



# Ministry of Environment

## LOWER MAINLAND REGION

### Ambient Water Quality Monitoring in Kilgaard Creek in 2001

ENVIRONMENTAL QUALITY



# **Ambient Water Quality Monitoring in Kilgaard Creek in 2001**

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## Preface

This report is one in a series of air and water quality reports that are being issued by the Lower Mainland Regional Office. It is the intention of the Regional Office to publish these reports on our website (<http://wlapwww.gov.bc.ca/sry/p2/eq/index.htm>) in order to provide the information to industry and local government, other stakeholders and the public at large. By providing such information in a readily understood format, and on an ongoing basis, we hope that local environmental quality conditions can be better understood, and better decisions regarding water and air quality management can be made.

## Acknowledgements

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Lower  
Mainland  
Region  
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## 1.0 INTRODUCTION

The Fraser River supports the world's largest salmonid runs and produces over 50% of all B.C. salmon. Up to 40% of the Fraser basin salmonids, including chinook, pink and sockeye salmon, spawn in Lower Fraser River tributaries such as Sumas River, Marshall Creek and Kilgaard Creek. These tributaries downstream of Hope are even more important for coho and chum salmon as 65% of Fraser River coho and 85% of Fraser River chum spawn in these smaller tributaries (Nener and Wernick 1997). The Sumas River and its tributaries also support steelhead, rainbow and cutthroat trout, white sturgeon, dolly varden, lampreys, mountain whitefish, northern pike, minnow, sculpins and three-spine stickleback (Fishwizard 2003). A decline in the fisheries resources in the Fraser River has occurred and may be attributed to a combination of the following: habitat destruction, low ocean survival rates, disease outbreaks and/or water pollution.

Sumas Lake covered a portion of the Sumas Prairie until the early 1920's when it and the surrounding wetlands were drained to create agricultural lands. These fertile soils of the floodplain have been intensively used by dairy, hog and poultry producers, as well as by hobby, nursery and produce farmers (Integrated Resource Consultants Inc. 1994). The farm lands of the Fraser Valley floodplain are now located in the Agricultural Land Reserve (ALR) which protects this fertile land from non-agricultural development. The Lower Fraser Valley is one of the most important agricultural areas in British Columbia with the Sumas Prairie being one of the most intensively farmed areas in Canada (Schreier *et al.* 1998). This intensification of agriculture operations over the past two decades has altered soil and water quality due to fertilizer application, waste generation, removal of riparian vegetation and introduction of contaminants. Water quality in the Sumas Prairie is now considered to be poor (De Solla 2002). More detailed information on the Sumas River, including water quality data, can be found on the B.C. Ministry of Environment Environmental Quality Section (Lower Mainland Region) web page at <http://wlapwww.gov.bc.ca/sry/p2/eq/index.htm> (refer to the report 'Summary of Surface Water Quality Sampling on Sumas River and Tributaries, Abbotsford, British Columbia').

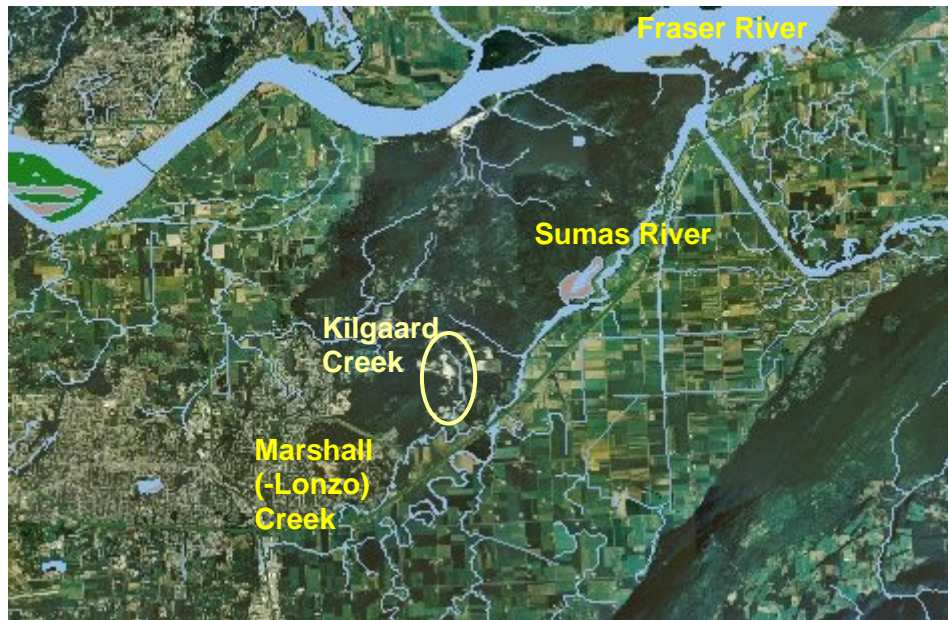
Development pressures from the growing population of the Lower Mainland have expanded eastward into the Fraser Valley. The population of the City of Abbotsford grew by 93% between 1983 and 1996, and continues to be one of the fastest growing communities in B.C. and Canada (City of Abbotsford). With a population increase of 22.2% between the 1991 and 1996 censuses, residential developments have expanded with more than 1,100 single family subdivision lots being created since 1997 (City of Abbotsford). Due to the ALR restrictions, much of this development is being pushed onto the mountain sides or concentrated around already developed areas. Forested hill slopes are thus being converted to residential areas while urban centres are facing densification. Residential, industrial and urban activities may potentially have harmful impacts on water quality.

To examine possible water pollution caused by land-based activities, water quality sampling or monitoring is often conducted. Water quality monitoring was initiated in Kilgaard Creek in 2001 to examine the potential impacts of local land activities. The Sumas First Nation is concerned about the current and future state of local waterbodies. Individually or cumulatively, the types of activities occurring in the Kilgaard Creek watershed have the potential to have detrimental effects on water quality, fish and fish habitat. The multiple activities occurring in the watershed, and the anticipated future increase in some of these pressures, spurred the submission of a proposal to have a local youth team begin a water quality investigation. As no extensive water quality sampling had previously been conducted in Kilgaard Creek, the primary objective of this work was to determine the current water quality conditions in the creek. The Sumas First Nations E-Team thus initiated a project to begin to assess the effects of local land use activities on Kilgaard Creek water quality. This data was then compared to B.C. ambient water quality criteria to provide information, or baseline data, against which future water quality data could be compared.

The main objective of this report is to detail the results of the 2001 E-Team water quality sampling in Kilgaard Creek. The water quality results are compared to the relevant B.C. water quality guidelines or criteria.

## 2.0 KILGAARD CREEK AND WATERSHED

Kilgaard Creek is located in Abbotsford, British Columbia and is part of the larger Sumas River watershed (Figure 1). This area consists of the extensive floodplains of the Lower Fraser Valley and the surrounding mountainous area. Kilgaard Creek is 2.5 kilometres in length with its headwaters originating on the southern slope of Sumas Mountain. The creek flows through the Sumas First Nations Reserve and discharges to Marshall Creek (also known as Lonzo or Marshall-Lonzo Creek) at the base of Sumas Mountain. Marshall Creek discharges into the Sumas River which then flows into the Fraser River.



**Figure 1: Location of Kilgaard Creek, Marshall (-Lonzo) Creek, Sumas River and Fraser River.**

Marshall Creek flows through the lower portions of the Sumas First Nations Reserve. There is moderate urban development in this watershed and further development may significantly alter the hydrologic regime. A 1997 survey found that approximately 27% of this watershed was used for residential/commercial activities while approximately 30% of the watershed was covered by trees (Kennedy *et al.* 1997). Most of this forested area was located on the south-facing slope of Sumas Mountain where development has been occurring at a rapid rate. The current amount of forested area is thus likely much lower now.

A consequence of the agricultural activities and the more recent residential developments in the Lower Fraser Valley is a decline in water quality, water quantity and fisheries habitat (Nener and Wernick 1997). Kilgaard Creek is believed to have historically played an important role in regulating Marshall Creek, and thus also Sumas River water quality. Kilgaard Creek's input of cold, clean water may alleviate some of the detrimental effects of the intensive land use in the floodplain. Fish populations may rely upon such tributaries for refuge from the heavily altered agricultural landscape of the Sumas Prairie. However, development in upland areas, such as on Sumas Mountain, may have altered the water quality and habitat features of Kilgaard Creek, or may alter it in the future.



## 2.1 Residential and Industrial Development

Housing developments continue to alter the natural environments of Sumas and Vedder Mountains, including the creeks and streams originating on their slopes. The Kilgaard Creek watershed is moderately developed with 2.9% effective impermeable area (EIA) cover (Nener and Wernick 1997). The amount of impermeable area in a watershed has been shown to correlate with habitat and water quality. This level of EIA (2.9%) tends to be associated with relatively small, but potential impacts on fish habitat or water quality (Nener and Wernick 1997). As the amount of impermeable surface area increases, both habitat features and water quality tend to deteriorate (Paul and Meyer 2001). Roads and other impervious surfaces built for residential and industrial areas allow contaminants such as polycyclic aromatic hydrocarbons (PAH's) and heavy metals to be introduced into water courses, lead to stream channel scouring and increase the variability of stream flows, which can alter temperature and suspended sediment loads.

The homes and facilities of the Sumas First Nations Reserve border Kilgaard Creek along its lower reaches as does Sumas Mountain Road. Many industries are also located adjacent to, or near Kilgaard Creek. These include a petroleum storage tank facility (Terasen Pipelines Inc.), a contaminated soil remediation facility (Sumas Environment Services), a brick manufacturing plant (Sumas Clay Products), a plastic manufacturing facility (Royal Flex-lox Pipe Ltd.), and gravel extraction pits (Clayburn Industries). Terasen Pipelines holds a permit allowing the discharge of stormwater near the top of Sumas Mountain. Royal Flex-lox, Clayburn Industries and Sumas Clay Products have air discharge permits, however, these operations do not have permits to discharge effluent or stormwater. Stormwater runoff from these sites is possible, especially at paved sites lacking stormwater holding facilities. Members of the Sumas First Nations band believe that since the development of these industries, the water quality in Kilgaard Creek has dramatically declined (E-Team 2001).

## 2.2 Agricultural Development

Agricultural activities occur along much of the lower reaches of Kilgaard Creek. The riparian vegetation in this area has been cleared, and a large part of this area has been colonized by the invasive Himalayan blackberry. The blackberry bushes have filled in the riparian area, completely covering Kilgaard Creek in the lower reaches. Algal blooms have been visible in the summer at the confluence of Kilgaard and Marshall Creeks (George Rushworth, pers.comm.).

In the floodplain, land filling and encroachment have narrowed Marshall Creek while industrial discharges (e.g. fish hatchery) may have detrimentally affected water quality. Agricultural lands and activities are abundant throughout the Marshall Creek watershed, occurring on approximately 33% of the total watershed area (Kennedy *et al.* 1997). These activities have been identified as the greatest threat to the fisheries resources in this creek and have already had an impact (Nener and Wernick 1997). Agricultural runoff has contributed to eutrophication and siltation in the system, and is thought to have added high copper and zinc concentrations to the watercourse (Nener and Wernick 1997). Dissolved oxygen levels below the minimum guideline have been measured, while temperature and ammonium have been measured above their respective criteria at the confluence with the Sumas River (Nener and Wernick 1997). High nitrate levels measured in the headwaters may be due to groundwater inputs from the contaminated Abbotsford Aquifer (Kennedy *et al.* 1997; Nener and Wernick 1997).

## 2.3 Fisheries Resources and Wildlife

Historically, Kilgaard Creek has held significant food, spiritual and recreational values for the Sumas First Nation's people. The plentiful supply of chum and coho salmon previously helped sustain the Sumas First Nations band (Kennedy *et al.* 1997). The lower reaches of Kilgaard Creek still support several fish species including coho salmon and cutthroat trout. Declining fish populations have affected the ability of first nations people to depend upon this fisheries resource (Kennedy *et al.* 1997). There is also the

perception that local fish could be contaminated from local urban and industrial pollution. Since the returning spawning salmon are not resident populations in the creek, it is unlikely that Kilgaard Creek would significantly contribute to any contaminant burden in the fish. Aspects of the creek's current fish habitat condition that may limit its fisheries productivity include riparian vegetation clearing in the lower reaches, as well as fish barriers such as culverts. Restoration projects such as riparian planting, removal of invasive species such as blackberries, and the building of fish ladders may reduce the impact of these problems.

Habitat restoration projects, however, may not result in the fisheries gains they are designed for if deteriorating water quality conditions limit fish reproduction and survival. Recent spawning surveys in urban streams in Washington State have documented high rates of pre-spawning mortality for coho salmon (20-90%) (Reed *et al.* 2003). Preliminary findings suggest that water quality may be a factor in these mortalities, as many of the mortalities occurred after rainfall events. Likewise, in the heavily urbanized Byrne Creek drainage located in Burnaby, B.C., first flush rainfall events tended to result in high mortalities of coho hatchery juveniles (City of Burnaby 2003). While the Kilgaard Creek drainage is not as developed as the Byrne Creek drainage, it is still possible that water quality could be a factor limiting fishery success.

