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August 28, 2002

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Incoming
C/007/005

Re: Eccles Creek Macro-Invertebrate Studies Compilation Report, Canyon Fuel Company, LLC, Skyline Mine, C/007/005

Dear Pam:

As per Permit Stipulation #4, I delivered to the Division on August 27, 2002 a copy of a report prepared by Dr. Dennis K. Shiozawa that included the compilation and analysis of available Eccles Creek macro-invertebrate data. Dr. Shiozawa is currently employed as a Professor at Brigham Young University, Provo, Utah where he teaches and performs research in the field of fisheries biology. The report was prepared under a contract between Dr. Shiozawa and Mt. Nebo Scientific.

If you have any questions regarding the report, please give me a call or you can call Dr. Shiozawa at (801) 422-4972.

Sincerely,

Chris D. Hansen

Chris D. Hansen
Environmental Coordinator
Canyon Fuel Company, LLC

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A Compilation and Comparison Of Eccles Creek Macro-Invertebrate Data For the Period of 1979-2002

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INTRODUCTION

Eccles Creek, Carbon County, Utah has been influenced by activities associated with the development and operation of the Skyline Mines. The mine began operation in 1981 and required that the road be widened (completed in 1980) and paved (completed in 1984) along Eccles Creek. Water discharged from the mine also enters the stream channel after being held in a settling basin. Baseline data on the benthos of Eccles Creek was established in 1979 and monitoring of the macrobenthos has continued at intervals through 2002. Several groups of investigators were involved in the collection and analysis of results over this time period. However, different procedures, analytical approaches, and sampling station designations, have made it difficult to compare studies. This report has the objective of reviewing and consolidating reports on the benthos of Eccles Creek so that long-term changes can be assessed.

STATION DESIGNATIONS

Several station identification codes have been used on the Eccles Creek drainage over the past 20 years (Table 1). To simplify this review a single site code system was used. The drainage was divided into three discrete sections. 1) The upper forks, above the mine, were coded as USF for the South fork of the upper drainage (Upper South Fork), and UMF for the Middle fork of the upper drainage (Upper Middle Fork). 2) The actual South Fork of Eccles Creek was designated as SF. 3) The main stem of Eccles Creek was designated as E. A number was added to separate different sites within each of the three general areas when needed. So the two stations on the

Upper South Fork of Eccles Creek were numbered USF1 and USF2. The Middle Fork of Eccles Creek had only one station, as did the South Fork of Eccles Creek. The main stem of Eccles Creek had five stations, designated as E1 through E5 with E1 being he uppermost station and E5 being the lowest station.

DISCHARGE

Since the most recent factor influencing Eccles Creek is the discharge of water from a perched aquifer intercepted by the mine in 2001, it is useful to briefly review the historical flows within Eccles Creek so that the role of the additional discharge in the stream can be understood. Mean annual discharge in Eccles Creek was 4.13 cubic feet per second (cfs) in 1980, 1.61 cfs in 1981, 4.76 cfs in 1982, and 6.58 cfs in 1983 (source: www.waterdata.usgs.gov). Mean monthly discharge during this same period averaged between 1.5 and 1.8 cfs for the months of October through March. The average flows doubled in April to about 3.5 cfs, and peaked in May and June (16.3 and 17.4 cfs respectively). July flows averaged 4.5 cfs after which the discharge fell to about 2.5 cfs through August and September. Both 1983 and 1984 were exceptionally wet years with the peak mean monthly discharge at 31.2 and 32.5 cfs respectively. If these two years are ignored, the mean monthly flows in May and June are reduced, but monthly discharge during peak runoff in a wet year can still be over 20 cfs.

The peak hydrograph is usually recorded in May or June (Figure 1). The timing of this peak varies with the amount of winter and spring precipitation as well as the rate of warming in

the spring. Drought years show essentially no peak hydrograph and low runoff years may peak at about 5 cfs. In contrast, wet years will peak at around 30 cfs. These peak flows are short lived, lasting only a few days. The wettest two years on record are 1983 and 1984. In 1983 the stream peaked on May 30th at 62 cfs, and in 1984 it peaked on May 23rd at 71 cfs.

In August of 2001 Skyline Mines intercepted a perched aquifer and water began to enter the mine. The water was discharged from the mine, and part of it was directed into Eccles Creek. The initial input was 10 cfs (measured on August 16, 2001). At the end of August the flow was increased to 13.4 cfs and by late September it had increased to about 20 cfs. Beginning in December the flow began to decline, reaching a low of 15.6 cfs in March of 2002. The flow currently is at about 19 cfs. The added water increases the discharge in Eccles Creek by two to ten times the base flow, creating bankfull conditions throughout the year. During peak runoff the stream can be expected to peak at much higher maximum flows than normal, although peak discharge as high as recorded in 1984 is unlikely to be attained. It is likely that most years will now experience spring flooding (defined as periods of over bank full flow).

FISH HABITAT STRUCTURES

A series of stream improvement structures were constructed in Eccles Creek, following the design presented by Winget (1980). These structures were washed out by high water in late spring, 1984 (see above). The structures have not been replaced.

WATER QUALITY AND BIOASSAYS

In 1988, in a letter to Lowell Braxton of the Utah Division of Oil, Gas and Mining, L. Dalton, Utah Division of Wildlife Resources (1988), noted that phosphorus and nitrate/nitrite concentrations in the mine settling pond were excessive. The phosphorus was originating from cleaning solvent and high nitrate and nitrite levels were being generated by the oil-water emulsion used in the long wall unit. Mr. Dalton believed that the nutrients (phosphorus, nitrates, and nitrites) were inducing eutrophication of the stream below the mine. Slime mats occurred in the main stem of Eccles Creek and no successful reproduction of trout in 1987 and 1988 was documented. The mine was instructed to modify the emulsion being used in the cleaning solution and to properly dispose of the effluent resulting from moving the long wall unit. Additional precautions were recommended to control possible catastrophic discharge of water associated with the long wall unit.

Acute 96 hour bioassays were conducted in October of 1991 (Ecosystems Research Institute 1992). Both a stonefly (*Pteronarcys*) and a caddisfly (*Ceratopsyche)* were placed in cages on the stream substrate. Some mortalities were reported, but these appeared to be due to shifting sediments within the cages. No response indicative of acute chemical toxicity was observed in these assays. Ecosystems Research Institute concluded that the observed decline in macroinvertebrates (see below) was not due to acute chemical toxicity. Instead they hypothesized either a chronic (long-term) impact due to toxic chemicals, or some other environmental impact, most likely associated with physical perturbations.

PERIPHYTON BIOMASS

Ecosystems Research Institute (1992) also monitored periphyton biomass. They documented a substantial drop in periphyton standing crop from the mine (station EC1) and downstream approximately 4000 feet (station EC3). The highest periphyton standing crop (14 mg/m2) was recorded at 9000 feet downstream from the mine (station EC2). High standing crops of periphyton (8+ mg/sq m) were also recorded in the drainage above the mine (USF and possibly UMF). The reduction of periphyton at the mine and downstreamis was given as evidence of an impact from the mining operation. Since eutrophication would be expected to increase periphyton biomass (per Dalton 1988), the results of the Ecosystems Research Institute suggest that the heavy nutrient loading identified in 1988 was no longer a problem. Instead conditions were not conducive to the establishment of algal communities on solid substrates within the stream channel.

SEDIMENTS

Four studies examined sediment particle sizes. The first three (Winget, 1980; Baumann, 1985; Winget and Bauman, ca.1986) reported sediment size structure from 1979 through 1985. The fourth (Figure2; Figure 2-6 in the Ecosystems Research Institute 1992 report) presented sediment size information for June of 1990. Some confounding factors exist in comparing the sediment data. While it is possible to match substrate size classes in the reports, the Ecosystems Research Institute (1992) report did not provide raw data, so estimates were derived from Figure 2-6. Further, Winget (1982) and Bauman (1985) explicitly selected spawning gravels for their

sample sites, while the 1992 study did not specify the type of habitat chosen for sediment analysis. The Ecosystems Research Institute (1992) study may have sampled riffle habitat rather than gravel beds.

