155	1466	2233	2424	10484	2096.8	2424	1466	367.025476	CG	1
Caudatella sp.	nymph	0	0	0	1	0	1	0.2	1	0	0.4472136	CG	1
Drunella grandis	nymph	10	4	4	6	3	27	5.4	10	3	2.79284801	CG	1
Ephemerella sp.	nymph	3	2	0	1	2	8	1.6	3	0	1.14017543	CG	1
Family : Heptageniidae													
Cinygmula sp.	nymph	51	37	36	94	158	376	75.2	158	36	51.9393878	SC	4
Epeorus sp.	nymph	8	0	0	0	0	8	1.6	8	0	3.57770876	SC	0
Family : Leptophlebiidae	nymph	8	0	5	5	16	34	6.8	16	0	5.89067059	CG	2
Order : Plecoptera													
Family : Capniidae	nymph	11	1	10	10	59	91	18.2	59	1	23.1667866	SH	1
Family : Chloroperlidae (D)	nymph	57	25	20	8	18	128	25.6	57	8	18.6091375	PR	1
Sweltsa sp.	nymph	13	19	22	17	29	100	20	29	13	6	PR	1
Family : Perlodidae													
Skwala sp.	nymph	3	8	5	1	1	18	3.6	8	1	2.96647939	PR	2
Family : Pteronarcydae													
Pteronarcys sp.	nymph	0	1	0	0	0	1	0.2	1	0	0.4472136	SH	0
Order : Trichoptera													
Family : Hydropsychidae (D)	larvae	170	34	0	20	35	259	51.8	170	0	67.5736635	CF	4
Family : Hydroptilidae													
Hydroptila sp.	larvae	10	18	1	11	0	40	8	18	0	7.51664819	SC	6
Oxyethira sp.	larvae	8	0	0	0	0	8	1.6	8	0	3.57770876	**??**	3
Family : Lepidostomatidae													
Lepidostoma sp.	larvae	9	18	10	26	58	121	24.2	58	9	20.1047258	SH	1
Family : Rhyacophilidae													
Rhyacophila sp.	larvae	5	4	3	1	5	18	3.6	5	1	1.67332005	PR	0
Order : Diptera													
Family : Athericidae													
Atherix sp.	larvae	1	0	0	0	0	1	0.2	1	0	0.4472136	PR	2
Family : Ceratopogonidae													
Bezzia sp.	larvae	43	12	2	15	19	91	18.2	43	2	15.221695	CG/PI	6
Family : Chironomidae	pupae	0	0	0	0	1	1	0.2	1	0	0.4472136		
Sub-family : Chironominae													
Tribe : Chironomini	larvae	1	0	5	0	1	7	1.4	5	0	2.07364414	UN	6
Polypedilum sp.	larvae	0	0	0	0	24	24	4.8	24	0	10.7331263	SH	6
Sub-family : Orthocladiinae	larvae	184	81	50	93	66	474	94.8	184	50	52.4089687	CG	6
Cricotopus/Orthocladius sp.	larvae	42	50	7	47	40	186	37.2	50	7	17.3407036	SH	7
Thienemanniella sp.	larvae	11	11	16	35	25	98	19.6	35	11	10.3344085	CG	6
Sub-family : Tanypodinae													
Theinemannimyia sp.	larvae	34	69	22	39	51	215	43	69	22	17.8745629	PR	6
Sub-family : Tanytarsini	larvae	338	18	2	36	219	613	122.6	338	2	148.891907	CF	6
Family : Empidiae													
Chelifera sp.	larvae	0	0	0	0	8	8	1.6	8	0	3.57770876	CG	6
Family : Simuliidae													
Simulium sp.	larvae	0	0	0	5	0	5	1	5	0	2.23606798	CF	6
Family : Tipulidae													

Table A5 Benthic Invertebrates at Beaver Creek at Marsh Site Cont.

Order : Coleoptera													
Family : Elmidae	adult	44	35	5	7	9	100	20	44	5	18.1383571	SC	4
Family : Elmidae (D)	larvae	322	276	136	237	150	1121	224.2	322	136	80.1511073	CG	4
Haliplidae sp.	larvae	1	0	0	0	0	1	0.2	1	0	0.4472136	CG	7
Narpus sp.	larvae	1	8	6	7	13	35	7	13	1	4.30116263	CG	4
Optioservus sp.	larvae	229	134	110	122	166	761	152.2	229	110	47.7304934	SC	4
Zaitzevia sp.	larvae	6	10	2	1	2	21	4.2	10	1	3.76828874	CG	4
Order : Collembola		0	0	0	0	8	8	1.6	8	0	3.57770876	CG	10
Class : Crustacea													
Sub-class : Cladocera		16	0	0	0	0	16	3.2	16	0	7.15541753	CF	8
Sub-class : Copepoda		8	0	0	0	8	16	3.2	8	0	4.38178046	CG	8
Sub-class : Ostracoda		8	16	5	10	0	39	7.8	16	0	5.93295879	CG	8
Order : Pelecypoda													
Family : Sphaeriidae													
Pisidium sp.		64	40	24	15	23	166	33.2	64	15	19.4602158	CF	8
Order : Gastropoda													
Family : Planorbidae		9	1	5	5	16	36	7.2	16	1	5.67450438	SC	7
Family : Physidae													
Physa sp.		3	5	10	0	10	28	5.6	10	0	4.39317653	SC	8
Class : Arachnida													
Group : Hydracarina		152	76	41	54	99	422	84.4	152	41	43.7641406	PR	8
Phylum : Annelida													
Class : Hirudinae													
Helobdella stagnalis		0	0	0	2	0	2	0.4	2	0	0.89442719	PR	10
Class : Oligochaeta													
Family : Enchytraeidae		8	3	2	10	19	42	8.4	19	2	6.80441033	CG	10
Family : Lumbriculidae		25	9	10	5	7	56	11.2	25	5	7.94984277	CG	8
Family : Naididae		49	18	7	7	58	139	27.8	58	7	24.0977177	CG	10
Family : Tubificidae		4	8	66	1	29	108	21.6	66	1	27.1348484	CG	10
Phylum : Nematoda		50	64	24	5	54	197	39.4	64	5	24.244587	PA	5
Phylum : Platyhelminthes													
Class : Turbellaria													
Polycelis coronata		1	1	0	1	3	6	1.2	3	0	1.09544512	CG	1
Dugesia sp.		15	9	9	9	3	45	9	15	3	4.24264069	PR	4
Phylum : Cnidaria													
Hydra sp.		16	8	0	5	8	37	7.4	16	0	5.81377674	PR	5
Total number of invertebrates found		4,339	3,370	2,175	3,282	4,042	17,208	3,442	4,339	2,175	836.761794		
Density of invertebrates (#/m^2)		48,211	37,444	24,167	36,467	44,911	38,240	38,240	48,211	24,167	9297.35327		