Other wildlife may also be affected by deteriorating habitat and water conditions of Kilgaard Creek. Amphibians are highly susceptible to water quality degradation and habitat alteration due to their permeable skins and their dependence upon water for at least part of their lifecycle. In the heavily used Fraser Valley, some amphibian populations are declining. Some of this may be due to agricultural land conversion and related activities. Research has found that northern red-legged frogs (*Rana aurora*) and northwestern salamanders (*Ambystoma gracile*) had significantly lower hatching success at agricultural sites in the Lower Fraser Valley than at reference sites (De Solla *et al.* 2002). This study concluded that agricultural runoff may contribute to lower reproductive success and ultimately reduced population viability of amphibian populations in the Lower Fraser Valley.

Small mammals are also likely to use Kilgaard Creek. The presence of the red-listed Pacific Water Shrew has been recorded in the Clayburn Creek drainage which is located near Kilgaard Creek and also drains from Sumas Mountain (Letay, pers.comm. 2003). The Ministry of Environment's red list includes species legally designated, or being considered for legal designation, as endangered or threatened (MELP 2001).

### **3.0 IMPACTS OF LAND USE ON WATER QUALITY**

The development and densification of agricultural, residential, industrial and commercial activities within local watersheds can reduce or remove riparian areas, alter water patterns and increase nutrient and/or pollutant loadings.

#### **3.1 Loss of Riparian Vegetation**

The loss of riparian vegetation and forestland in the Fraser Valley is virtually ubiquitous in the lowlands. There can be many detrimental impacts from such loss of riparian cover. The lack of shading can result in an increase in water temperature as more light reaches the water, while the aquatic food web may be altered by a reduction in leaf and needle inputs which form a food source for some aquatic invertebrates. As well, the loss of root structure can increase bank instability resulting in erosion events that deposit sediment into the water and alter in-stream habitat. The loss of riparian trees will also decrease the amount of coarse woody debris (CWD) entering the stream ecosystem in the future. Woody debris in streams provides cover for aquatic organisms, creates pools for retreat in both fast-flowing conditions and when water levels drop, and dissipates water energy, thus reducing the water's velocity and erosion potential. This lost forest cover may also alter local hydrological patterns due to the lack of water uptake by the trees for photosynthesis.

### 3.2 Surface Runoff Pollution

There are two broad types of water pollution resulting from anthropogenic land use. One is pollution from a single, clearly identifiable point discharge, such as from an industrial or sewer pipe, and the other is from non-point source discharges. Non-point source (NPS) pollution results from surface water flowing over an altered landscape and then entering water bodies. The runoff picks up contaminants deposited on fields or impervious surfaces (such as concrete or pavement), and carries it into local waters. Land use in a watershed thus affects the amount and type of NPS pollution. NPS pollution is more difficult to control than point source discharges as it is intermittent, variable and widely dispersed.

Due to the intensity of agricultural operations and the wet local climate in the Lower Fraser Valley, there are potentially significant environmental problems associated with surface runoff into streams. Runoff carrying nutrients, bacteria and pesticides may contaminate surface and ground waters, altering its usefulness to people and creating conditions toxic to aquatic life. Bacterial contamination from manure may alter the usefulness of water to people for recreational activities, livestock watering and irrigation. An excess of nutrients in aquatic systems from manure and/or fertilizers can also lead to environmental degradation. Nutrient enrichment can cause the proliferation of plants and algae which is termed eutrophication. Eutrophication causes water conditions to become turbid, thereby harming aesthetic values and preventing underwater photosynthesis and oxygen production. Although the excessive planktonic and/or periphytic growths maintain high dissolved oxygen levels, once the plants and algae eventually die, their decomposition uses up the available oxygen in the water, and the dissolved oxygen concentration plummets. Low oxygen levels caused by eutrophication may have severe consequences for stream biota including physiologically stressing aquatic organisms, harming salmon migrations and when severe, leading to fish kills. Additionally, nutrients such as ammonia and nitrite which may be present in runoff have been found to be toxic to fish, while nitrate has been found to be toxic to some amphibians.

The wet local conditions prevalent in the Fraser Valley-Sumas area combined with heavy agricultural activities have resulted in groundwater contamination as well. The Abbotsford aquifer is rated IA by the Ministry of Environment indicating it is heavily developed and highly vulnerable. This aquifer is susceptible to contamination due to the highly permeable local geology (Zebarth *et al.* 1998). The Abbotsford aquifer has already become contaminated with nitrate and pesticides (Hii *et al.* 1999).

### 3.3 Toxic Contaminants

Toxic contaminants may also be introduced into watercourses from nearby agricultural, residential, industrial and commercial activities. Chemicals such as pesticides may enter watercourses via direct spray, aerial drift or surface runoff. Toxic runoff from farms treated with pesticides has resulted in documented fish kills in the Sumas River watershed (Moore, pers.comm.). Metals may also be found in agricultural runoff. Some of the copper in surface waters around agricultural areas has been found to be associated with manure/feed runoff. As well, soon after the application of hog manure to fields, endocrine disrupting compounds (EDC) have been found to enter aquatic habitats (Environment Canada 1998). These chemicals may have long-term impacts on the growth, development and reproduction of fish and wildlife.

Urban and industrial activities may contribute other toxic contaminants to local waterbodies. Among some of the toxic contaminants potentially found in industrial, urban or road stormwater runoff are polycyclic aromatic hydrocarbons (PAHs), metals, surfactants (soaps), and pesticides. Specific industrial activities could also contribute polychlorinated biphenyls (PCBs), dioxins and furans to local waterways. These contaminants may accumulate in animal tissue and reach elevated levels in organisms higher in the food web such as larger fish, birds and mammals. Elevated levels of these contaminants are harmful to organisms as they can alter growth, development and reproduction. Industrial spills of toxic chemicals are another potential mechanism of contamination of surface waters.

## 4.0 2001 WATER QUALITY SAMPLING INVESTIGATION

### 4.1 Water Quality Sampling

Water quality sampling may be employed to examine the state of water quality conditions in a watershed and to provide information regarding the real or potential impacts of various activities. Water quality monitoring or sampling involves measuring these physical and chemical components of the water. The results may then provide information about whether the existing conditions are potentially lethal to aquatic organisms or harmful to people's use of the water. A detailed description of water quality parameters is provided in Appendix A with sampling data tabled in Appendices B through F.

The Ministry of Environment develops province-wide ambient water quality (WQ) guidelines for variables that are important in the surface waters of British Columbia. WQ guidelines are considered safe levels of a parameter and are set to protect various water uses such as for drinking, recreating, irrigating or protecting aquatic life. Guidelines are set after researching the scientific literature, guidelines from other jurisdictions, and the general conditions in British Columbia (Nordin and Pommen 1986). The results from water quality sampling may then be compared to these provincial guidelines or criteria. Site specific objectives may be set for a waterbody after a comprehensive monitoring program has been conducted and information on the watershed has been collected. Water quality objectives have been developed to protect aquatic life, wildlife, livestock watering and irrigation uses of Sumas River water (B.C. Ministry of Environment, Lands & Parks 1996).

### 4.2 Field Sampling Methodology

#### 4.2.1 Grab Sampling

Discrete water samples were collected on five dates between August 28 and November 7, 2001. All discrete water quality sampling was conducted according to standards outlined in the *Ambient Fresh Water and Effluent Sampling Manual* (Resources Inventory Committee 1994). Samples for pH, turbidity and nutrients were collected in clean, one litre polyethylene bottles. Non-filterable residue samples were submitted in separate one litre polyethylene bottles. Each bottle was labeled with a unique identifier and the date. Time and conditions at the time of sampling were recorded in field notes. Visual fish, wildlife and water condition observations were also recorded in field notes. Precipitation measurements at the time of sampling are illustrated in Figure 2.

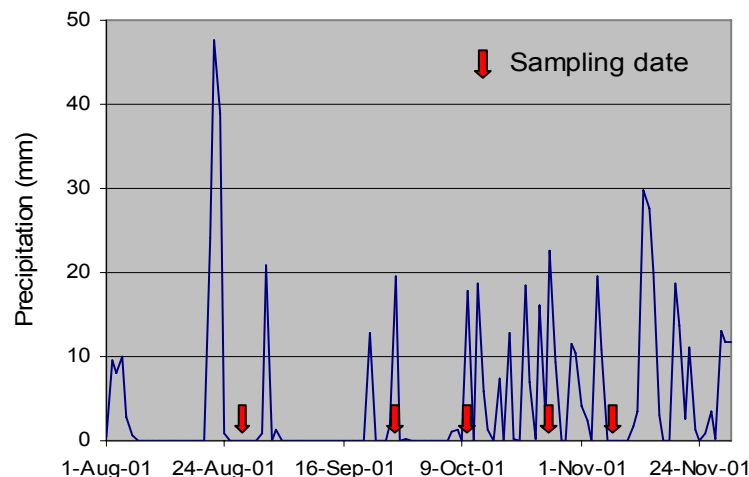


Figure 2: Rainfall in Abbotsford during the sampling period and the time of each sample collection.

In order to minimize the samplers' disturbance in the creek, sampling began at the most downstream site (near Marshall Creek) and proceeded upstream. Sampling locations were chosen to be representative of the area and where a safe access point was available. Depending on water conditions, the sampler stood either in the creek, or on the bank and reached upstream into an area of flowing water where the sample was then collected. Bottles were held at the base and plunged into the water below the surface and filled. Samples for pH and nutrients (ammonia, nitrite, nitrate and dissolved ortho-phosphate) were rinsed with water three times before being filled. All samples were stored on ice in coolers and couriered to laboratories in Vancouver for analyses. Samples for metals analyses were collected on all but the first sampling date. These samples were collected in 250 millilitre (mL) acid-washed polyethylene bottles and were preserved in the field with pre-measured allotments of nitric acid. Samples were shipped overnight to Pacific Environmental Science Centre and arrived at the laboratory within 24 hours of collection.

Bacterial samples were collected in sterilized 500 mL polyethylene bottles which were not pre-rinsed during sample collection. These samples were shipped overnight to CanTest laboratories and arrived at the laboratory within 24 hours of collection.

At each sample site, on each sampling date, a multimeter probe was deployed in the centre of the stream to measure dissolved oxygen and temperature.

### 4.3 Limitations

#### 4.3.1 Sample Size

Many B.C. water quality guidelines are based on the results from five samples collected in 30 days. Water quality monitoring programs would thus ideally include weekly sampling for five weeks in a row. Preferably this would occur in both low flow and high flow conditions. Due to time constraints within the E-Team schedule and budget constraints, samples were not collected every week, but instead every other week between August 28 and November 7, 2001. The dataset available is thus limited and interpretation must proceed with caution. Trends in the data and comparison to water quality criteria are the extent of the interpretation available.

There are other factors which limit the interpretation of the data such as the lack of a control site and the small sample size. No location was identified from which to collect a true 'control' or background sample. The data assessment, therefore, is limited to comparisons between the data collected at upstream and downstream sites. Besides limiting statistical analyses, the small sample size (five dates over approximately 70 days) may not be adequate to determine whether conditions could be causing chronic stress to sensitive aquatic organisms. Chronic toxicity or stress results from levels of contaminants that are too low to cause acute effects but persist for longer durations. These lower, chronic concentrations may lead to physiological stress in aquatic organisms.

#### 4.3.2 Guidelines and Criteria

There are some difficulties in the interpretation of the results for some of the parameters due to the sampling requirements in the criteria documents. The criteria for fecal coliform is based on the geometric mean being calculated from five weekly samples taken in 30 days. Sampling for this project was conducted over 10 weeks, not over 30 days. Additionally, the laboratory analyses resulted in some 'greater than 300 colony forming units per 100 mL results rather than an actual numerical value. The actual number of microbes in these samples is thus unknown. Calculating the geometric mean using 300 as the concentration (as was used for these samples), likely underestimates the actual microbial contamination in these samples and thus the resulting estimated geometric mean is likely lower than the actual value.

Two measurements were used to quantify the amount of suspended sediment in the water column in Kilgaard Creek. Non-filterable residue (NFR) measures the amount of particle matter (greater than 45 µm

in diameter) that is suspended within the water column. NFR is alternatively referred to as suspended solids or total suspended solids (TSS). Turbidity measures water clarity by determining how much the passage of light through the water decreases with suspended material in the water column. The criteria for both of these parameters requires that either there is knowledge of the background conditions in the system, and/or that samples are collected over a 24-hour period. As multiple samples were not collected over 24 hours, the data for each site were compared to the data from the most upstream sampling site (Ward Road) on each sampling date. This site was anticipated to be the least impacted site and thus the closest to a control site.

For some of the metals measured it was not possible to determine whether their respective criteria were exceeded. It is not possible to determine whether aluminum exceeded the criteria since the laboratory methodology measured total aluminum concentration, however, the criteria is for dissolved aluminum concentrations. It was also not possible to determine whether chromium exceeded the working guidelines as the lab methodology measured total chromium, however, the criteria is based upon the concentrations of individual chromium species.