Between 1979 and 1985, large particles (>12.5 mm) comprised 30%, 30%, 39%, and 39% of the sediment mass in sites EC2, EC3, EC4, and EC5 respectively (Winget 1980 and Winget and Baumann ca.1986). The 1979-1985 studies indicate that the sediments in the lower portion of Eccles Creek were slightly larger than those in the upper portion of Eccles Creek. No sediment samples were taken from the headwater tributaries (USF and UMF). The size structure histograms (Figure 2) from Ecosystems Research Institute (1992) suggest that the sediment particle size class >12.5 mm was much more abundant in the tributaries above the mine than it was below the mine. At sample station USF2 approximately 73% of the sediment mass was >12.5 mm diameter. USF1 had 46% of the sediments >12.5 mm. Just below the mine (EC1), coarse particles (>12.5 mm) made up about 35% of the substrate, about the same as in the 1979-1985 studies. The Ecosystems Research Institute (1992) study showed that the percent composition of large particles (>12.5 mm) at stations EC4 and EC5 were also about the same as reported in 1979-1985. However, station EC2 consisted of only about 5% particles >12.5 mm in 1990, while that size class made up about 30% of the particle mass at the same location in 1979-85. The major factor in the reduced frequency of particles larger than 12.5 mm at station EC2 was a significant increase in the 4–12.5 mm size fraction.

Winget (1980) and Winget and Baumann (ca.1986) reported coarse and medium sands

(0.5 mm to 2 mm) at sites EC2, EC3, EC4, and EC5 at approximately 22%, 28%, 22%, and 23% respectively. The coarse to medium sand components in the Ecosystems Research Institute (1992) study were quite similar. In 1990 Ecosystems Research Institute found that EC2 had the highest percentage of sand in this size range, about 25%, and EC4 and EC5 had less than 20% coarse to medium sand. Ecosystems Research Institute (1992) noted that sediments filled the bioassay cages at EC1 after just 4 days, but the amount of sedimentation diminished downstream. Upstream of the mine little sedimentation was noted. They placed sediment traps in the stream at EC1and after one week they were unable to locate these sediment traps.

The downstream most site for the 1990 samples, EC5 (Figure 2; designated EC-01 in their study), has similar sediment distributions to that found at the same station in 1979-1985. However, the next station upstream, EC4 (their EC-02) shows a decrease in coarse and medium sand (0.5 to 2.0 mm) and a concurrent increase in fine sands (0.25 to 0.5mm) and very fine sands (>0.25 mm). The fine and very fine sands make up about 30% of the sediments at EC 4, while upstream at EC3 they make up only about 10% and in the lowest elevation station, EC5, these same sediments also comprise about 10% of the total sediment mass. It appears that a slug of sediment was in downstream transport in 1990. Water transport would move fine sands more rapidly downstream than it would the larger particle sizes. The fine component in EC4 represents the mobile fine sediments, which have moved further downstream from the source, which appears to be the mine area. It is likely that this slug of particles continued downstream in subsequent years.

It appears that sedimentation did not change significantly with the road construction in the early 1980's, or with the high water in 1984. But, while the type of substrate sampled in the 1990 series is not specified, the description of imbedded substrates at station EC1, as well as the data provided by Ecosystems Research Institute (1992; Figure 2), indicates that by 1990 sedimentation was a problem to the benthos of the main stem of Eccles Creek. This sedimentation was the likely cause of depressed algal biomass in the upper portion of the main stem of Eccles Creek. It is not clear from the studies whether or not the sedimentation problem was resolved.

BENTHOS

Number of Samples

The number of samples taken per site in Eccles Creek varied from one to five (Table 2). Most were collected with a standard Surber sampler, but the device utilized by the Ecosystems Research Institute is unknown and Shiozawa (2002) used a box sampler. Since the benthos is strongly clumped in distribution (Elliott 1977), a single sample risks collecting organisms that have very similar habitat associations (ie they are autocorrelated). By increasing the number of samples it is more likely that a wider range of microhabitat types will be included in the assessment, and thus a more robust measure of community structure is possible. Four replicate samples were taken in the assessment studies of 1979-1985, and Shiozawa (2002) also took four samples. However only two samples were taken per station in June of 1990 and just one sample was taken per station in October of 1990. In 1991 three samples were taken per station

(Ecosystems Research Institute 1992). Because of that, the 1990-1991 data will give a less robust estimate of diversity and species richness.

Number of Taxa

Overall a total of 81 taxa (Table 6) were collected in the Eccles Creek drainage, but the number of taxa collected at any given station on any given date in the drainage varies from a low of two to a high of 42 (Table 3). The 1979 through 1985 samples showed seasonal fluctuation in numbers of taxa and many stations have no trends that clearly indicate external impacts. A slight dip in the number of taxa in May-June of 1981 may have been induced by low flows associated with a drought year (Figure 1), by early season work associated with the opening of the mine, or by the widening of the road in 1980. But by the fall 1981 the numbers of taxa were again near reference levels. In June of 1982 the three main stem sites below the South Fork, EC3, EC4, and EC5, and the South Fork of Eccles Creek (SF) decreased in the numbers of taxa by almost half, yet the upstream sites showed no similar depression. The cause of this change is not known, but the mine began operation in 1981, the year immediately before the decline. Both EC3 and EC4 recovered by October of that year. However, the lower Eccles Creek station, EC5, appears to have permanently shifted to a lower mean number of taxa. By October of 1985 both EC2 and EC3 also had trends towards lower mean numbers of taxa. The road to the mine had been paved the year before the decline.

The1990-1991 study reported decreased numbers of taxa per station for the entire

drainage. Part of the decrease may be an artifact due to the low number of replicates taken. This is especially apparent in the upper tributaries. In the Upper South Fork (USF), for October of 1990, one sample was taken and 11 taxa were collected. In June of that same year two samples were taken and a total of 14 taxa were found, and in September of 1991, when three samples were taken, 21 taxa were recorded. This increase in number of taxa as sample size increases behaves as would be expected in the generation of a classical species-area curve (Palmer and White 1994). However the low numbers of taxa in stations EC2, EC4, and EC5, for 1990-1991, appear to be indicative of an external impact rather than sampling bias. In all three cases the total number of taxa, considering the three samples per station taken in September 1991, are considerably below the 1979-1981 mean number of taxa. EC2 had 6 taxa in 1991 versus a mean of 30 from 1979-1981; EC4 had15 taxa in 1991versus a mean of 32 for 1979-1981; EC5 had 14 taxa in 1991 as opposed to a mean of 29 for 1979-1981. It thus appears that the number of taxa do record an impact on the stream system in the late 1980s or in 1990. As discussed above the immediate cause was probably the input of sediment into the stream system, although the potential impact of heavy nutrient loading in 1988 cannot be ruled out.

The 2001 and 2002 sample series were taken at a limited subset of sites along the river. Only six taxa were collected from a transect between E4 and E5 in November 2001 (Shiozawa 2002), and the same number of taxa were found at sites EC2 and EC5 in 2002. Site EC4 contained 14 taxa in the 2002 sample series. These lower taxa counts could be a result of the impacts of sedimentation and even of eutrophication over a decade earlier, but the most proximal cause if the increased discharge into Eccles Creek from the mine. The added flow has generated

bank-full conditions mimicking the annual spring flood. In November 2001 the water temperature in the stream was higher than would be expected under normal early winter conditions (Shiozawa, personal observation). Elevated temperatures can induce emergence of aquatic insects during times when ambient air temperatures are not conducive to their survival. The high flows were also occurring at a time when the benthos would normally be adapting to low discharge conditions. Benthic invertebrates in mountain streams often key their life cycles to the seasonal input and retention of allochthonous organic material. High flows increase the erosive nature of streams, while low flows tend to generate depositional environments. The high flows likely removed most of the detritus from the system. By flushing this material out of the system, the food base for most of the benthos was eliminated. In November of 2001 the lower portion of the sampling transect was dominated by loose, migratory sand (Shiozawa, personal observations). Rocks and logs in the stream had very few attached benthos, indicating scouring by the high flows. By the July 2002 sample period, some invertebrate colonization had been reinitiated, as indicated by changes in densities (see below).