D = extremely small or damaged individuals

Table A5 Benthic Invertebrates at Beaver Creek at Marsh Site Cont.

Functional Feeding Group Analysis										
By Total Numbers	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	326	219	128	141	231	1045	209	326	128	79.7778165
Shredders	65	70	28	83	181	427	85.4	181	28	57.2127608
Collector-Gatherers	2947	2695	1797	2738	2938	13115	2623	2947	1797	475.62748
Collector-Filterers	588	92	26	76	277	1059	211.8	588	26	230.809878
Scrapers	354	230	167	239	359	1349	269.8	359	167	83.8850404
Parasite	50	64	24	5	54	197	39.4	64	5	24.244587
Unknown	1	0	5	0	1	7	1.4	5	0	2.07364414
Total	4331	3370	2175	3282	4041	17199				
By Percentages	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Predators	7.53	6.50	5.89	4.30	5.72	29.923	5.98	7.53	4.30	1.18069595
Shredders	1.50	2.08	1.29	2.53	4.48	11.873	2.37	4.48	1.29	1.27345835
Collector-Gatherers	68.04	79.97	82.62	83.42	72.70	386.76	77.35	83.42	68.04	6.70302702
Collector-Filterers	13.58	2.73	1.20	2.32	6.85	26.672	5.33	13.58	1.20	5.08112837
Scrapers	8.17	6.82	7.68	7.28	8.88	38.843	7.77	8.88	6.82	0.79739764
Parasite	1.1545	1.89911	1.1034	0.1523	1.3363	5.6457	1.13	1.90	0.15	0.63071344
Unknown	0.0231	0	0.2299	0.00	0.02475	0.2777	0.06	0.23	0.00	0.09819225
Total	100	100	100	100	100	500				

Biostatistical Metrics	**1**	**2**	**3**	**4**	**5**	**Total**	**Avg**	**Max**	**Min**	**St. Dev.**
Total No. of Taxa	50	40	38	42	43	57	42.60	50.00	38.00	4.5607017
No. EPT Taxa	17	15	12	16	13	19	14.60	17.00	12.00	2.07364414
EPT/Total Taxa	34.00	37.50	31.58	38.10	30.23	33.333	34.28	38.10	30.23	3.48856359
EPT/EPT+Chironomid Ratio	81.12	91.31	94.01	90.92	87.11	88.136	88.90	94.01	81.12	4.99463402
% Dominant Taxa	50.84	63.95	67.40	68.04	59.97	60.925	62.04	68.04	50.84	7.03667661
SC / (SC+CF) Ratio	37.58	71.43	86.53	75.87	56.45	56.02	65.571	86.528	37.58	19.0159972
(SC+CF) / (SH+CG) Ratio	31.27	11.65	10.58	11.17	20.39	17.78	17.011	31.275	10.575	8.9337964
% Ephemeroptera	53.81	67.63	70.39	73.43	66.33	331.59	66.32	73.43	53.81	7.50392178
% Plecoptera	1.94	1.60	2.62	1.10	2.65	9.9031	1.98	2.65	1.10	0.66709559
% Trichoptera	4.66	2.20	0.64	1.77	2.42	11.687	2.34	4.66	0.64	1.46584398
% Diptera	15.83	7.18	5.10	8.38	11.65	48.149	9.63	15.83	5.10	4.20185076
% Other Orders	23.76	21.39	21.24	15.33	16.95	98.67	19.73	23.76	15.33	3.48015599
Hilsenhoff Biotic Index	3.06	2.44	2.37	2.23	2.65	2.597	2.55	3.06	2.23	0.32158142

Biometric (based on average data)	**No Impact**	**Slight Impact**	**Mod. Impact**	**Severe Impact**
Total No. Taxa	X			
No. EPT Taxa	X			
EPT/Total Taxa		X		
EPT/EPT+Chironomid Ratio	X			
% Dominant Taxa				X
HBI	X			