Water hardness was not directly measured on the Kilgaard Creek water samples. As hardness measurements are necessary to determine the criteria/guidelines for some metals, an estimate of hardness was calculated for each sample from the following formula (Horvath pers.comm 2002):

Total Hardness (milligrams (mg)/L  $\text{CaCO}_3$ ) =  
(2.497 \* Calcium concentration in mg/L) + (4.116 \* Magnesium concentration in mg/L)

#### 4.4 Sampling Locations

Water samples were collected from five reaches in Kilgaard Creek (Figure 3). Each reach has a different type of land use bordering, or in close vicinity, to the creek and thus potentially impacting on water quality. The most upstream site (Ward Road site) was collected north (upstream) of where Ward Road crosses the creek in a stretch of the stream that flows parallel to the road. At this location, the water in the stream is slow moving and there is a great deal of decomposing leaves and organic matter as well as some gravel and cobble. The bank separating the creek and the road is steep and covered with rip-rap (Figure 4). There is no riparian vegetation between the road and the creek, whereas the bank on the other side of the creek is forested. Upstream of the sampling location is a wetland area, forested land and Terasen's petroleum storage tank farm.

The next sampling site (the gravel extraction site) was located downstream and southeast of Sumas Shale. At this site, both stream banks are steep and forested and is shaded with good leaf litter input (Figure 5). The substrate is mainly gravel, cobble and sand. Upstream of the sampling site the area is forested.

Samples were also collected behind the Sumas First Nations band office. This area has riparian vegetation on both sides of the creek and is forested upstream (Figure 6). The substrate is composed of gravel and bedrock. A culvert discharges to the creek upstream of the sampling location on the west side of the creek. This culvert appears to direct the flow of a small tributary under Sumas Mountain Road and into Kilgaard Creek. A brick manufacturing operation (Sumas Clay Products) is located west of this area, across Sumas Mountain Road.

The next site was located upstream of Kilgaard Road (Flex-lox site). There is riparian vegetation on both sides of Kilgaard Creek in this area and upstream is forested (Figure 7). Samples were collected upstream of the culvert, which the creek flows through to pass under Kilgaard Road. The substrate here is rocky with many large boulders and the bedrock is visible. Bordering both sides of the creek in this area is Flex-lox Industries, which manufactures PVC piping.



Figure 3: Sampling sites in Kilgaard Creek.



Figure 4: Ward Road sampling site.



Figure 5: Gravel extraction sampling site.



**Figure 6: Band office sampling site.**



**Figure 7: Flex-lox sampling site.**

The most downstream site sampled in Kilgaard Creek was just upstream of its confluence with Marshall Creek. Between Flex-lox Industries and this site, the landscape changes as the creek enters the floodplain and is primarily bordered by agricultural activities. Upstream of this sampling site, a few houses, band buildings, a soccer field and a major road (Sumas Mountain Road) border the creek. The riparian area has been removed in these lowlands and has subsequently been colonized by blackberry bushes. At the confluence with Marshall Creek, there is very little shade cover as only grass borders the creek (Figure 8). The bottom substrate is gravel in this area although fine sediments appear to be filling in some of the stream bottom. During the sampling period, adult coho salmon were observed migrating upstream. Waste from the cleaning of harvested fish was visible in Marshall Creek near this sampling site. People were seen cleaning fish and then disposing of the waste into the creek from the Sumas Mountain Road bridge, which passes over Marshall Creek.



**Figure 8: Sampling site at Marshall Creek confluence.**



## 5.0 RESULTS

Bacteriological and water chemistry data have been summarized in appended tables (Appendices B to F). Raw field data are also shown in these tables. The geometric means were calculated from at least five samples for the bacteriological results. For the other parameters, the arithmetic means were calculated for each site. When the concentration of a parameter was below the minimum detectable concentration (MDC), the laboratory detection limit was used in calculating the average.

## 6.0 ASSESSMENT

### 6.1 Temperature

The water temperature decreased at all of the sampling sites in Kilgaard Creek during the sampling period (Figure 9). This was anticipated as the sampling began in the summer and carried on through the fall. Water temperatures were consistently elevated above the recommended guidelines on some dates. The guideline suggests that the water temperature should be no more than 1° above or below the optimal temperature ranges for salmonid species present in the watercourse. Coho are known to use Kilgaard Creek as they were seen returning to spawn during the course of the sampling. Water temperatures were above the spawning guideline (13.8°C) on the first date (August 28, 2001) at all sites, as well as on the second date (September 26<sup>th</sup>) at the two most downstream sites (Flex-lox and Marshall).

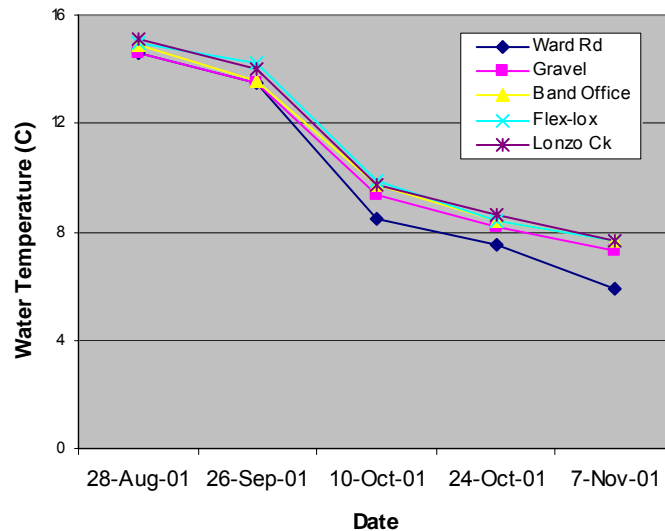
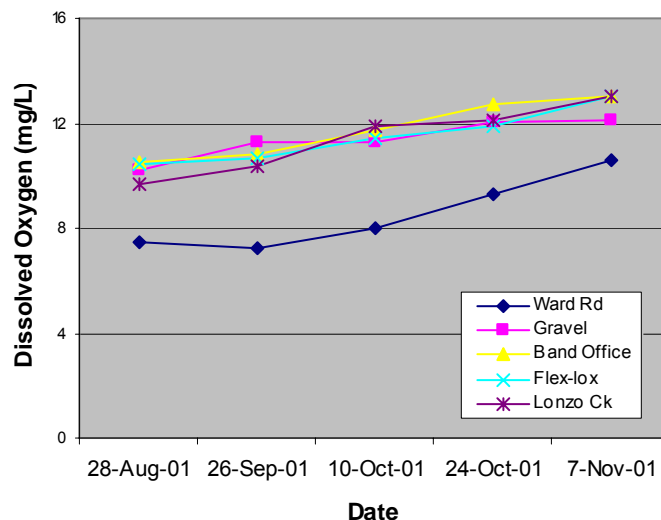


Figure 9: Water temperature at each site on each sampling date.

### 6.2 Dissolved Oxygen

The dissolved oxygen (DO) concentrations in Kilgaard Creek showed a general increase during the sampling period as the sampling progressed from summer to fall months (Figure 10). This is due to the solubility of oxygen in freshwater increasing with decreasing temperature. The Ward Road site showed the same pattern however the DO was lower than at the other sites. The lower DO at this site may reflect the decomposition of the large amount of organic matter in the creek in this area. As well, this site is closest to the headwaters with less turbulent water flow upstream of it, and thus less atmospheric oxygen is likely to get dissolved in the water. Downstream of the Ward Road site, the creek progresses down Sumas Mountain and flows over steep, rocky reaches which generate more turbulent water action.



**Figure 10: Dissolved oxygen at each sampling site on each sampling date.**

The DO concentrations were never below the instantaneous minimum DO criteria for salmonids (excluding buried embryo and alevins) (5 mg/L) at any of the sites (Truelson 1997). From the time of spawning until fry emerge, the criteria for buried embryos and alevins applies. The instantaneous minimum criteria for buried embryo/alevin (9 mg/L) was not reached at the Ward Road site on the first three dates. Low DO can be common in freshwater systems in late summer or in fall during algal decomposition. It is unlikely however that spawning salmon reach these upper sections of Kilgaard Creek. On the first two sampling dates, most sites had DO concentrations below 11 mg/L, which is the 30-day mean criteria for buried embryos and alevins. There are not adequate samples, however, to determine whether these conditions persisted over time and thus whether this chronic criteria was exceeded.

### 6.3 pH

The pH was near neutral or slightly alkaline at all sites on all dates (Appendices B-F). The most alkaline pH's (8.36 - 8.43) were measured at the Band Office site whereas more neutral pH's (7.39 - 7.97) were measured at the Ward Road site. There should not be any detrimental impacts to aquatic life from pH values in these ranges.

### 6.4 Nutrients

Currently, nutrient inputs do not appear to be a problem in Kilgaard Creek as they were low at all of the sampling sites (Appendices B-F). Low nutrient concentrations are characteristic of coastal B.C. streams. As anticipated, there was a general trend toward increasing nutrient concentrations at downstream sites. The most upstream site (Ward Road) often had the lowest ammonia, nitrite, nitrate and ortho-P concentrations with the values often being less than, or close to laboratory detection limits. Nutrient concentrations were often highest at Marshall Creek. This is not surprising since this site is the furthest downstream, is bordered by agricultural activities and is at the confluence with the degraded Marshall Creek. None of the nutrient concentrations exceeded the maximum (acute) criteria at any of the sites. Nitrite may have exceeded the average (chronic) criteria (0.02 mg/L) at the Marshall Creek site on the first sampling date, however, it is not known how long this nitrite concentration was maintained in Kilgaard Creek prior to this sampling date, nor what the chloride concentration in the water was which is necessary to determine the exact nitrite criteria. The elevated nitrite concentration did not persist until the next

sampling date, one month later, when the nitrite concentration was found to be undetectable at <0.002mg/L.

### 6.5 Total Suspended Solids and Turbidity

Two common patterns seen in water quality data from altered watersheds is that siltation tends to increase with precipitation as well as with movement downstream in a watershed. Both the TSS and turbidity data reflect these patterns (Figures 11 and 12). All suspended sediment concentrations (measured as non-filterable residue) and turbidity values were lowest and quite similar, at all sites on the first and last sampling dates which corresponded with dry conditions prior to sampling. The most upstream site, Ward Road, had relatively consistent TSS and turbidity values on all dates, regardless of precipitation. When sampling occurred during wet weather (the three middle sampling dates), suspended sediment and turbidity increased at the other sites, although to different levels. TSS and turbidity values at the three more downstream sites on these dates increased by up to approximately 40 times that of the Ward Road site.

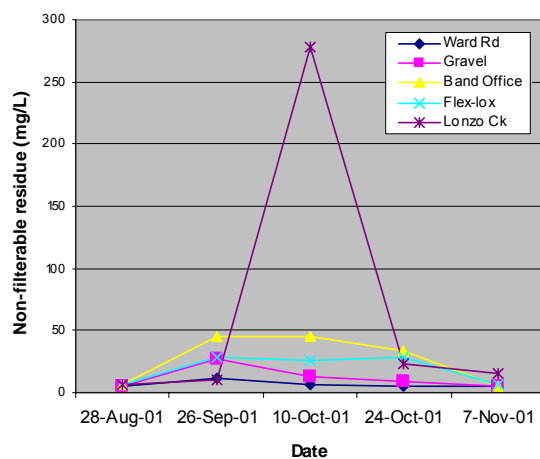


Figure 11: Total suspended solids (NFR) at each site.

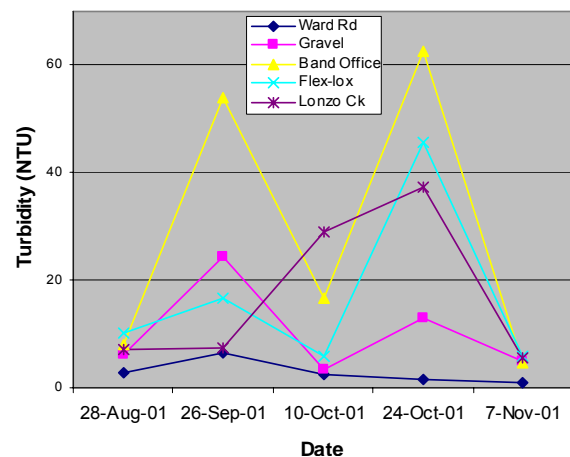


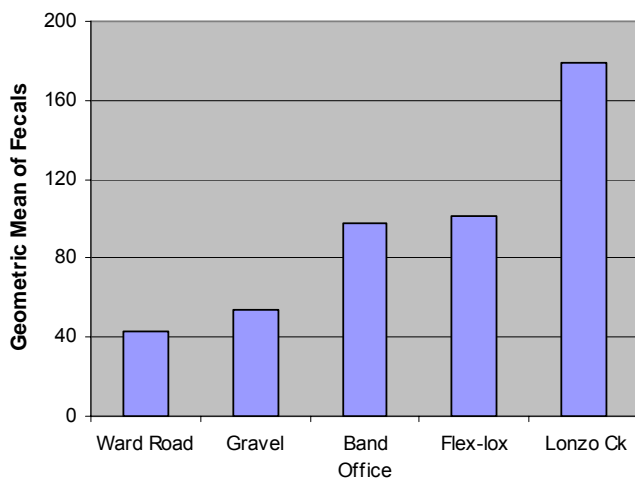
Figure 12: Turbidity at each site.

Higher turbidity and suspended sediments are common downstream of developed areas and road surfaces as was seen in Kilgaard Creek. The most upstream sites consistently had the lowest suspended sediment measurements. These values were relatively consistent on all of the sampling dates at these sites. Downstream, however, the values of these parameters increased with the Band Office site often having the highest TSS and turbidity values on the wet weather dates. Consequently, the higher values downstream of the more residential and industrial locations near the band office, Flex-lox Industries and Marshall Creek sites are likely due to the surface runoff they receive from roadways, residential, agricultural and industrial areas. The peak TSS value occurred at Marshall Creek on October 10<sup>th</sup> which was elevated nearly six times above the next highest value. There was no corresponding peak in turbidity nor in TSS at the other sites on this date. As this only occurred at this most downstream site located near Kilgaard Creek's confluence with Marshall Creek, it is possible that Marshall Creek was the actual source of this elevated sediment measurement at this site.