Total Densities of Invertebrates

Total densities, in numbers per square meter, range from a low of 16 to a high of 73,181 (Table 4). Densities vary with season as well as with annual differences in precipitation or discharge. Further, as with the estimation of the number of taxa, estimates of the density of the benthos is strongly influenced by the number of samples taken. The contagious distribution of organisms results in a high variance between samples. Some investigators have estimated that

well over 30 samples are needed to generate relatively narrow confidence intervals about the density estimates (Needham and Usinger 1956). Taking and processing such a large number of samples is far too expensive to be practical. Most investigations have utilized 3 to 5 samples to generate an estimate of standing crop or density. Despite being below the sample size for accurate density estimation, the estimates will give general trends in benthic densities.

During the 1979-1985 studies the stations showed seasonal fluctuations of as much as an order of magnitude. The first notable decrease in benthic densities occurs in June of 1982 at Stations EC3, EC4 and EC5 one fifth to one tenth of the previously recorded lows. This decline is significant but transitory. By August of that same year the densities had returned to the normal range. The 1982 decline in densities may have been induced by the return of a normal spring flood pulse following the drought of the previous year, or it could have a function of the initiation of the mining operation the previous year. Spring snowmelt could have generated an initial flush of contaminants that had accumulated during the previous dryer year. It should be noted that upstream stations in the tributaries also underwent a decrease in density in June of 1982, suggesting that the mine itself may not have been the major factor in the decline.

Station EC4 shows decreasing densities in 1985, which may indicate an impact on the stream, but since sampling ceased with that project in 1985, further evaluation is not possible. By the 1990's densities had fallen across the entire drainage. However the densities recorded for the upper tributaries (USF and UMF) may again be illustrating the influence of low numbers of samples, since the September 1991 density is at least near the estimate for the same site in August

of 1980 (Table 4). However stations EC1 and EC2 had very low densities, indicating some perturbation to the stations. Sedimentation (Ecosystems Research Institute 1992), as noted above may have been a major factor. The lower Eccles Creek stations (EC4 and EC5) continued the low density trend seen in 1985 (Table 4; Baumann 1985).

Very low densities were found in the EC4 transect in November, 2001 (Shiozawa 2002). These were most likely due to the depression of invertebrate numbers by the catastrophic influx of water from the mine. By the following summer densities at all sites had rebounded to near the 1985 levels. However, this increase in densities consisted of species that are mainly sediment burrowers (chironomids, oligochaetes) with some filter feeders (hydropsychids and *Brachycentrus*) and the vagrant mayfly, *Baetis*. Still, the presence of these organisms indicates that, by the summer of 2002, an invertebrate community more adapted to the new stream environment was colonizing Eccles Creek.

Community Tolerance Quotient, CTQa.

Winget and Magnum (1979) proposed a community tolerance measure as a part of their Biotic Condition Index. After surveying invertebrates over a wide range of habitat and water quality conditions, they assigned a tolerance value to each taxon. Species that are capable of surviving under a range of conditions receive a tolerance value of 108. Those species requiring more pristine conditions receive a lower tolerance value. The community tolerance quotient, or CTQa is the mean tolerance value for all taxa in the community surveyed. The CTQa value

should increase with increasing stress on a system. The CTQa for the surveyed stations are given in Table 5. The CTQa for the samples taken by Winget (1982), Baumann (1985), and Baumann and Winget (1986) in the Eccles Creek drainage, range from 83 to 52. Those for the 1990 series (Ecosystems Research Institute, 1992) range from 108 to 45. In 2001 Shiozawa (2002) reported a CTQa value of 94 for EC4 and, in the July 2002 sample series, EC2 had a value of 99. However both EC4 and EC5 had CTQa values of 53 and 66 respectively.

The CTQa measure suffers from being a mean value that is independent of both the number of taxa present and the relative densities of those taxa. The presence of a single organism with a TQ value of 48 in an otherwise empty sample would be indistinguishable from a community of 50 species with a mean value of 48. The loss of scaling for number of taxa and density results in the measure that must be evaluated in context with other data, including taxa lists and densities. The CTQa in November 1981 at EC2 was 80, higher than the previous CTQa values for the station, and similarly elevated CTQa values from EC3, EC4 and EC5 suggest an impact in the lower reaches of Eccles Creek, that may have been induced by mining activities. Similar shifts in CTQa values for the upper tributaries and for the South Fork did not occur. Over time the CTQa values for station EC2 through EC5 declined so that by the end of 1985 they were again near the levels recorded in 1979. The CTQa value clearly identifies several impacted sites after 1985 (ie. EC1 in October of 1990, EC4 in November of 2001, and EC2 in July of 2002), but other sites that have strong evidence of impacts are not discernable from the normal variation of CTQa values among stations.

Diversity Indices

The development of information theory during World War II and its subsequent application to the study of community structure Margalef (1958) led to diversity indices. These measures are an attempt to generate a single number that includes both relative density information as well as total numbers of taxa. The most widely used diversity index, the Shannon-Weiner index (Hayek 1994), is the one utilized in the studies reviewed for this report. Generally, the higher the diversity value, the higher the information content of the community and thus the higher the quality of the community. Systems with low diversity tend to be dominated by high densities of just a few species or taxa, while those with high diversity values tend to have many species with a more even proportional distribution of density per species.

Diversity values (Table 6) for the sample stations range from a high of 4.848 in June of 1984 to a low of 0.398 in July of 2002. In general the diversity for the 1979-1985 period was highest in the upper tributary sites (USF and UMF). The average diversity over that time period was 3.366 and 3.244 for the Upper Middle Fork and the Upper South Fork respectively. The mean diversity from South Fork of Eccles Creek was lower (2.834) over that same time span. The 1979 to1985 mean diversity in the main stem of Eccles Creek, declines progressively from the upper site (EC2) to the lower site, (EC5). The mean value for EC02 in that time period was 2.676, while EC03 was 2.406, EC94 was 2.010, and EC05 was 1.697. In part this decrease in diversity reflects a progressive downstream change in the physical characteristics of the stream. The shift is apparent even in the pre-impact samples. But, as the years progress, all of the main

stem Eccles Creek sites decline in diversity. By October 1985 the four stations on the main stem (EC2-EC5) had decreased from an October 1979 mean diversity value of 2.452 to a mean diversity value of 1.801.

The 1990-1991 sample series (Ecosystems Research Institute 1992) reinforced this pattern. None of the diversity values in that study (Table 6) exceeded 1.9 and five of the19 values given were less than 1.0, and these included all of the September 1991 stations which consisted of 3 samples per station. This low diversity also includes the upper tributaries, which act as a sort of control for this system. That makes interpretation of the diversity results for 1990-1991 difficult because the controls also declined significantly in diversity. The 2001-2002 samples also had diversities less than 1.0 and, as has been discussed earlier, this is most likely due to the increase in discharge in the stream system.

Density at Individual Sites

A subset of the reports included the raw taxa data, either in numbers of individuals per sample or in numbers per square meter. These data were converted to numbers per square meter per station for comparative purposes (Table 7). The most abundant organisms in the stream system over the 20 year range of studies are *Baetis*, *Cinygmula*, and Chironomidae. These comprise 70% of the taxa by total numbers. The next most abundant taxon, *Zapada*, makes up just 3.5% of the taxa and each of the remaining taxa comprise less that 2.4% of the total. Table 7 illustrates the changes that have occurred in the stream since 1979. The early samples had a range

of taxa, although they are dominated by just a few. The 1990-1991 sample series has very few taxa, and, generally, low densities of the taxa that are present. The 2001 samples also had low densities, similar to the 1990-1991 series. The 2002 samples also had low numbers of taxa but the densities of both chironomids and oligochaetes are similar to what was found for those taxa from 1979-1985.

These data are not as easy to assimilate as are the summary total taxa, total densitiy, CTQa, and diversity tables. However, the significance of differences in taxa composition between stations and sampling dates are not clear with the summary data approaches reviewed above. To facilitate the understanding of these differences, a cluster analysis (Figure 3) was completed on the data presented in Table 7. Cluster analysis is an agglomerative technique that allows a hierarchial view of the data set. The data are used to generate a similarity or dissimilarity matrix. In this case the Bray-Curtis dissimilarity index was utilized with non-transformed data. The dissimilarity matrix was then clustered using the unweighted pairs group method with averaging algorithm (UPGMA). The stations joining together to the right on Figure 3 are less dissimilar (more similar) to one another than are those that join farther to the left.

Four deep clusters are apparent. The first consists of samples taken in 1979 and 2002. The second consists of samples taken in the 1990-1991 study. A third consists of samples also taken in 1990-1991 and 2001. A final cluster, consisting on just one site (station EC1) was taken in 1990. This indicates a major difference in taxa and density between the 1979 and the 1990 studies. The shift in taxa may have been related to the impact of sedimentation in the 1990's, to

differences in the identification /level of identification of taxa between the two studies, or to the differences in the number of replicate samples taken per station. The sample taken in 2001 clustered with the lower Eccles Creek samples of the 1990 study (EC1 and EC2). Those two stations had high sand imbeddedness (Ecosystems Research Institute 1992) and shifting sand beds were also noted in 2001 (Shiozawa 2002). But by 2002, the samples have shifted to an association closer to the 1979 sample series. While the diversity is still significantly lower in the 2002 samples, the increase in both chironomids and oligochaetes towards 1979 levels is detected by the analysis. The 2002 samples are still quite dissimilar to the 1979 samples, but the fact that the system has moved from the highly dissimilar cluster in 2001, to a lower dissimilarity level in the control cluster is positive. It is unclear whether the system can continue to move towards the 1979 condition. The change in the hydrograph and the increased water temperature associated with the mine discharge suggests that the aquatic community that should develop in Eccles Creek may be more similar to those below reservoirs or in spring creeks.

CONCLUSIONS

The data gathered from 1979 through 2002 indicate that the Eccles Creek drainage has undergone a progressive change in benthic community structure. Road widening activities confounded with drought conditions in 1980 produced what appear to be transient decreases in the number of taxa and in densities of benthic invertebrates. Immediately following the opening of the mine in 1981 and the widening of the road stations downstream from the mine began to show a decline in number of taxa, density, and diversity. This decline was apparent by 1985. In the

early 1990's sedimentation significantly impacted the stream, and in 2001 the impact of increased discharge again resulted in finding fewer taxa, lower density, and lower diversity than existed in 1979. One positive factor associated with the high discharge is that the sands which were impacting the stream bed in the 1990 sampling period, will be flushed farther downstream, possibly out of the system. By 2002 the benthos was beginning to reestablish itself. While the number of taxa was still very low, at least the densities of the more resilient taxa were increasing.

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Table 1. Station designations for the existing studies on Eccles Creek.

	Winget (1980)			Baumann and Winget									
Station Descriptions	May-June 1979	Aug 1979	Oct 1979	Apr-June 1980	Aug 1980	Oct-Nov 1980	May-June 1981	Sept 1981	Nov 1981	June 1982	Aug 1982	Oct 1982	Oct 1983
South Fork tributary above mine, upper site (USF2)													
South Fork tributary above mine (USF)	UP-SF			UP-SF	UP-SF	UP-SF	UP-SF	UP-SF	UP-SF	UP-SF	UP-SF	UP-SF	UP-SF
Middle Fork tributary above mine (UMF)	UP-MF			UP-MF	UP-MF	UP-MF	UP-MF	UP-MF	UP-MF	UP-MF	UP-MF	UP-MF	UP-MF
Eccles Creek below mine (EC1)													
Eccles Creek above South Fork (EC2)	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02
South Fork Eccles Creek (SF)	EC-SF	EC-SF	EC-SF		EC-SF	EC-SF	EC-SF	EC-SF		EC-SF	EC-SF	EC-SF	EC-SF
Eccles Creek below South Fork (EC3)	EC-03	EC-03	EC-03	EC-03	EC-03	EC-03	EC-03	EC-03		EC-03	EC-03	EC-03	EC-03
Eccles Creek at Whisky Canyon (EC4)	EC-04	EC-04	EC-04	EC-04	EC-04	EC-04	EC-04	EC-04		EC-04	EC-04	EC-04	EC-04
Lower Eccles Creek (EC5)	EC-05	EC-05	EC-05	EC-05	EC-05	EC-05	EC-05	EC-05		EC-05	EC-05	EC-05	EC-05

	Baumann (1985)			Baumann and Winget			Ecosystems Research Institute (1992)			Shiozawa (2002)	Shiozawa (in prep)
Station Descriptions	June 1984	Sept 1984	Oct 1984	June 1985	Jul 1985	Oct 1985	Oct 1990	June 1990	Sept 1991	Nov 2001	July 2002
South Fork tributary above mine, upper site (USF2)							SF02	SF02			
South Fork tributary above mine (USF)	UP-SF	UP-SF	UP-SF	UP-SF	UP-SF	UP-SF	SF01	SF01	SF01		
Middle Fork tributary above mine (UMF)	UP-MF	UP-MF	UP-MF	UP-MF	UP-MF	UP-MF	MF1	MF1			
Eccles Creek below mine (EC1)							EC04	EC04			
Eccles Creek above South Fork (EC2)	EC-02	EC-02	EC-02	EC-02	EC-02	EC-02		EC03	EC03		EC2
South Fork Eccles Creek (SF)	EC-SF	EC-SF	EC-SF	EC-SF	EC-SF	EC-SF		SFF01			
Eccles Creek below South Fork (EC3)	EC-03	EC-03	EC-03	EC-03	EC-03	EC-03					
Eccles Creek at Whisky Canyon (EC4)	EC-04	EC-04	EC-04	EC-04	EC-04	EC-04	EC02	EC02	EC02	Eccles	EC4
Lower Eccles Creek (EC5)	EC-05	EC-05	EC-05	EC-05	EC-05	EC-05	EC01	EC01	EC01		EC5

Table 2. Number of samples per site on Eccles Creek.

	Winget (1980)			Baumann and Winget									
Station Descriptions	May-June 1979	Aug 1979	Oct 1979	Apr-June 1980	Aug 1980	Oct-Nov 1980	May-June 1981	Sept 1981	Nov 1981	June 1982	Aug 1982	Oct 1982	Oct 1983
South Fork tributary above mine, upper site (USF2)													
South Fork tributary above mine (USF)	4			4	4	4	4	4	4	4	4	4	4
Middle Fork tributary above mine (UMF)	4			4	4	4	4	4	4	4	4	4	4
Eccles Creek below mine (EC1)													
Eccles Creek above South Fork (EC2)	4	4	4	4	4	4	4	4	4	4	4	4	4
South Fork Eccles Creek (SF)	4	4	4		4	4	4	4		4	4	4	4
Eccles Creek below South Fork (EC3)	4	4	4	4	4	4	4	4		4	4	4	4
Eccles Creek at Whisky Canyon (EC4)	4	4	4	4	4	4	4	4		4	4	4	4
Lower Eccles Creek (EC5)	4	4	4	4	4	4	4	4		4	4	4	4

	Baumann (1985)			Baumann and Winget			Ecosystems Research Institute (1992)			Shiozawa (2002)	Shiozawa (in prep)
Station Descriptions	June 1984	Sept 1984	Oct 1984	June 1985	Jul 1985	Oct 1985	Oct 1990	June 1990	Sept 1991	Nov 2001	July 2002
South Fork tributary above mine, upper site (USF2)							1	2			
South Fork tributary above mine (USF)	4	4	4	4	4	4	1	2	3		
Middle Fork tributary above mine (UMF)	4	4	4	4	4	4	1	2			
Eccles Creek below mine (EC1)							1	2			
Eccles Creek above South Fork (EC2)	4	4	4	4	4	4		2	3		5
South Fork Eccles Creek (SF)	4	4	4	4	4	4		2			
Eccles Creek below South Fork (EC3)	4	4	4	4	4	4					
Eccles Creek at Whisky Canyon (EC4)	4	4	4	4	4	4	1	2	3	4	5
Lower Eccles Creek (EC5)	4	4	4	4	4	4	1/1	2	3		5

Table 3. Number of Taxa reported for the existing studies on Eccles Creek.