As periods of elevated sedimentation may be common and natural in coastal B.C. waterways, the B.C. water quality criteria are utilized to determine whether anthropogenic elevations may be detrimental to aquatic life. Both suspended sediment and turbidity exceeded their respective criteria at the gravel site (on September 26<sup>th</sup>), the band office and Flex-lox sites (on September 26<sup>th</sup>, October 10<sup>th</sup> and October 24<sup>th</sup>) and at the Marshall site (on October 10<sup>th</sup>, October 24<sup>th</sup> and November 7<sup>th</sup>). Turbidity was also exceeded at the gravel site on October 24<sup>th</sup>. This shows that there are consistently sedimentation

problems at the three most downstream sites and that these are mostly associated with rainfall events. As the impact of sediment pulses depends on both the concentration and duration of pulse, more regular sampling would be necessary to distinguish what any impacts may be. Since grab sampling does not necessarily capture the peak flow of a storm event, the turbidity and suspended sediment results may not reflect the actual maximum sediment concentrations that occurred in the waterbody. Actual stream conditions may thus have been even less favourable for aquatic life than those recorded.

Specific conductance is a measurement of the water's ability to conduct an electrical current and it increases as the amount of dissolved minerals in the water increases. Specific conductance in streams is primarily affected by the geology of the area, however, discharges into streams can also affect the measurement. The specific conductance measurements in Kilgaard Creek correspond with the sediment results, as the lowest numbers were measured at the Ward Road site and the higher numbers downstream. There are no criteria for specific conductance, however, the values do indicate that there are more ions in the water at downstream sites than at upstream sites. The results also showed that specific conductance values were higher on the sampling dates corresponding with wet weather events.



## 6.6 Bacteriology

There was a general trend of increasing fecal coliform concentrations at the more downstream sites in Kilgaard Creek (Figure 13). Fecal coliform concentrations in individual samples were also found to be highest during the three wet weather sampling dates (Appendices B-F). Rainfall flowing over land can carry fecal matter such as pet feces and manure into surface waters as well as down into the groundwater (depending on the local geology). Bacteriological contamination is thus often strongly correlated with rainfall.

Figure 13: Fecal coliform concentrations at each site.

The highest fecal coliform concentration in the Kilgaard Creek samples occurred at the band office site on October 10<sup>th</sup> (440 cfu/100mL). However, on September 26<sup>th</sup> at all sites and on October 10<sup>th</sup> at the Marshall site, the concentrations may have been even higher. As the lab results only recorded that there were 'greater than 300 cfu/100mL', it is not known what the actual fecal coliform concentrations were on these dates.

Water quality criteria for fecal coliform are based on water uses. As there are no criteria set to protect aquatic life, the most common criteria used is to protect human uses of the waters. As Kilgaard Creek is not a drinking water source, the next most stringent criteria is set to protect contact recreation. Elder members of the Sumas First Nations swam in the creek as children. However, many of the local residents now believe that water quality has declined and this may not be a common use anymore (E-Team 2001). Samples were not compared to this criteria as it requires that five samples be collected within 30 days.

## 6.7 Metals

The surface water concentrations of many of the metals were quite low at all of the sites. In general, many of the metals analyzed (aluminum, antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, magnesium, molybdenum, nickel, strontium, thallium, tin, uranium, vanadium and zinc) increased in concentration at downstream sites in Kilgaard Creek. Many of these are natural

constituents of coastal B.C. waters and are at normal background levels. This assessment thus focused on those metals which exceeded, or were approaching, their respective criteria for the protection of aquatic life.

### 6.7.1 Iron, Aluminum, Chromium

The concentrations of most metals were low at the Ward Road site. A few metals exceeded (or may have exceeded) their criteria at all sites. Iron was consistently elevated in Kilgaard Creek with concentrations exceeding the maximum working guideline (0.3 mg/L) on all dates at all sites (Figure 14). The site with the highest iron concentration varied with date. This data suggests that there is likely no one large point source of iron and the iron elevations may not be indicative of anthropogenic impacts. These high iron concentrations are similar to those in other coastal B.C. streams which are naturally iron-rich.

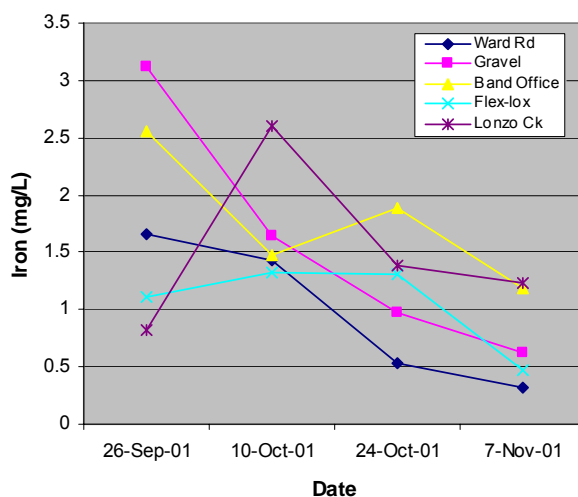


Figure 14: Iron concentrations at each site.

Total aluminum concentrations in Kilgaard Creek were greater than the maximum (0.1 mg/L dissolved Al) and average 30-day criteria (0.05 mg/L dissolved Al) for dissolved aluminum at most sites on many of the dates (Figure 15). Ward Road had the lowest aluminum concentrations, only exceeding the acute criteria on the first sampling date and the chronic criteria on two sampling dates. At the other sites, either the acute or chronic criteria was exceeded on each date. This data is not conclusive regarding whether the criteria were exceeded, however, since aluminum was measured as total aluminum, yet the criteria are based on dissolved aluminum concentrations. The value for total aluminum will be higher than the dissolved fraction and thus when measurements of total aluminum exceed that of the dissolved aluminum criteria, it does not necessarily mean that there is an exceedance of the dissolved criteria value. In order to determine how much of the total is dissolved, further analyses would need to be conducted.

Chromium concentrations were also elevated at some sites on some dates. Chromium concentrations were very high at the middle three sampling sites (gravel, band office and flex-lox sites) on the first date (Figure 16). The concentrations were 36 to 64 times higher at these sites than at the Ward Road site on the same sampling date. Chromium concentrations may have exceeded the maximum working guideline (1 ug/L Cr<sup>+6</sup>; 9 ug/L Cr<sup>+3</sup>) at all sites on the first three sampling dates (first two dates at Ward Road) depending upon the species of chromium present. As the criteria is based upon the specific species of chromium present, it is not possible to be certain whether the guideline was exceeded or not. Hexavalent chromium (+6) is the most common chromium species found in surface waters. This is also the more toxic form.

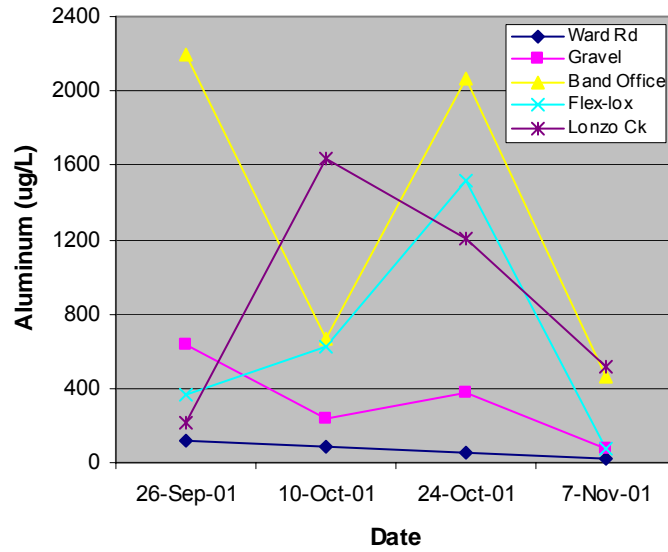


Figure 15: Aluminum concentrations at each site.

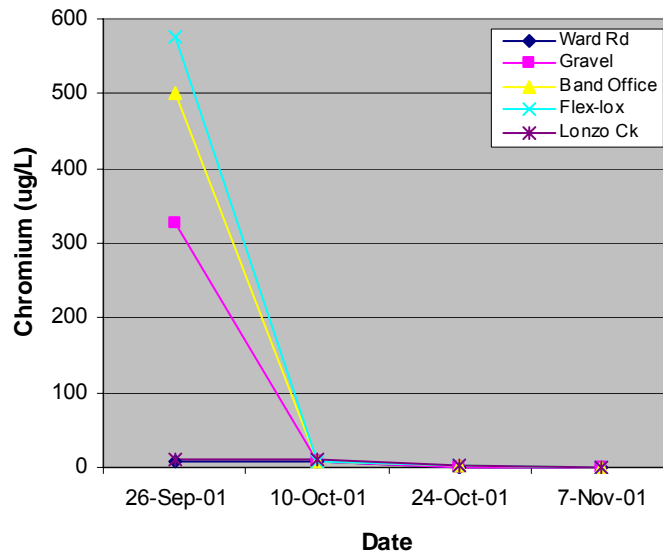


Figure 16: Chromium concentrations at each site.

Iron, aluminum and chromium were the only metals elevated in concentrations enough to have, or possibly have, exceeded their respective guidelines at the Ward Road site. These elevations at this site could be a result of natural conditions due to the local geology, upstream activities or surface runoff from the road. Since the elevations of aluminum and chromium did increase with movement downstream, it appears that there may be a source or an input of these metals into Kilgaard Creek. Aluminum concentrations peaked at the band office and Marshall Creek sites, both downstream of gravel extraction or mining operations while the chromium concentrations were greatly elevated at the band office, Flex-lox and Marshall on just one date. The man-induced exposure of geologic formations (i.e. the gravel extraction, mining activities on Sumas Mountain) may result in elevations in the metals (i.e. aluminum)

content of local waters. These areas, however, are also likely to receive road surface runoff due to the proximity to Sumas Mountain Road. Further sampling would be needed to investigate the chromium elevations measured on the first date. Any such sampling should include chromium speciation being conducted.

### 6.7.2 Selenium

In general, selenium concentrations increased over the sampling period. There was a peak in concentration at all sites downstream of Ward Road on October 24<sup>th</sup> and November 7<sup>th</sup> (Figure 17). The concentration at the gravel site was equal to or greater than the criteria (2.0 µg/L) on these dates. As this is a chronic criteria, and it is not known how long the selenium concentration was elevated, it is not known whether these conditions persisted long enough to have chronic impacts on aquatic life. This was the only potential selenium exceedance in Kilgaard Creek during sampling, although the concentrations did approach the criteria on some dates at the other downstream sites. Selenium was the only metal of concern which did not exhibit a positive trend in concentration with storm events.

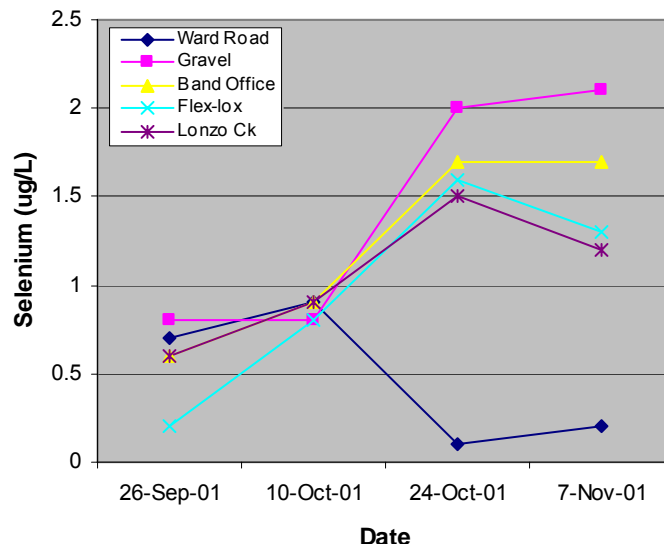


Figure 17: Selenium concentrations at each site.

### 6.7.3 Arsenic

The concentration of arsenic was low at most sites on most dates. The maximum working guideline (5.0 µg/L) was exceeded at the band office site on September 26<sup>th</sup> and at the Flex-lox site on this date and October 10<sup>th</sup> (Figure 18). The other sites however had much lower arsenic concentrations than the Flex-lox site on these two dates suggesting that this is not a natural elevation.

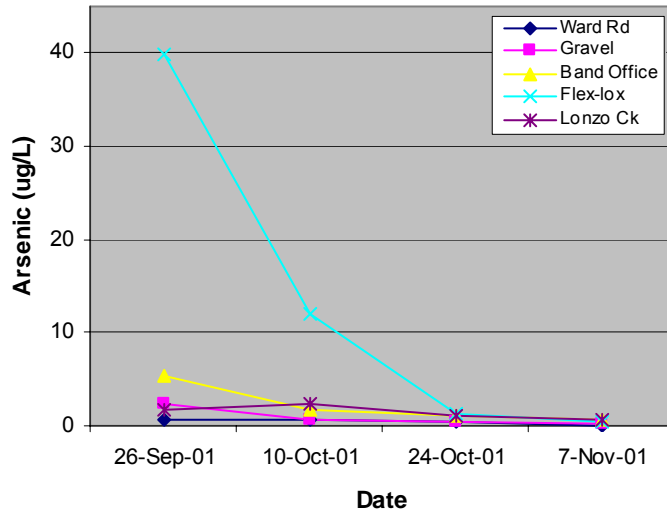


Figure 18: Arsenic concentrations at each site.