	Winget (1980)			Baumann and Winget									
Station Descriptions	May-June 1979	Aug 1979	Oct 1979	Apr-June 1980	Aug 1980	Oct-Nov 1980	May-June 1981	Sept 1981	Nov 1981	June 1982	Aug 1982	Oct 1982	Oct 1983
South Fork tributary above mine, upper site (USF2)													
South Fork tributary above mine (USF)	30			22	33	31	23	32	32	29	33	33	34
Middle Fork tributary above mine (UMF)	31			26	33	38	35	34	32	30	33	38	27
Eccles Creek below mine (EC1)													
Eccles Creek above South Fork (EC2)	36	42	32	27	31	30	21	30	24	30	26	30	23
South Fork Eccles Creek (SF)	36	35	37		38	33	29	40		24	29	33	36
Eccles Creek below South Fork (EC3)	27	30	34	23	23	34	23	24		15	26	29	28
Eccles Creek at Whisky Canyon (EC4)	35	37	39	28	29	37	23	29		14	21	26	28
Lower Eccles Creek (EC5)	28	21	32	28	24	33	26	27		14	16	24	19

	Baumann (1985)			Baumann and Winget			Ecosystems Research Institute (1992)			Shiozawa (2002)	Shiozawa (in prep)
Station Descriptions	June 1984	Sept 1984	Oct 1984	June 1985	Jul 1985	Oct 1985	Oct 1990	June 1990	Sept 1991	Nov 2001	July 2002
South Fork tributary above mine, upper site (USF2)							11	20			
South Fork tributary above mine (USF)	35	31	33	32	28	28	9	12	21		
Middle Fork tributary above mine (UMF)	24	33	27	29	29	29	18	14			
Eccles Creek below mine (EC1)							2	4			
Eccles Creek above South Fork (EC2)	21	29	28	22	24	23		6	6		6
South Fork Eccles Creek (SF)	29	38	32	35	30	29		12			
Eccles Creek below South Fork (EC3)	29	25	25	21	22	22					
Eccles Creek at Whisky Canyon (EC4)	18	27	30	23	25	27	17	7	15	6	14
Lower Eccles Creek (EC5)	15	23	21	20	17	22	13/11	12	14		6

Table 4. Total invertebrate densities per square meter for the existing studies on Eccles Creek.

	Winget (1980)			Baumann and Winget									
Station Descriptions	May-June 1979	Aug 1979	Oct 1979	Apr-June 1980	Aug 1980	Oct-Nov 1980	May-June 1981	Sept 1981	Nov 1981	June 1982	Aug 1982	Oct 1982	Oct 1983
South Fork tributary above mine, upper site (USF2)													
South Fork tributary above mine (USF)	10,176			7728	2892	14,834	10,545	31,185	36,788	4608	24,457	34,868	29,477
Middle Fork tributary above mine (UMF)	8449			4019	17,090	44,127	41,684	50,134	65,729	8113	33,332	55,457	46,497
Eccles Creek below mine (EC1)													
Eccles Creek above South Fork (EC2)	12,339	73,181	17,761	4350	5232	9745	11,274	19,077	2320	6053	7798	28,718	2556
South Fork Eccles Creek (SF)	9321	17,773	10,453		6994	17,243	3532	39,070		6136	20,460	38,228	14,276
Eccles Creek below South Fork (EC3)	18,093	23,247	15,871	26,251	6873	58,069	3882	13,585		619	11,193	16,008	4931
Eccles Creek at Whisky Canyon (EC4)	11,634	25,273	34,233	13,420	5130	46,338	3307	31,347		683	13,520	11,207	18,908
Lower Eccles Creek (EC5)	18,661	2526	14,308	12,560	6085	34,303	9870	15,909		1216	17,609	22,613	6047

	Baumann (1985)			Baumann and Winget			Ecosystems Research Institute (1992)			Shiozawa (2002)	Shiozawa (in prep)
Station Descriptions	June 1984	Sept 1984	Oct 1984	June 1985	Jul 1985	Oct 1985	Oct 1990	June 1990	Sept 1991	Nov 2001	July 2002
South Fork tributary above mine, upper site (USF2)							528	1089			
South Fork tributary above mine (USF)	13,821	24,842	42,666	28,778	13,378	27,438	216	1144	2455		
Middle Fork tributary above mine (UMF)	13,316	26,338	54,411	13,991	11,858	41,512	3812	1503			
Eccles Creek below mine (EC1)							16	164			
Eccles Creek above South Fork (EC2)	14,843	4070	11,190	5544	13,758	13,391		267	89		3703
South Fork Eccles Creek (SF)	13,278	27,739	71,992	15,852	17,567	34,540		1356			
Eccles Creek below South Fork (EC3)	15,790	2749	10,615	7231	16,789	25,781					
Eccles Creek at Whisky Canyon (EC4)	13,969	5159	11,621	4939	5204	4288	3928	1719	1419	61	8757
Lower Eccles Creek (EC5)	5431	41,232	51,680	11,419	19,691	18,001	4104/2863	2212	1468		4927

Table 5. Community Tolerance Quotient, CTQa, for the existing studies on Eccles Creek.

	Winget (1980)			Baumann and Winget									
Station Descriptions	May-June 1979	Aug 1979	Oct 1979	Apr-June 1980	Aug 1980	Oct-Nov 1980	May-June 1981	Sept 1981	Nov 1981	June 1982	Aug 1982	Oct 1982	Oct 1983
South Fork tributary above mine, upper site (USF2)													
South Fork tributary above mine (USF)	69			74	62	71	67	64	66	68	68	70	66
Middle Fork tributary above mine (UMF)	67			72	63	70	65	70	61	68	65	59	61
Eccles Creek below mine (EC1)													
Eccles Creek above South Fork (EC2)	66	65	64	64	68	66	64	71	80	72	64	70	70
South Fork Eccles Creek (SF)	59	64	68		69	61	66	62		64	61	63	64
Eccles Creek below South Fork (EC3)	65	55	63	70	70	57	73	75		80	71	69	68
Eccles Creek at Whisky Canyon (EC4)	63	61	60	61	70	62	74	72		83	67	66	60
Lower Eccles Creek (EC5)	59	74	65	72	64	59	58	59		79	70	70	75

	Baumann (1985)			Baumann and Winget			Ecosystems Research Institute (1992)			Shiozawa (2002)	Shiozawa (in prep)
Station Descriptions	June 1984	Sept 1984	Oct 1984	June 1985	Jul 1985	Oct 1985	Oct 1990	June 1990	Sept 1991	Nov 2001	July 2002
South Fork tributary above mine, upper site (USF2)							53	59			
South Fork tributary above mine (USF)	67	71	68	66	64	55	59	49	45		
Middle Fork tributary above mine (UMF)	66	59	59	62	57	56	49	54			
Eccles Creek below mine (EC1)							108	67			
Eccles Creek above South Fork (EC2)	67	71	68	71	65	65			73		99
South Fork Eccles Creek (SF)	62	59	58	66	58	52		55			
Eccles Creek below South Fork (EC3)	66	63	57	59	59	60					
Eccles Creek at Whisky Canyon (EC4)	67	59	56	74	69	57	70	69	63	94	52
Lower Eccles Creek (EC5)	75	71	67	70	67	53	55/57	53	58		66

Table 6. Diversity Indices (based on natural logs) for the existing studies on Eccles Creek.

	Winget (1980)			Baumann and Winget									
Station Descriptions	May-June 1979	Aug 1979	Oct 1979	Apr-June 1980	Aug 1980	Oct-Nov 1980	May-June 1981	Sept 1981	Nov 1981	June 1982	Aug 1982	Oct 1982	Oct 1983
South Fork tributary above mine, upper site (USF2)													
South Fork tributary above mine (USF)	3.800			3.715	3.453	3.855	3.619	3.453	3.197	3.850	3.406	2.634	3.788
Middle Fork tributary above mine (UMF)	3.150			3.884	3.114	3.844	3.301	3.542	3.148	3.862	3.199	3.427	1.852
Eccles Creek below mine (EC1)													
Eccles Creek above South Fork (EC2)	3.510	1.964	2.534	3.389	3.468	3.020	2.173	2.554	3.970	2.411	2.514	1.838	3.746
South Fork Eccles Creek (SF)	3.510	3.322	3.289		3.134	2.634	3.409	2.681		2.939	2.811	2.572	2.607
Eccles Creek below South Fork (EC3)	2.450	2.743	2.892	2.407	2.472	1.904	3.201	1.383		2.688	2.424	2.107	3.567
Eccles Creek at Whisky Canyon (EC4)	2.450	3.060	2.227	2.301	2.676	0.973	0.973	1.291		2.292	1.927	1.678	1.645
Lower Eccles Creek (EC5)	2.280	2.590	2.155	2.319	2.057	1.865	1.441	2.554		1.863	1.361	0.990	2.160

	Baumann (1985)			Baumann and Winget			Ecosystems Research Institute (1992)			Shiozawa (2002)	Shiozawa (in prep)
Station Descriptions	June 1984	Sept 1984	Oct 1984	June 1985	Jul 1985	Oct 1985	Oct 1990	June 1990	Sept 1991	Nov 2001	July 2002
South Fork tributary above mine, upper site (USF2)							1.9	1.63			
South Fork tributary above mine (USF)	3.399	2.908	2.523	3.173	3.573	2.873	1.9	1.72	0.702		
Middle Fork tributary above mine (UMF)	4.848	2.959	2.118	3.043	3.391	2.467	1.9	1.66			
Eccles Creek below mine (EC1)							0.7	1.06			
Eccles Creek above South Fork (EC2)	1.040	2.923	2.142	2.849	2.770	2.037		1.58	0.400		0.398
South Fork Eccles Creek (SF)	2.483	2.808	1.900	2.699	2.942	2.445		1.62			
Eccles Creek below South Fork (EC3)	2.106	3.086	2.228	2.155	1.869	1.619					
Eccles Creek at Whisky Canyon (EC4)	0.579	3.002	2.689	2.008	2.366	2.037	1.6	1.22	0.666	0.757	0.957
Lower Eccles Creek (EC5)	1.042	0.828	0.615	1.256	1.661	1.511	1.8/1.4	1.24	0.416		0.829

Table 7. Density (per square meter) for selected samples taken on Eccles Creek between 1979 and 2002.

Original Code	UPSF 6-79	UPMF 6-79	EC02 6-79	EC02 8-79	ECSF 5-79	ECSF 8-79	EC03 5-79	EC03 8-79	EC04 5-79	EC04 8-79	EC05 5-79	EC05 8-79
Code for this review	USF 6-79	UMF 6-79	EC2 6-79	EC2 8-79	SF 5-79	SF 8-79	EC3 5-79	EC3 8-79	EC4 5-79	EC4 8-79	EC5 5-79	EC5 8-79
Ameletus	11	5	8	0	0	0	0	0	8	0	0	0
Baetis sp.	753	2109	1915	47204	845	882	9870	7693	6779	8468	5942	51
Cinygmula	452	382	904	3895	958	3796	1310	8005	369	3605	81	116
Epeorus	0	0	86	0	0	0	0	0	16	0	30	0
Early instar ephemerellidae	0	0	0	3586	0	409	0	1162	0	366	0	0
Drunella grandis	11	38	215	0	129	0	153	11	75	129	43	0
Ephemerella coloradensis	0	0	0	1275	0	46	0	22	0	65	0	0
Drunella doddsi	0	0	0	0	0	0	0	11	0	22	0	0
Seretella	0	0	508	0	100	638	0	204	22	151	51	0
Paraleptophlebia sp.	0	0	108	3	35	43	97	86	13	0	22	0
Amphinemoura	0	0	0	0	0	0	0	11	0	0	0	0
Capniidae	0	8	8	433	0	162	0	2012	0	473	0	0
Chloroperlidae	54	51	8	43	30	22	11	86	19	0	19	24
Diura knowltoni	0	0	0	0	0	0	0	97	0	0	0	0
Early instar plecoptera	0	0	0	0	0	0	0	0	0	0	0	0
Hesperoperla	24	0	0	0	0	0	0	22	0	22	0	0
Isoperla sp.	0	0	38	0	0	0	0	0	0	0	11	0
Isoperla fulva	0	0	8	0	0	0	0	0	0	0	0	0
Malenka californica	0	0	0	0	0	0	0	0	0	0	22	0
Megarcys	13	8	97	3	62	67	24	97	22	0	13	0
Perlodidae	0	0	0	3	0	0	0	0	0	0	0	0
Prostoia	0	0	0	73	8	22	43	118	301	516	4842	0
Skwala	0	0	0	0	5	0	0	0	0	0	8	0
Sweltza sp.	0	0	0	0	0	0	0	0	0	0	0	0
Taenionema	0	0	0	0	0	0	56	97	46	291	13	0
Zapada	689	613	1609	1022	1149	516	807	775	223	990	186	167
Arctopsyche grandis	11	0	0	0	0	22	0	0	0	0	0	0

Ceratopsyche	0	0	0	0	0	0	0	0	0	0	0	0
Brachycentrus	0	0	0	0	5	0	0	0	11	0	148	0
Chyranda	0	5	0	0	3	0	0	0	0	0	0	0
Dicosmoecus	0	0	0	0	0	3	0	0	0	0	0	0
Glossoma	0	0	0	8	0	0	0	0	0	0	0	0
Hesperophylax	0	0	0	0	0	0	0	0	0	0	8	0
Hydropsyche	0	0	0	0	0	22	0	0	0	108	67	62
Hydroptilidae	0	0	0	0	0	0	0	0	0	0	0	0
Lepidostoma sp.	0	0	0	0	0	0	0	0	0	43	0	0
(Limniphilidae) *Allomyia*	0	0	0	0	0	0	0	0	0	43	0	8
(Limniphilidae)*Oligoplebodes*	11	0	35	406	81	2655	11	86	11	452	0	[illegible]
Onocosmoecus	0	0	0	0	0	0	0	0	0	0	0	0
Limniphilidae (adult)	86	0	8	22	0	0	0	0	0	0	0	0
Micrasema bactro	0	0	0	0	8	0	483	0	135	430	0	0
Neothremma alicia	710	78	8	0	32	0	0	43	0	0	0	0
Parapsyche	22	51	0	35	16	0	0	0	0	0	0	0
Rhyacophila	161	196	761	194	288	202	487	43	417	420	291	30
Haliplidae	0	0	0	0	0	0	0	0	11	0	0	0
Heterlimnius (larva)	312	27	266	221	70	229	183	97	70	159	11	11
Optioservus (larva)	0	0	0	0	0	0	0	0	0	0	0	0
Dryopidae	0	0	0	0	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0	0	0	0	0
Antocha monticola	0	0	0	0	0	0	0	0	11	22	0	0
Ceratopogonidae	32	40	30	94	32	94	94	11	30	22	30	105
Chironomidae (larva)	1173	2179	3223	12226	2340	5173	2967	1356	861	6553	5958	13[illegible]
Dixidae	22	0	8	16	0	0	0	0	0	0	0	0
Simulium sp.	1872	62	24	97	13	51	0	32	0	52	0	0
Hexatoma	0	13	21	0	62	65	0	22	0	22	8	8
Holorusia	24	24	11	11	24	11	5	11	3	3	13	0
limnophora	0	0	0	0	0	0	0	0	0	0	0	0
(Tipulidae) *Anthocha*	0	0	0	0	0	0	0	0	0	0	0	0
Ormosia	0	0	0	0	0	0	0	0	0	0	0	0
(Tipulidae) *Tipula*	0	0	0	11	0	0	0	0	0	0	0	8
(Tipulidae) *Dicronata*	86	11	11	13	27	22	32	237	0	0	0	0