6.7.4 Cadmium, Copper, Zinc

Besides iron, aluminum and chromium, cadmium was also elevated at the three most downstream sites on some dates (Figure 19). Total cadmium concentrations exceeded the maximum working guidelines (0.01 - 0.06 ug/L depending upon water hardness) on one or both of the first two sampling dates at these sites. The highest cadmium concentrations were measured at the Flex-lox site on both of these dates. Cadmium concentrations were below detection limits at most sites on the last two sampling dates, and near or below detection on all dates at the two upstream sites. This data again suggests that there may be a source upstream of this site.

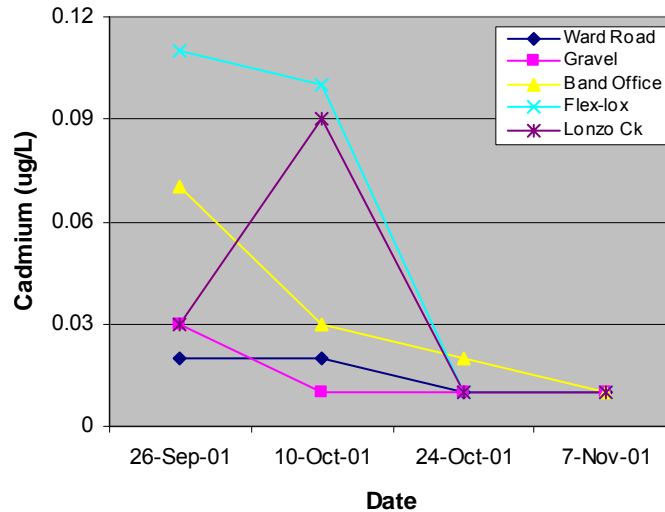


Figure 19: Cadmium concentrations at each site.



Copper is usually found in trace amounts in B.C. waters. In Kilgaard Creek, copper concentrations exceeded the chronic criteria at Flex-lox on the first two dates (Figure 20) as other metals (Figures 18, 19 and 21). By the last sampling date, the concentration was closer to the value at Ward Road, and was lower than at the Band Office. Elevated copper concentrations in the local surface waters could come from mining operations and/or urban development.

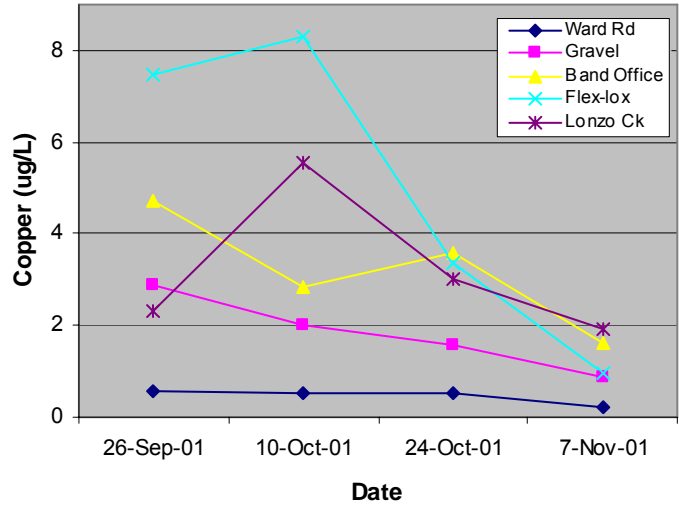


Figure 20: Copper concentrations at each site.

Zinc concentrations were low at most sites on most dates. At the Flex-lox site on the first two dates, however, the maximum criteria (40-115 ug/L) was exceeded (Figure 21). At the gravel site, the chronic criteria (33-115 ug/L) was exceeded on the first date. It is not known, however, how long these conditions lasted and whether the chronic criteria at the gravel site was actually exceeded. The values at the Flex-lox site, however, were 6 - 8 times higher than the next highest concentrations on these dates and exceeded the maximum criteria. As these values were so much higher only at this site on the two dates, it appears that there is a source of this metal entering Kilgaard Creek upstream of Flex-lox.

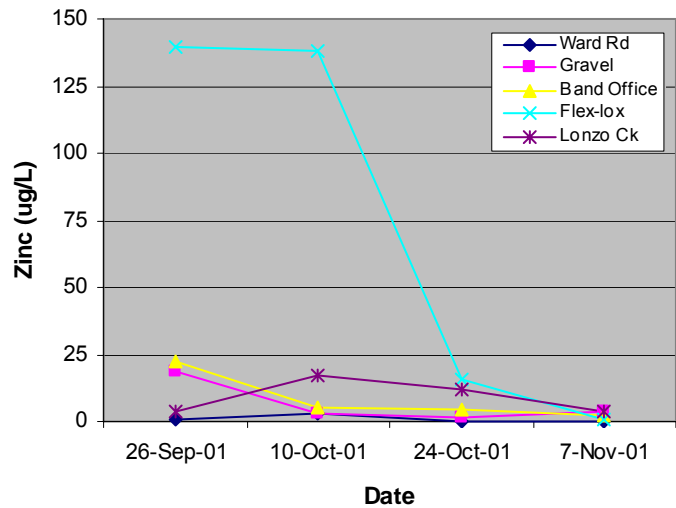


Figure 21: Zinc concentrations at each site.

## 6.8 Summary

The water quality sampling in the Kilgaard Creek found that:

- **Water temperature** was greater than the criteria for coho spawning in the late summer at all sites. It could be anticipated that future development in the watershed which removes riparian vegetation or increases the amount of surface runoff entering the creek may result in further increases in water temperature, especially in the downstream reaches. This is a potential stressor to aquatic organisms including salmonids.
- **Dissolved oxygen** concentrations were never below the instantaneous minimum for adult salmonids at any of the sites. However, the instantaneous minimum criteria for buried embryo and alevins was not reached at the Ward Road site on three dates. The low DO conditions are a greater concern in the lower reaches of Kilgaard Creek that are accessible to fish. These problems could become exacerbated in the future with more development and altered land use in the watershed resulting in the removal of riparian vegetation and increased surface runoff. Greater runoff could be expected to result in elevated water temperatures and more organic matter input, both of which can increase the likelihood of eutrophication and subsequently lower the DO concentrations.
- **Nutrient enrichment** does not currently appear to be a problem in Kilgaard Creek. Nutrient concentrations were low at all sites, however, concentrations did increase downstream indicating the contribution of surface runoff. Phosphorous, nitrate-nitrite and ammonia have all been found to exceed guidelines in other Sumas Prairie waterways (Schreier 1998; Nener and Wernick 1997). These problems are most often attributed to poor manure management practices in the region. Although nutrients do not appear to be a problem in Kilgaard Creek at this time, further development of the watershed would likely lead to greater nutrient inputs to Kilgaard Creek.
- **Total suspended sediment** and **turbidity** were both higher at downstream sites and when samples were collected during precipitation events. Criteria were exceeded at the four downstream sites most often during rain events. These results suggest that stormwater runoff may be consistently resulting in TSS and turbidity problems in Kilgaard Creek.
- **Fecal coliform** concentrations increased at the downstream sampling sites, however, results were likely still below the recreational contact criteria of a geometric mean of 200 fecals/100 mL. As Kilgaard Creek water uses are unconfirmed and five samples were not collected within 30 days, it is not possible to determine whether any users are at risk. The bacterial elevations are consistent with elevations that could be expected from stormwater runoff over a developed landscape.
- **Iron** concentrations were elevated beyond the maximum working guideline at all sites on all dates. This data suggests that there is no one point source of iron and that these elevations may be natural.
- **Aluminum** concentrations may have exceeded the acute and chronic criteria at most sites on many dates. Aluminum concentrations were very high at the three most downstream sites. Analyses for dissolved aluminum rather than total aluminum would need to be conducted to confirm the exceedance of the criteria.
- **Chromium** concentrations may have exceeded the maximum working guideline at all sites on the first two or three dates. Chromium concentrations at the three middle sites were very high on the first date, potentially suggesting an intermittent source of chromium.

- **Selenium** concentrations were elevated on the last two sampling dates (at all but the most upstream Ward Road site), and possibly exceeded the chronic criteria at the gravel site twice. Storm runoff thus may not be the source of the selenium in Kilgaard Creek.
- **Arsenic** concentrations exceeded the maximum working guideline at the band office site (once) and at Flex-lox (twice). The arsenic concentrations at the Flex-lox site were much higher than at the other sites on the same dates, suggesting that there is a source of the arsenic upstream of this sampling site.
- **Cadmium** concentrations were elevated and exceeded the maximum working guidelines at the band office, Flex-lox and Marshall sites (twice). The highest concentrations were at the Flex-lox site suggesting that there may be a source upstream of this site.
- **Copper** concentrations possibly exceeded the chronic criteria at the Flex-lox site, again suggesting a source of this metal upstream of this site.
- **Zinc** concentrations exceeded the maximum criteria at Flex-lox twice and the chronic criteria at the gravel site once. Again, the highest concentrations were measured at the Flex-lox site suggesting that there is a source upstream of this site.

## 7.0 CONCLUSIONS AND RECOMMENDATIONS

The elevations of some of the water quality parameters in Kilgaard Creek (temperature, TSS, fecals, nutrients, some metals) were typical of a drainage with reduced riparian functioning and with stormwater inputs from a developed landscape. Future sampling should consider:

- Summer and fall sampling for dissolved oxygen and temperature. Ideally, more frequent measurements of these parameters would be made to determine potential problem conditions and times for spawning and incubating coho and resident cutthroat trout. Automated monitoring would be a potential way of doing this however the costs would likely be prohibitive. A less expensive temperature thermister (records water temperature at pre-set intervals) could provide some beneficial data.
- Fall sampling for total suspended sediment and turbidity would be useful to better detail potentially detrimental storm-related problems. Again, automated sampling would be the ideal manner of accomplishing this, however, simply increasing the frequency of grab sampling would also provide useful data.

There were some surprising elevations of metal concentrations in the Kilgaard Creek water quality data, such as the high concentrations of arsenic, cadmium, copper and zinc upstream of the Flex-lox site. These concentrations may be a concern for aquatic life and should be further investigated. Future sampling should consider:

- More frequent water quality sampling for metals during storm events (5 times in 30 days), in order to determine whether conditions may be present that may result in chronic problems for aquatic life.
- Metals analyses should include dissolved aluminum and chromium speciation analyses in order to determine whether these criteria are being exceeded in Kilgaard Creek.
- Sediment sampling in depositional areas in late summer in order to examine metal accumulation.

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## **APPENDIX A WATER QUALITY PARAMETERS**

### **Temperature**

Temperature is an important water quality parameter as it governs the rates of biological and chemical processes and the oxygen content of water. Consequently, aquatic species have preferred temperature ranges for optimal health and organisms living outside of these temperature ranges may become physiologically stressed. Different life stages of aquatic organisms may have different temperature requirements and susceptibilities to stress outside of these ranges. The reproductive stages of fish tend to be more sensitive than adults. Fish as well as benthic macroinvertebrates (insects) are both sensitive to water temperature and may move to seek out their optimal temperature ranges.

Temperature varies naturally with the width and depth of a water body. Water temperature is also influenced by its origins (whether from a glacier or lake), riparian vegetation, discharges and groundwater inputs. The removal of riparian vegetation reduces shading and therefore results in increases in water temperature. Groundwater inputs tend to be cool and reduce water temperature.

### **Dissolved Oxygen**

Dissolved oxygen (DO) is a measure of the amount of oxygen dissolved in water and it is essential to the respiratory metabolism of most aquatic organisms. Aquatic species have optimal DO ranges for optimal health. Organisms living outside of these DO ranges may become physiologically stressed which can ultimately lead to asphyxiation or suffocation. Different life stages of aquatic organisms may have different DO requirements and different susceptibilities to stress outside of these ranges. Early life stages of fish tend to be more sensitive than adults.

Natural sources of DO include aquatic plant photosynthesis and natural re-aeration from the atmosphere in areas of turbulent water such as waterfalls and rapids. The amount of oxygen dissolvable in water varies with temperature and altitude. DO concentrations are consequently subject to diurnal and seasonal fluctuations based on variations in temperature, photosynthetic activity and discharges. The measurements in this study were taken in the morning when readings are expected to be lowest due to the lack of photosynthesis overnight.

Dissolved oxygen is consumed during the decomposition of organic matter and thus oxygen depletion can be an indicator that some pollutants may be elevated in creeks and lakes. Where pollutants such as septic effluent, manure or fertilizer enter watercourses, a large amount of oxygen may be utilized by aerobic bacteria during its decomposition and, consequently, the DO concentration becomes depressed.