Pedicia	0	0	0	13	0	0	0	0	0	0	0	0
(Psychodidae) *Pericoma*	0	0	35	75	62	94	81	86	27	22	16	19
Psychoda	0	0	0	43	0	0	0	0	0	0	0	0
(Ptychopteridae) *Ptychoptera*	0	0	0	0	8	0	22	3	22	0	0	0
Caloparyphus	0	0	0	0	0	0	0	0	0	0	0	0
(Stratiomyidae) *Euparyphus*	0	102	46	56	91	92	30	108	19	161	0	0
(Empididae) *Chelifera*	11	110	245	161	196	0	51	0	207	172	398	247
Clinocera	0	0	0	0	0	0	0	0	0	0	0	0
Collembola	366	51	30	59	0	0	0	0	16	0	0	0
Amphipoda	11	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	323	16	30	129	417	745	91	11	19	75	0	0
Copepod	11	22	213	54	51	129	56	43	11	0	0	0
Hydracarina	280	831	810	785	619	482	126	140	207	506	202	75
Planorbidae	0	0	0	0	0	22	0	0	8	0	0	0
Sphaerium sp.	0	19	0	11	0	0	0	43	0	11	0	0
Hirudinea	0	0	0	430	0	0	0	0	0	0	0	0
Oligochaeta	818	250	272	339	38	116	369	237	1364	646	143	126
Nematoda	1098	35	8	89	8	258	19	0	43	54	43	0
Turbellaria	732	111	734	0	1501	654	616	118	223	65	0	0
Total	10179	7447	12341	73138	9313	17744	18094	23236	11619	25139	18619	2442
Number of Taxa	30	29	35	37	34	32	27	36	34	34	28	16

Table 7. continued. Density (per square meter) for selected samples taken on Eccles Creek between 1979 and 2002.

Original Code	EC01 9-91	EC02 9-91	EC03 9-91	SF-01 9-91	EC01 10-90	EC01A 10-90	EC04 10-90	EC02 10-90	SF01 10-90	SF02 10-90	MF01 10-90	EC01 6-90
Code for this review	EC5 9-91	EC4 9-91	EC2 9-91	USF 9-91	EC5 10-90	EC5 10-90	EC1 10-90	EC4 10-90	USF1 10-90	USF2 10-90	UMF 10-90	EC5 6-90
Ameletus	0	0	0	54	0	0	0	0	20	0	0	0
Baetis sp.	1079	416	16	825	252	1056	0	924	4	108	800	6
Cinygmula	0	0	0	0	0	0	0	0	12	12	140	0
Epeorus	3	0	0	1038	0	0	0	0	0	0	0	0
Early instar ephemerellidae	0	0	0	0	0	0	0	0	0	0	0	0
Drunella grandis	0	0	0	0	4	8	0	4	0	0	0	2
Ephemerella coloradensis	0	5	0	49	0	0	0	0	0	0	0	0
Drunella doddsi	0	0	0	0	0	0	0	0	0	0	0	0
Seretella	0	0	0	0	0	0	0	0	0	0	0	0
Paraleptophlebia sp.	0	0	0	0	0	0	0	0	0	0	0	0
Amphinemoura	0	0	0	0	0	0	0	0	0	0	156	0
Capniidae	0	0	0	0	0	0	0	0	0	0	0	0
Chloroperlidae	0	0	0	0	0	0	0	4	0	0	16	0
Diura knowltoni	0	0	0	0	0	0	0	0	0	0	0	0
Early instar plecoptera	0	0	0	0	0	0	0	0	0	0	0	0
Hesperoperla	0	0	0	0	0	0	0	0	0	0	0	0
Isoperla sp.	0	0	0	38	24	8	0	0	0	0	13	0
Isoperla fulva	0	3	0	0	0	0	0	0	0	0	0	0
Malenka californica	0	0	0	0	0	0	0	0	0	0	0	0
Megarcys	0	0	0	3	0	0	0	0	0	0	0	0
Perlodidae	0	0	0	0	0	0	0	0	0	0	0	0
Prostoia	0	0	0	0	0	0	0	0	0	0	0	0
Skwala	0	0	0	0	0	0	0	0	0	0	4	0
Sweltza sp.	0	0	0	27	0	0	0	0	0	0	0	0
Taenionema	0	0	0	0	0	0	0	0	0	0	0	0
Zapada	0	0	3	157	0	0	0	32	20	24	160	0
Arctopsyche grandis	8	0	0	0	0	0	0	0	0	8	112	0
Ceratopsyche	219	565	11	49	436	112	4	452	0	0	0	100

Brachycentrus	78	224	3	19	44	112	0	160	0	0	0	61
Chyranda	0	0	0	0	0	0	0	0	0	0	0	0
Dicosmoecus	0	11	0	0	0	0	0	0	0	0	4	0
Glossoma	0	0	0	0	0	0	0	0	0	0	0	0
Hesperophylax	0	0	0	0	0	0	0	0	4	0	0	0
Hydropsyche	0	0	0	0	0	0	0	0	0	0	0	0
Hydroptilidae	0	0	0	0	0	0	0	4	0	0	0	0
Lepidostoma sp.	3	8	0	3	0	0	0	0	0	0	0	0
(Limniphilidae) *Allomyia*	0	0	0	0	0	0	0	0	0	0	0	0
(Limniphilidae)*Oligoplebodes*	0	0	0	0	0	0	0	0	0	0	0	0
Onocosmoecus	0	0	0	0	0	0	0	0	0	0	0	0
Limniphilidae (adult)	0	0	0	0	0	0	0	0	0	0	0	0
Micrasema bactro	0	0	0		0	0	0	0	0	0	0	0
Neothremma alicia	0	0	0	3	0	0	0	0	0	8	8	0
Parapsyche	0	0	0	14	0	0	0	0	0	0	0	0
Rhyacophila	8	8	0	119	24	20	0	4	8	52	72	28
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	0
Heterlimnius (larva)	0	0	0	0	4	0	0	4	0	0	0	4
Optioservus (larva)	5	0	0	19	0	0	0	0	0	8	4	0
Dryopidae	3	8	0	11	0	0	0	0	0	0	0	0
Dytiscidae	0	0	0	0	0	0	0	0	0	0	0	0
Lepidoptera	0	0	0	0	0	0	0	0	0	0	0	0
Antocha monticola	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae	0	0	0	0	0	0	0	0	0	0	0	0
Chironomidae (larva)	35	14	3	3	480	16	0	64	4	0	372	376
Dixidae	0	0	0	0	0	0	0	0	0	0	0	0
Simulium sp.	0	0	0	0	0	0	0	0	0	0	0	0
Hexatoma	0	3	0	0	0	0	0	4	0	0	0	2
Holorusia	0	0	0	0	0	0	0	0	0	0	0	0
limnophora	0	0	0	0	0	0	0	12	0	0	0	0
(Tipulidae) *Anthocha*	0	0	0	0	564	4	0	0	0	0	0	32
Ormosia	0	0	0	0	0	0	0	0	0	0	0	0
(Tipulidae) *Tipula*	14	27	0	5	16	0	0	180	32	0	0	2
(Tipulidae) *Dicronata*	0	0	0	3	0	0	0	0	0	0	0	0
Pedicia	0	0	0	0	0	0	0	0	0	0	0	0

(Psychodidae) *Pericoma*	0	0	0	3	0	0	0	0	0	4	4	0
Psychoda	0	0	0	0	0	0	0	0	0	0	0	0
(Ptychopteridae) *Ptychoptera*	0	0	0	0	0	0	0	0	0	0	0	0
Caloparyphus	5	0	0	8	4	4	0	4	0	8	0	0
(Stratiomyidae) *Euparyphus*	0	0	0	0	0	0	0	8	0	0	0	0
(Empididae) *Chelifera*	5	3	3	0	84	4	0	0	0	4	8	12
Clinocera	0	0	0	0	0	0	0	0	0	0	8	0
Collembola	0	0	0	0	0	0	0	0	0	0	0	0
Amphipoda	0	0	0	0	0	0	0	0	0	0	0	0
Ostracoda	0	0	0	0	0	0	0	0	0	0	0	0
Copepod	0	0	0	0	0	0	0	0	0	0	0	0
Hydracarina	0	5	0	0	0	0	0	0	0	0	4	0
Planorbidae	0	0	0	0	0	0	0	0	0	0	0	0
Sphaerium sp.	0	0	0	0	0	0	0	0	0	0	0	0
Hirudinea	0	0	0	0	0	0	0	0	0	0	0	0
Oligochaeta	5	60	0	0	88	68	4	84	0	4	0	18
Nematoda	0	0	0	0	0	0	0		0	0	0	0
Turbellaria	0	0	0	0	0	0	0	12	4	0	24	0
Total	1470	1360	39	2450	2024	1412	8	1956	108	240	1909	643
Number of Taxa	14	15	6	21	13	11	2	17	9	11	18	12

Table 7. continued. Density (per square meter) for selected samples taken on Eccles Creek between 1979 and 2002.