### **pH**

The pH of a substance indicates its alkalinity or acidity. It is measured on a scale between 0 and 14, with 7 being considered neutral. As the pH gets lower (below 7), acidity increases, and as the pH increases (above 7), alkalinity increases. pH affects many chemical and biological processes in the aquatic environment. Lethal effects of pH on aquatic life can occur at both high and low pH values. Aquatic organisms tend to have optimal pH ranges just as they have optimal temperature and DO ranges. Changes in the pH may affect physiological functions in aquatic organisms as well as other water quality parameters. The geological composition of surrounding lands and the pH of the surface waters or of precipitation determines the amount of chemicals that will dissolve in the water. A reduction in pH can allow toxic elements to become more available for uptake by plants and animals. High pH values tend to facilitate the solubilization of ammonia, heavy metals and salts which can be toxic to aquatic life.

## **Nutrients**

Nutrients such as nitrogen and phosphorus are normal components of aquatic ecosystems. In excess, however, nutrients may have detrimental impacts on aquatic life and harm the recreation and aesthetic values of water bodies.

### *Nitrate and Nitrite*

Nitrate is the most oxidized and stable form of nitrogen in water and the primary form of nitrogen used by plants. Excess nitrates and phosphorus can cause water quality problems by accelerating eutrophication. Eutrophication can result in a proliferation of aquatic plants and algae which can alter the aquatic plant and animal community. Dissolved oxygen levels may then be depleted when the plants or algae die, sink and decompose. As well, nitrate has been shown to be toxic to some amphibians (Nagpal *et al.* 1998). It can also be a problem to babies when consumed as it gets converted to nitrite in their incompletely developed digestive tracts. The nitrite can then combine with hemoglobin in the blood to form methemoglobin which does not bind oxygen (Nordin and Pommen 1986). Consequently, the blood is less capable of absorbing oxygen and this lack of oxygen can be fatal to infants in what has been referred to as the blue baby syndrome.

Nitrite is an intermediate form of nitrogen in the nitrogen cycle which is readily oxidized. It can be used as a nutrient source by plants and is normally present in only minute quantities in surface waters. When at elevated levels it can cause proliferation of aquatic plant growth or eutrophication. This results in prolific algal growths that can have deleterious impacts on other aquatic life, drinking water supplies, and recreation.

Nitrite is toxic to aquatic life at relatively low concentrations.

The main sources of nitrate and nitrite in surface waters are fertilizers, waste from humans, farm animals, domestic pets and wildlife, urban development and industrial effluents.

### *Ammonia*

Ammonia is the most reduced inorganic form of nitrogen in water and can be in the form of dissolved ammonia or the ammonium ion. Dissolved ammonia is highly toxic to fish. The presence of these two forms of ammonia is controlled by temperature, dissolved oxygen and pH. Higher temperature and pH, and lower DO increase the amount of ammonia in water and thus toxicity to fish. Excess ammonia contributes to eutrophication of water bodies.

Ammonia may be present naturally due to the decomposition of organic matter. It may also be present due to human activities such as from animal manure, fertilizers, septic tanks and urban runoff.

### *Phosphorous*

Phosphorus is an essential plant nutrient and is often the most limiting nutrient to plant growth in freshwater. It is rarely found in significant concentrations in surface waters. As a result, even small increases in phosphorus can cause extreme proliferations of plant and algal growths. Inputs of phosphorus is the prime contributing factor to eutrophication in most freshwater systems. Orthophosphate is a measure of the inorganic oxidized form of soluble phosphorus and is the form that is most readily available for uptake during photosynthesis. High concentrations generally occur in conjunction with algal blooms.

Sources of phosphorous to the aquatic environment include the drainage of fertilized land, urban developments (particularly where detergents are used), rock leaching and the decomposition of organic matter.

### **Suspended Sediment**

Suspended sediment in watercourses can come from natural and anthropogenic sources. Some systems such as those that are glacially fed, are often naturally turbid for at least part of the year and the aquatic organisms native to these systems are adapted to these conditions. Detrimental effects of suspended sediment in water may occur when the amount of sediment increases, the timing it occurs at changes, the frequency with which sediment loading occurs at changes or the duration of the loading increases. Land activities such as agriculture, forestry and mining are often the greatest contributors of suspended sediment into surface waters. Riparian vegetation removal for any type of development also influences suspended sediment concentrations. Rain events often result in increases in suspended sediment in watercourses as stormwater runoff picks up particles on the land and transports them into streams.

High concentrations of suspended sediment in the water column may have many detrimental impacts on aquatic life. In fish, it can induce physiological stress, clog gills, increase respiration rates, reduce feeding rates or success, or cause the abandonment of cover areas. Sediment-laden water can also destroy spawning grounds, smother fish eggs, restrict light from reaching aquatic plants and harm aquatic invertebrates by reducing their feeding rates and success, causing increased drift and changing the community structure. Sediment pulses into water can also interfere with water disinfection technologies and be aesthetically unappealing.

Specific conductance is a measurement of the water's ability to conduct an electrical current and it increases as the amount of dissolved minerals in the water increases. Specific conductance in streams is affected primarily by the geology of the area, however, discharges into streams can also affect the measurement.

### **Bacteriology**

Fecal coliforms are the traditional microbiological indicator examined to determine bacterial contamination of water. Fecal coliforms are microscopic organisms found in the intestines of humans and other warm-blooded animals. Presence of the bacteria in a water sample indicates that other harmful pathogenic organisms which also originate in human and animal digestive systems may also be present in the water. Consequently, swimming in fecal contaminated water or eating shellfish grown in contaminated waters may present a health risk to humans. Recreation in fecal contaminated waters may cause gastrointestinal illnesses from ingestion, and skin, ear or eye infections from immersion. As well, fecal contaminated water may pose a threat to the use of the water for livestock watering and irrigation. Elevated fecal bacteria can also increase both water turbidity and the oxygen demand in the water.

Sources of fecal contamination include human, pet, farm animal and wildlife wastes. Failing septic systems and runoff from manure piles or fields fertilized with manure may contaminate surrounding surface water bodies or groundwater. Wells may be contaminated if groundwater becomes impacted or if contaminated surface water flows into well heads.

### **Metals**

The geology of an area affects the constituents, which may be dissolved in local waters. As a result, some metals may naturally occur at elevated levels in surface waters. Native aquatic life in such systems are adapted to living in these conditions. In some surface waters, metal concentrations can naturally occur at levels high enough to be toxic to aquatic life and consequently, these systems would be naturally devoid of aquatic life intolerant of these conditions. Anthropogenic activities which introduce metals or increase their concentrations beyond background levels can be harmful or lethal to aquatic life. Metals can exert acute or chronic toxic effects on aquatic organisms via their concentration in water and/or sediment. Aquatic organisms may absorb metals in the water column through their gills or through their skin.



## **APPENDIX A**

### **WATER QUALITY PARAMETERS**

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They could also ingest particles bound with metals. As organic matter has a high affinity for binding metals, the consistent loading of metals into a waterbody can result in the buildup of metals in sediment. These sediment-bound metals may exert harmful effects on the buried life stages of fish, on the benthic invertebrate community and on bottom feeders.

**APPENDIX B**  
**SAMPLE SITE 1 - Kilgaard Creek at Ward Road**

**APPENDIX B KILGAARD CREEK AT WARD ROAD WATER QUALITY DATA**

Ward Road	Aug 28/01	Sept 26/01	Oct 10/01	Oct 24/01	Nov 7/01	Average	Minimum	Maximum	Max Criteria	Avg Criteria
<b>Field Data</b>										
Temperature (°C)	14.6	13.5	8.5	7.5	5.9	10.0	5.9	14.6	depends on species and life stage <sup>1</sup>	
Dissolved Oxygen (mg/L)	7.48	7.23	8.01	9.26	10.62	8.52	7.2	10.6	depends on life stage <sup>1</sup>	
<b>Lab Data</b>										
pH (relative units)	7.46	7.39	7.78	7.97	7.96	7.71	7.4	8.0		
(NFR) (mg/L)	<5	11	7	<5	<5	6.6	7.0	11.0	used as control site	
Turbidity (NTU)	2.81	6.45	2.61	1.63	0.86	2.87	0.9	6.5	used as control site	
Specific Conductance	.	226	245	185	151	201.8	151.0	245.0		
N-Ammonia (mg/L)	0.034	<0.005	0.005	0.007	0.007	0.012	0.0	0.0	depends on pH & temperature each day <sup>1</sup>	
N-Nitrite (mg/L)	<0.002	<0.002	<0.002	<0.002	<0.002	<0.002	0.0	0.0	0.06 mg/L <sup>1</sup>	< 0.02 mg/L <sup>1</sup>
N-Nitrate (mg/L)	0.4	0.002	<0.002	0.01	0.232	0.129	0.0	0.4	200 mg/L <sup>1</sup>	< 40 mg/L <sup>1</sup>
P-Ortho-phosphate (mg/L)	0.002	0.003	0.001	0.002	<0.001	0.002	0.0	0.0		
Fecal coliform (col./100mL)	64	>300	100	13	6	43	6.0	100.0		
<b>Metals</b>										
Calcium (mg/L)	.	21.2	23.4	15.7	12.9	18.3	12.9	23.4	> 8 mg/L - low sensitivity to acid inputs <sup>2</sup>	
Iron (mg/L)	.	1.654	1.426	0.531	0.327	0.985	0.3	1.7	0.3 mg/L <sup>2</sup>	
Phosphorus (mg/L)	.	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.0		
Potassium (mg/L)	.	2.3	2	1.4	0.8	1.6	0.8	2.3		
Silicon (mg/L)	.	6.99	6.75	5.3	4.62	5.92	4.6	7.0		
Sodium (mg/L)	.	14.5	18.1	12.6	10.6	14.0	10.6	18.1		
Sulphur (mg/L)	.	1.67	2.26	1.86	2.28	2.02	1.7	2.3		
Titanium (mg/L)	.	0.003	0.003	<0.002	<0.002	0.003	0.0	0.0	100 ug/L <sup>2</sup>	
Aluminum (ug/L)	.	120	81.5	49	25.7	69.1	25.7	120.0	0.1 mg/L Dissolved <sup>1</sup>	0.05 mg/L Dissolved <sup>1</sup>
Antimony (ug/L)	.	0.05	0.199	0.026	0.018	0.073	0.0	0.2	20 ug/L <sup>2</sup>	
Arsenic (ug/L)	.	0.7	0.6	0.4	0.1	0.5	0.1	0.7	5.0 ug/L <sup>1</sup>	
Barium (ug/L)	.	31.45	28.65	19.78	14.83	23.68	14.8	31.5	5 mg/L <sup>2</sup>	
Beryllium (ug/L)	.	0.015	0.015	0.03	<0.002	0.016	0.0	0.0	5.3 ug/L <sup>2</sup>	
Bismuth (ug/L)	.	0.02	0.13	<0.02	<0.02	0.05	0.0	0.1		
Boron (ug/L)	.	48	51	28	25	38.0	25.0	51.0		
Cadmium (ug/L)	.	0.02	0.02	<0.01	<0.01	0.02	0.0	0.0	0.01 - 0.06 ug/L <sup>2</sup>	
Chromium (ug/L)	.	9	6.7	0.9	0.5	4.3	0.5	9.0	1 ug/L for Cr <sup>+6</sup> ; 9 ug/L for Cr <sup>+3</sup> <sup>2</sup>	
Cobalt (ug/L)	.	0.41	0.294	0.179	0.119	0.251	0.1	0.4	0.9 ug/L <sup>2</sup>	
Copper (ug/L)	.	0.56	0.53	0.51	0.22	0.46	0.2	0.6	2-14 ug/L <sup>1*</sup>	2-5 ug/L <sup>1*</sup>
Lead (ug/L)	.	0.12	0.1	0.03	<0.01	0.07	0.0	0.1	10-197 ug/L <sup>1*</sup>	4-11 ug/L <sup>1*</sup>
Lithium (ug/L)	.	0.12	0.1	0.06	0.11	0.10	0.1	0.1		
Magnesium (ug/L)	.	6678.75	7381.86	5224.98	4117.35	5850.7	4117.4	7381.9		
Manganese (ug/L)	.	135.152	88.651	36.249	24.461	71.128	24.5	135.2	0.8 - 2.2 mg/L <sup>1*</sup>	0.7-1.3 mg/L <sup>1*</sup>
Molybdenum (ug/L)	.	0.44	0.44	0.18	0.16	0.31	0.2	0.4		
Nickel (ug/L)	.	1.95	1.77	1.35	0.86	1.48	0.9	2.0	25 -	
Selenium (ug/L)	.	0.7	0.9	<0.2	<0.2	0.5	0.7	0.9	2.0 ug/L <sup>1</sup>	
Silver (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0		
Strontium (ug/L)	.	128.507	128.352	116.466	70.666	111.00	70.7	128.5		
Thallium (ug/L)	.	0.004	0.008	<0.002	0.013	0.007	0.0	0.0		
Tin (ug/L)	.	0.06	0.15	<0.01	<0.01	0.06	0.1	0.2		
Uranium (ug/L)	.	0.041	0.051	0.027	0.015	0.034	0.0	0.1		
Vanadium (ug/L)	.	2.65	1.98	0.5	0.29	1.36	0.3	2.7		
Zinc (ug/L)	.	0.5	3.2	0.1	<0.1	1.0	0.1	3.2	33 - 265 ug/L <sup>1*</sup>	7.5 - 240 ug/L <sup>1*</sup>
Hardness (calculated)		80.5	88.9	60.6	49.1	69.8	49.1	88.9		
<b>number in red are calculated from the geometric mean</b>				1 = BC Criteria						
<b>yellow shaded boxes - number exceeds maximum criteria or guideline</b>				2 = BC Compendium of Guidelines						
<b>blue shaded boxes - number exceeds average criteria or guideline</b>				3 = CCME WQ Guidelines						
				* depends upon hardness						

**APPENDIX C**  
**SAMPLE SITE 2 - Kilgaard Creek near Gravel extraction**

**APPENDIX C KILGAARD CREEK NEAR GRAVEL EXTRACTION WATER QUALITY DATA**

Gravel	Aug 28/01	Sept 26/01	Oct 10/01	Oct 24/01	Nov 7/01	Average	Minimum	Maximum	Max Criteria	Avg Criteria
<b>Field Data</b>										
Temperature (°C)	14.6	13.5	9.4	8.2	7.3	10.6	7.3	14.6	depends on species and life stage <sup>1</sup>	
Dissolved Oxygen (mg/L)	10.18	11.31	11.27	12.02	12.11	11.38	10.2	12.1	depends on life stage <sup>1</sup>	
<b>Lab Data</b>										
pH (relative units)	8.2	8.26	8.27	8.35	8.31	8.28	8.2	8.4		
(NFR) (mg/L)	<5	27	13	9	<5	11.8	9.0	27.0	10 mg/L over control	
Turbidity (NTU)	6.22	24.4	3.42	13.1	5.02	10.43	3.4	24.4	8 NTU over control	
Specific Conductance	436	325	345	364	322	358.4	322.0	436.0		
N-Ammonia (mg/L)	.	.	0.011	<0.005	0.014	0.010	0.0	0.0	depends on pH & temperature each day <sup>1</sup>	
N-Nitrite (mg/L)	.	.	<0.002	0.002	0.004	0.003	0.0	0.0	0.06 mg/L <sup>1</sup>	< 0.02 mg/L <sup>1</sup>
N-Nitrate (mg/L)	.	.	0.298	0.78	1.07	0.72	0.3	1.1	200 mg/L <sup>1</sup>	< 40 mg/L <sup>1</sup>
P.Ortho-phosphate (mg/L)	.	.	0.005	0.002	<0.001	0.003	0.0	0.0		
Fecal coliform (col./100mL)	42	>300	90	38	11	45	11.0	90.0		
<b>Metals</b>										
Calcium (mg/L)	.	22.9	24.1	27.3	20.6	23.7	20.6	27.3	> 8 mg/L - low sensitivity to acid inputs <sup>2</sup>	
Iron (mg/L)	.	3.125	1.65	0.977	0.629	1.595	0.6	3.1	0.3 mg/L <sup>2</sup>	
Phosphorus (mg/L)	.	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.0		
Potassium (mg/L)	.	2.6	2.7	2.9	2.2	2.6	2.2	2.9		
Silicon (mg/L)	.	6.53	4.91	5.35	4.11	5.23	4.1	6.5		
Sodium (mg/L)	.	29.1	34.6	31.5	28.8	31.0	28.8	34.6		
Sulphur (mg/L)	.	5.96	7.36	11.92	9.46	8.68	6.0	11.9		
Titanium (mg/L)	.	0.023	0.008	0.008	0.003	0.011	0.0	0.0	100 ug/L <sup>2</sup>	
Aluminum (ug/L)	.	632	237.8	375.3	74	329.8	74.0	632.0	0.1 mg/L Dissolved <sup>1</sup>	0.05 mg/L Dissolved <sup>1</sup>
Antimony (ug/L)	.	0.082	0.04	0.088	0.047	0.064	0.0	0.1	20 ug/L <sup>2</sup>	
Arsenic (ug/L)	.	2.3	0.6	0.5	0.3	0.9	0.3	2.3	5.0 ug/L <sup>1</sup>	
Barium (ug/L)	.	63.73	53.79	55.94	46.85	55.08	46.9	63.7	5 mg/L <sup>2</sup>	
Beryllium (ug/L)	.	0.028	0.005	0.018	<0.002	0.01	0.0	0.0	1 mg/L <sup>2</sup>	
Bismuth (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0	5.3 ug/L <sup>2</sup>	
Boron (ug/L)	.	131	156	156	193	159.0	131.0	193.0		
Cadmium (ug/L)	.	0.03	0.01	<0.01	<0.01	0.02	0.0	0.0	0.01 - 0.06 ug/L <sup>2*</sup>	
Chromium (ug/L)	.	327.3	7	1.1	0.6	84.0	0.6	327.3	1 ug/L for Cr <sup>+6</sup> ; 9 ug/L for Cr <sup>+3</sup> <sup>2</sup>	
Cobalt (ug/L)	.	0.708	0.339	0.355	0.193	0.399	0.2	0.7	0.9 ug/L <sup>2</sup>	
Copper (ug/L)	.	2.88	2.03	1.56	0.86	1.83	0.9	2.9	2-14 ug/L <sup>1*</sup>	2-5 ug/L <sup>1*</sup>
Lead (ug/L)	.	0.57	0.18	0.24	<0.01	0.25	0.2	0.6	10-197 ug/L <sup>1*</sup>	4-11 ug/L <sup>1*</sup>
Lithium (ug/L)	.	0.34	0.21	0.69	0.64	0.47	0.2	0.7		
Magnesium (ug/L)	.	9270.78	9927.89	11116	8951.7	9816.6	8951.7	11116.0		
Manganese (ug/L)	.	90.042	55.911	27.036	26.175	49.791	26.2	90.0	0.8 - 2.2 mg/L <sup>1*</sup>	0.7-1.3 mg/L <sup>1*</sup>
Molybdenum (ug/L)	.	0.4	0.35	0.74	0.46	0.49	0.4	0.7		
Nickel (ug/L)	.	2.7	2.21	2.08	1.18	2.04	1.2	2.7	25 -	
Selenium (ug/L)	.	0.8	0.8	2	2.1	1.4	0.8	2.1	2.0 ug/L <sup>1</sup>	
Silver (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0		
Strontium (ug/L)	.	126.731	128.601	153.617	107.116	129.02	107.1	153.6		
Thallium (ug/L)	.	0.017	0.007	0.007	0.018	0.012	0.0	0.0		
Tin (ug/L)	.	0.04	0.05	0.03	<0.01	0.04	0.0	0.1		
Uranium (ug/L)	.	0.175	0.179	0.323	0.235	0.228	0.2	0.3		
Vanadium (ug/L)	.	86.64	2.51	1.25	0.75	22.79	0.8	86.6		
Zinc (ug/L)	.	18.8	2.8	1.8	4	6.9	1.8	18.8	33 - 265 ug/L <sup>1*</sup>	7.5 - 240 ug/L <sup>1*</sup>
Hardness (calculated)		95.5	100.9	113.9	88.5	99.7	88.5	113.9		
<p>number in red are calculated from the geometric mean</p> <p>yellow shaded boxes - number exceeds maximum criteria or guideline</p> <p>blue shaded boxes - number exceeds average criteria or guideline</p>										

**APPENDIX D**  
**SAMPLE SITE 3 - Kilgaard Creek behind Band Office**

**APPENDIX D KILGAARD CREEK BEHIND THE BAND OFFICE WATER QUALITY DATA**

Band Office	Aug 28/01	Sept 26/01	Oct 10/01	Oct 24/01	Nov 7/01	Average	Minimum	Maximum	Max Criteria	Avg Criteria
<b>Field Data</b>										
Temperature (°C)	14.9	13.6	9.7	8.4	7.7	10.9	7.7	14.9	depends on species and life stage <sup>1</sup>	
Dissolved Oxygen (mg/L)	10.5	10.8	11.75	12.7	13.05	11.76	10.5	13.1	depends on life stage <sup>1</sup>	
<b>Lab Data</b>										
pH (relative units)	8.39	8.43	8.4	8.41	8.36	8.40	8.4	8.4		
(NFR) (mg/L)	7	45	45	33	<5	27.0	7.0	45.0	10 mg/L over control	
Turbidity (NTU)	8.14	54.1	16.8	62.5	4.71	29.25	4.7	62.5	8 NTU over control	
Specific Conductance	558	498	529	415	359	471.8	359.0	558.0		
N-Ammonia (mg/L)	.	.	0.007	<0.005	0.015	0.009	0.0	0.0	depends on pH & temperature each day <sup>1</sup>	
N-Nitrite (mg/L)	.	.	0.002	0.002	0.003	0.002	0.0	0.0	0.06 mg/L <sup>1</sup>	< 0.02 mg/L <sup>1</sup>
N-Nitrate (mg/L)	.	.	0.248	0.77	1.07	0.70	0.2	1.1	200 mg/L <sup>1</sup>	< 40 mg/L <sup>1</sup>
P.Ortho-phosphate (mg/L)	.	.	0.011	0.004	0.002	0.006	0.0	0.0		
Fecal coliform (col./100mL)	92	>300	440	68	11	153	11.0	440.0		
<b>Metals</b>										
Calcium (mg/L)	.	28.5	27.6	30	23.5	27.4	23.5	30.0	> 8 mg/L - low sensitivity to acid inputs <sup>2</sup>	
Iron (mg/L)	.	2.562	1.478	1.894	1.186	1.780	1.2	2.6	0.3 mg/L <sup>2</sup>	
Phosphorus (mg/L)	.	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.0		
Potassium (mg/L)	.	4.7	3.8	3.7	2.7	3.7	2.7	4.7		
Silicon (mg/L)	.	8.18	5.35	7.69	4.75	6.49	4.8	8.2		
Sodium (mg/L)	.	58.7	47.4	37.6	30.9	43.7	30.9	58.7		
Sulphur (mg/L)	.	12.44	11.47	14.1	11.11	12.28	11.1	14.1		
Titanium (mg/L)	.	0.056	0.021	0.034	0.02	0.033	0.0	0.1	100 ug/L <sup>2</sup>	
Aluminum (ug/L)	.	2195	>666	2068	458.3	1346.8	458.3	2195.0	0.1 mg/L Dissolved <sup>1</sup>	0.05 mg/L Dissolved <sup>1</sup>
Antimony (ug/L)	.	0.224	0.107	0.113	0.065	0.127	0.1	0.2	20 ug/L <sup>2</sup>	
Arsenic (ug/L)	.	5.4	1.7	1.1	0.6	2.2	0.6	5.4	5.0 ug/L <sup>1</sup>	
Barium (ug/L)	.	82.59	58.72	62.83	51.32	63.87	51.3	82.6	5 mg/L <sup>2</sup>	
Beryllium (ug/L)	.	0.05	0.015	0.052	<0.002	0.03	0.0	0.1	5.3 ug/L <sup>2</sup>	
Bismuth (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0		
Boron (ug/L)	.	343	263	194	209	252.3	194.0	343.0		
Cadmium (ug/L)	.	0.07	0.03	0.02	<0.01	0.03	0.0	0.1	0.01 - 0.06 ug/L <sup>2</sup>	
Chromium (ug/L)	.	500	7.7	3	0.7	127.9	0.7	500.0	1 ug/L for Cr <sup>+6</sup> ; 9 ug/L for Cr <sup>+3</sup> <sup>2</sup>	
Cobalt (ug/L)	.	0.862	0.496	0.777	0.491	0.657	0.5	0.9	0.9 ug/L <sup>2</sup>	
Copper (ug/L)	.	4.73	2.82	3.6	1.63	3.20	1.6	4.7	2-14 ug/L <sup>1*</sup>	2-5 ug/L <sup>1*</sup>
Lead (ug/L)	.	3.31	0.62	0.78	0.14	1.21	0.1	3.3	10-197 ug/L <sup>1*</sup>	4-11 ug/L <sup>1*</sup>
Lithium (ug/L)	.	1.69	0.8	1.31	0.8	1.15	0.8	1.7		
Magnesium (ug/L)	.	14314	12286	12161	9598.9	12090.0	9598.9	14314.0		
Manganese (ug/L)	.	60.879	63.465	33.998	43.857	50.550	34.0	63.5	0.8 - 2.2 mg/L <sup>1*</sup>	0.7-1.3 mg/L <sup>1*</sup>
Molybdenum (ug/L)	.	0.72	0.49	0.8	0.52	0.63	0.5	0.8		
Nickel (ug/L)	.	4.03	2.81	3.51	1.84	3.05	1.8	4.0	25 -	
Selenium (ug/L)	.	0.6	0.9	1.7	1.7	1.2	0.6	1.7	2.0 ug/L <sup>1</sup>	
Silver (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0		
Strontium (ug/L)	.	144.224	138.976	166.026	116.18	141.35	116.2	166.0		
Thallium (ug/L)	.	0.025	0.009	0.018	0.038	0.023	0.0	0.0		
Tin (ug/L)	.	0.11	0.23	0.09	0.05	0.12	0.1	0.2		
Uranium (ug/L)	.	0.492	0.299	0.419	0.26	0.368	0.3	0.5		
Vanadium (ug/L)	.	136.52	3.46	4.63	1.55	36.54	1.6	136.5		
Zinc (ug/L)	.	22.6	5.4	4.5	2.6	8.8	2.6	22.6	33 - 265 ug/L <sup>1*</sup>	7.5 - 240 ug/L <sup>1*</sup>
Hardness (calculated)		130.0	119.5	124.7	97.8	118.0	97.8	130.0		
<b>number in red are calculated from the geometric mean</b>										
<b>yellow shaded boxes - number exceeds maximum criteria or guideline</b>										
<b>blue shaded boxes - number exceeds average criteria or guideline</b>										

**APPENDIX E**  
**SAMPLE SITE 4 - Kilgaard Creek near Flex-Lox Industries**

**APPENDIX E KILGAARD CREEK NEAR FLEX-LOX INDUSTRIES WATER QUALITY DATA**

Flex-Lox	Aug 28/01	Sept 26/01	Oct 10/01	Oct 24/01	Nov 7/01	Average	Minimum	Maximum	Max Criteria	Avg Criteria
<b>Field Data</b>										0.0
Temperature (°C)	15	14.2	9.9	8.4	7.7	11.0	7.7	15.0	depends on species and life stage <sup>1</sup>	
Dissolved Oxygen (mg/L)	10.45	10.69	11.45	11.9	13.02	11.50	10.5	13.0	depends on life stage <sup>1</sup>	
<b>Lab Data</b>										
pH (relative units)	8.34	8.35	8.39	8.38	8.35	8.36	8.3	8.4		
(NFR) (mg/L)	7	29	26	28	6	19.2	6.0	29.0	10 mg/L over control	
Turbidity (NTU)	10.1	16.7	5.71	45.6	5.83	16.79	5.7	45.6	8 NTU over control	
Specific Conductance	590	460	432	426	387	459.0	387.0	590.0		
N-Ammonia (mg/L)	.	.	0.015	0.006	0.007	0.009	0.0	0.0	depends on pH & temperature each day <sup>1</sup>	
N-Nitrite (mg/L)	.	.	0.007	0.002	0.002	0.004	0.0	0.0	0.06 mg/L <sup>1</sup>	< 0.02 mg/L <sup>1</sup>
N-Nitrate (mg/L)	.	.	0.187	0.74	1.15	0.69	0.2	1.2	200 mg/L <sup>1</sup>	< 40 mg/L <sup>1</sup>
P-Ortho-phosphate (mg/L)	.	.	0.005	0.003	0.002	0.003	0.0	0.0		
Fecal coliform (col./100mL)	98	>300	55	142	46	85	46.0	142.0		
<b>Metals</b>										
Calcium (mg/L)	.	25.4	24.7	26.2	23.5	25.0	23.5	26.2	> 8 mg/L - low sensitivity to acid inputs <sup>2</sup>	
Iron (mg/L)	.	1.113	1.317	1.309	0.47	1.052	0.5	1.3	0.3 mg/L <sup>2</sup>	
Phosphorus (mg/L)	.	<0.1	<0.1	<0.1	<0.1	<0.1	0.0	0.0		
Potassium (mg/L)	.	3.7	4.1	3.6	3	3.6	3.0	4.1		
Silicon (mg/L)	.	5.22	4.74	5.92	4.26	5.04	4.3	5.9		
Sodium (mg/L)	.	51.3	55.5	34.3	33.9	43.8	33.9	55.5		
Sulphur (mg/L)	.	9.74	11.13	12.28	11.67	11.21	9.7	12.3		
Titanium (mg/L)	.	0.014	0.026	0.022	0.004	0.017	0.0	0.0	100 ug/L <sup>2</sup>	
Aluminum (ug/L)	.	371.2	>624	1514	80.7	647.5	80.7	1514.0	0.1 mg/L Dissolved	0.05 mg/L Dissolved <sup>1</sup>
Antimony (ug/L)	.	0.264	0.261	0.129	0.051	0.176	0.1	0.3	20 ug/L <sup>2</sup>	
Arsenic (ug/L)	.	39.9	11.9	1.3	0.5	13.4	0.5	39.9	5.0 ug/L <sup>1</sup>	
Barium (ug/L)	.	61.42	49.74	64.75	52.39	57.08	49.7	64.8	5 mg/L <sup>2</sup>	
Berytium (ug/L)	.	0.019	0.025	0.061	0.027	0.03	0.0	0.1	5.3 ug/L <sup>2</sup>	
Bismuth (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0		
Boron (ug/L)	.	326	356	228	250	290.0	228.0	356.0		
Cadmium (ug/L)	.	0.11	0.1	0.01	<0.01	0.06	0.0	0.1	0.01 - 0.06 ug/L <sup>2*</sup>	
Chromium (ug/L)	.	577	8.3	2.3	0.7	147.1	0.7	577.0	1 ug/L for Cr <sup>+6</sup> ; 9 ug/L for Cr <sup>+3</sup> <sup>2</sup>	
Cobalt (ug/L)	.	0.32	0.496	0.635	0.158	0.402	0.2	0.6	0.9 ug/L <sup>2</sup>	
Copper (ug/L)	.	7.46	8.32	3.38	0.94	5.03	0.9	8.3	2-14 ug/L <sup>1*</sup>	2-5 ug/L <sup>1*</sup>
Lead (ug/L)	.	1.19	1.94	0.62	<0.01	0.94	0.6	1.9	10-197 ug/L <sup>1*</sup>	
Lithium (ug/L)	.	1.11	1.34	1.26	1.06	1.19	1.1	1.3		
Magnesium (ug/L)	.	11727	11350	13500	12440	12254.3	11350.0	13500.0		
Manganese (ug/L)	.	36.618	53.508	36.476	21.069	36.918	21.1	53.5	0.8 - 2.2 mg/L <sup>1*</sup>	0.7-1.3 mg/L <sup>1*</sup>
Molybdenum (ug/L)	.	0.74	0.69	0.92	0.51	0.72	0.5	0.9		
Nickel (ug/L)	.	2.42	2.89	3.36	1.44	2.53	1.4	3.4	25 -	
Selenium (ug/L)	.	<0.2	0.8	1.6	1.3	1.0	0.8	1.6	2.0 ug/L <sup>1</sup>	
Silver (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0		
Strontium (ug/L)	.	136.446	129.766	179.618	123.723	142.39	123.7	179.6		
Thallium (ug/L)	.	0.015	0.008	0.014	0.017	0.014	0.0	0.0		
Tin (ug/L)	.	5.5	37.79	2.42	0.59	11.58	0.6	37.8		
Uranium (ug/L)	.	0.333	0.314	0.493	0.362	0.376	0.3	0.5		
Vanadium (ug/L)	.	153.98	3.52	3.56	0.97	40.51	1.0	154.0		
Zinc (ug/L)	.	139.5	138	16	0.6	73.5	0.6	139.5	33 - 265 ug/L <sup>1*</sup>	7.5 - 240 ug/L <sup>1*</sup>
Hardness (calculated)		111.6	108.6	121.0	109.7	112.7	108.6	121.0		
<b>number in red are calculated from the geometric mean</b>										
<b>yellow shaded boxes - number exceeds maximum criteria or guideline</b>										
<b>blue shaded boxes - number exceeds average criteria or guideline</b>										

## APPENDIX F KILGAARD CREEK NEAR MARSHALL CREEK WATER QUALITY DATA

Lonzo	28/Aug/01	26/Sep/01	10/Oct/01	24/Oct/01	07/Nov/01	Average	Minimum	Maximum	Max Criteria	Avg Criteria
<b>Field Data</b>										
Temperature (°C)	15.1	14	9.7	8.6	7.7	11.0	7.7	15.1	depends on species and life stage <sup>1</sup>	
Dissolved Oxygen (mg/L)	9.66	10.4	11.85	12.08	13.03	11.40	9.7	13.0	depends on life stage <sup>1</sup>	
<b>Lab Data</b>										
pH (relative units)	8.1	8.42	7.7	8.33	8.26	8.16	7.7	8.4		
(NFR) (mg/L)	6	10	278	23	16	66.6	6.0	278.0	10 mg/L over control	
Turbidity (NTU)	7.04	7.25	29.1	37.2	5.58	17.23	5.6	37.2	8 NTU over control	
Specific Conductance	.	488	369	521	380	439.5	369.0	521.0		
N-Ammonia (mg/L)	0.022	0.007	0.008	0.023	0.026	0.017	0.0	0.0	depends on pH & temperature each day <sup>1</sup>	
N-Nitrite (mg/L)	0.024	<0.002	0.017	0.002	0.002	0.009	0.0	0.0	0.06 mg/L <sup>1</sup>	< 0.02 mg/L <sup>1</sup>
N-Nitrate (mg/L)	1.7	0.278	3.47	0.71	1.12	1.46	0.3	3.5	200 mg/L <sup>1</sup>	< 40 mg/L <sup>1</sup>
P-Ortho-phosphate (mg/L)	0.01	0.007	0.004	0.003	0.002	0.005	0.0	0.0		
Fecal coliform (col./100mL)	112	>300	>300	200	92	135	92.0	200.0		
<b>Metals</b>										
Calcium (mg/L)	.	27.3	23	29.6	24.6	26.1	23.0	29.6	> 8 mg/L - low sensitivity to acid inputs <sup>2</sup>	
Iron (mg/L)	.	0.824	2.607	1.378	1.234	1.511	0.8	2.6	0.3 mg/L <sup>2</sup>	
Phosphorus (mg/L)	.	<0.1	0.1	<0.1	<0.1	<0.1	0.1	0.1		
Potassium (mg/L)	.	4	4.1	3.8	3.1	3.8	3.1	4.1		
Silicon (mg/L)	.	5.07	6.36	6.31	5.15	5.72	5.1	6.4		
Sodium (mg/L)	.	49.8	46.2	38.9	35.1	42.5	35.1	49.8		
Sulphur (mg/L)	.	11.08	10.14	13.96	11.96	11.79	10.1	14.0		
Titanium (mg/L)	.	0.006	0.059	0.021	0.019	0.026	0.0	0.1	100 ug/L <sup>2</sup>	
Aluminum (ug/L)	.	214.3	>1633	1208	518	893.3	214.3	1208.0	0.1 mg/L Dissolved <sup>1</sup>	0.05 mg/L Dissolved <sup>1</sup>
Antimony (ug/L)	.	0.138	0.144	0.129	0.058	0.117	0.1	0.1	20 ug/L <sup>2</sup>	
Arsenic (ug/L)	.	1.7	2.4	1.1	0.7	1.5	0.7	2.4	5.0 ug/L <sup>1</sup>	
Barium (ug/L)	.	61.17	59.61	60.11	56.15	59.26	56.2	61.2	5 mg/L <sup>2</sup>	
Beryllium (ug/L)	.	<0.002	0.025	0.033	0.018	0.02	0.0	0.0	5.3 ug/L <sup>2</sup>	
Bismuth (ug/L)	.	0.09	<0.02	<0.02	<0.02	0.04	0.1	0.1		
Boron (ug/L)	.	317	268	217	231	258.3	217.0	317.0		
Cadmium (ug/L)	.	0.03	0.09	<0.01	<0.01	0.04	0.0	0.1	0.01 - 0.06 ug/L <sup>2*</sup>	
Chromium (ug/L)	.	9.6	9.5	2.2	0.9	5.6	0.9	9.6	1 ug/L for Cr <sup>+6</sup> ; 9 ug/L for Cr <sup>+3</sup> <sup>2</sup>	
Cobalt (ug/L)	.	0.24	0.974	0.577	0.586	0.594	0.2	1.0	0.9 ug/L <sup>2</sup>	
Copper (ug/L)	.	2.33	5.53	3.01	1.91	3.20	1.9	5.5	2-14 ug/L <sup>1*</sup>	2-5 ug/L <sup>1*</sup>
Lead (ug/L)	.	0.29	2.16	0.62	0.48	0.89	0.3	2.2	10-197 ug/L <sup>1*</sup>	4-11 ug/L <sup>1*</sup>
Lithium (ug/L)	.	0.93	1.42	1.14	1.22	1.18	0.9	1.4		
Magnesium (ug/L)	.	>13949	10946	12921	11622	12359.5	10946.0	12921.0		
Manganese (ug/L)	.	21.118	106.686	36.321	65.571	57.424	21.1	106.7	0.8 - 2.2 mg/L <sup>1*</sup>	0.7-1.3 mg/L <sup>1*</sup>
Molybdenum (ug/L)	.	1.63	0.61	0.87	0.52	0.91	0.5	1.6		
Nickel (ug/L)	.	2.54	4.51	3.06	2.19	3.08	2.2	4.5	25 -	
Selenium (ug/L)	.	0.6	0.9	1.5	1.2	1.1	0.6	1.5	2.0 ug/L <sup>1</sup>	
Silver (ug/L)	.	<0.02	<0.02	<0.02	<0.02	<0.02	0.0	0.0		
Strontium (ug/L)	.	154.448	122.436	172.128	129.226	144.56	122.4	172.1		
Thallium (ug/L)	.	0.009	0.015	0.012	0.034	0.018	0.0	0.0		
Tin (ug/L)	.	0.34	0.82	1.54	0.55	0.81	0.3	1.5		
Uranium (ug/L)	.	0.387	0.306	0.448	0.345	0.372	0.3	0.4		
Vanadium (ug/L)	.	3.22	5.93	3.29	1.83	3.57	1.8	5.9		
Zinc (ug/L)	.	4	17	12.3	3.9	9.3	3.9	17.0	33 - 265 ug/L <sup>1*</sup>	7.5 - 240 ug/L <sup>1*</sup>
Hardness (calculated)	.	125.4	102.3	127.0	109.2	116.0	102.3	127.0		
number in red are calculated from the geometric mean										
yellow shaded boxes - number exceeds maximum criteria or guideline										
blue shaded boxes - number exceeds average criteria or guideline										