	EC02 6-90	EC03 6-90	EC04 6-90	SF01 6-90	SF02 6-90	SFF01 6-90	MF01 6-90	Eccles 11-01	EC2 7-02	EC4 7-02	EC5 7-02	
	EC4 6-90	EC2 6-90	EC1 6-90	USF 6-90	USF2 6-90	SF 6-90	UMF 6-90	EC4 11-01	EC2 7-02	EC4 7-02	EC5 7-02	Row Totals
Ameletus	0	0	0	0	2		0	0	0	0	0	108
Baetis sp.	0	6	28	42	90	102	234	8	242	491	200	99440
Cinygmula	0	0	2	20	152	186	46	0	6	6	0	24455
Epeorus	0	0	0	0	0	0	0	0	0	0	0	1173
Early instar ephemerellidae	0	0	0	0	0	0	0	0	0	0	0	5523
Drunella grandis	18	0	0	2	2	18	10	0	0	0	0	872
Ephemerella coloradensis	0	2	0	10	2	12	0	0	0	0	0	1488
Drunella doddsi	0	0	0	0	0	0	0	0	0	0	0	33
Seretella	0	0	0	0	0	0	0	0	0	0	0	1674
Paraleptophlebia sp.	0	0	0	0	0	0	0	0	0	0	0	407
Amphinemoura	0	0	0	0	0	0	0	0	0	0	0	167
Capniidae	0	0	0	0	0	0	0	0	0	0	0	3096
Chloroperlidae	0	0	0	0	2	18	0	0	0	0	0	407
Diura knowltoni	0	0	0	0	0	0	0	0	0	0	0	97
Early instar plecoptera	0	0	0	0	0	0	0	0	0	12	12	24
Hesperoperla	0	0	0	2	0	0	0	0	0	0	0	70
Isoperla sp.	0	0	0	4	0	0	6	0	0	0	0	142
Isoperla fulva	0	0	0	0	0	0	0	0	0	0	0	11
Malenka californica	0	0	0	0	0	0	0	0	0	0	0	22
Megarcys	0	0	0	0	0	0	0	0	0	0	0	409
Perlodidae	0	0	0	0	0	0	0	0	0	0	0	3
Prostoia	0	0	0	0	0	0	0	0	0	0	0	5923
Skwala	0	0	0	0	0	0	0	0	0	0	0	17
Sweltza sp.	0	0	0	0	0	0	0	0	0	0	0	27
Taenionema	0	0	0	0	0	0	0	0	0	0	0	503
Zapada	0	0	0	6	6	8	16	0	0	0	0	9178

Arctopsyche grandis	0	0	0	0	0	0	0	0	0	0	0	161
Ceratopsyche	82	0	0	0	0	0	0	0	0	0	0	2030
Brachycentrus	4	0	0	0	0	0	0	0	6	36	0	911
Chyranda	0	0	0	0	0	0	0	0	0	0	0	8
Dicosmoecus	0	0	0	2	0	0	0	0	0	0	0	20
Glossoma	0	0	0	0	0	0	0	0	0	0	0	8
Hesperophylax	0	0	0	0	0	0	0	0	0	0	0	12
Hydropsyche	0	0	0	0	2	0	0	45	18	1097	424	1845
Hydroptilidae	0	0	0	0	0	0	0	0	0	42	0	46
Lepidostoma sp.	0	0	0	0	0	0	0	0	0	0	0	57
(Limniphilidae) *Allomyia*	0	0	0	0	0	0	0	0	0	0	0	51[illegible]
(Limniphilidae)*Oligoplebodes*	0	0	0	0	0	0	0	0	0	0	0	3748[illegible]
Onocosmoecus	0	0	0	0	2	0	0	0	0	0	0	2
Limniphilidae (adult)	0	0	0	0	0	0	0	0	0	0	0	116
Micrasema bactro	0	0	0	0	0	0	0	0	0	24	0	1080
Neothremma alicia	0	0	0	0	2	0	0	0	0	0	0	892
Parapsyche	0	0	0	16	0	0	8	0	0	0	0	162
Rhyacophila	0	0	0	24	10	16	44	0	0	6	6	3939
Haliplidae	0	0	0	0	0	0	0	0	0	0	0	11
Heterlimnius (larva)	0	0	0	0	6	8	0	0	0	0	0	1682
Optioservus (larva)	0	0	0	0	0	0	0	0	0	0	0	36
Dryopidae	0	0	0	0	0	0	0	0	0	0	0	22
Dytiscidae	0	2	0	0	0	0	0	0	0	0	0	2
Lepidoptera	0	2	0	0	0	0	0	0	0	0	0	2
Antocha monticola	0		0	0	0	0	0	0	0	0	0	33
Ceratopogonidae	0	4	0	0	0	0	0	0	0	0	0	61[illegible]
Chironomidae (larva)	216	28	12	168	4	8	22	8	3339	6339	3709	60614
Dixidae	0	0	0	0	0	0	0	0	0	0	0	46
Simulium sp.	0	0	0	0	2	0	0	0	0	0	0	2205
Hexatoma	0	0	0	0	2	0	0	0	0	0	0	232
Holorusia	0	0	0	0	0	0	0	0	0	0	0	140
limnophora	0	0	0	0	0	0	0	0	0	0	0	12
(Tipulidae) *Anthocha*	0	0	0	0	0	0	0	0	0	0	0	600
Ormosia	0	0	0	0	6	0	0	0	0	0	0	6
(Tipulidae) *Tipula*	2	0	0	8	4	2	2	0	0	6	0	319

(Tipulidae) *Dicronata*	0	0	0	0	0	0	0	0	0	0	0	442
Pedicia	0	0	0	0	0	0	0	0	0	0	0	13
(Psychodidae) *Pericoma*	0	0	0	0	0	0	0	0	0	0	0	528
Psychoda	0	0	0	0	0	0	0	0	0	0	0	43
(Ptychopteridae) *Ptychoptera*	2	0	0	0	4	0	0	0	0	0	0	61
Caloparyphus	0	0	2	0	0	0	0	0	0	0	0	35
(Stratiomyidae) *Euparyphus*	0	0	0	0	0	0	0	0	0	0	0	713
(Empididae) *Chelifera*	2	0	0	0	0	0	8	0	0	0	0	1931
Clinocera	0	0	0	0	0	0	4	0	0	0	0	12
Collembola	0	0	0	0	0	0	0	0	0	0	0	522
Amphipoda	0	0	0	0	0	0	0	0	0	0	0	11
Ostracoda	0	0	0	0	0	0	0	0	0	0	0	1856
Copepod	0	0	0	0	0	0	0	0	0	6	0	596
Hydracarina	0	0	0	0	0	0	0	0	0	0	0	5072
Planorbidae	0	0	0	0	0	0	0	0	0	0	0	30
Sphaerium sp.	0	0	0	0	0	0	0	0	0	12	0	96
Hirudinea	0	0	0	0	0	0	0	0	0	0	0	430
Oligochaeta	0	0	0	2	2	14	0	0	79	654	576	6376
Nematoda	0	0	0	0	0	0	0	0	0	0	0	1655
Turbellaria	0	0	0	16	16	4	0	0	0	6	0	4836
Total	326	44	44	322	318	396	400	61	3690	8737	4927	262195
Number of Taxa	7	6	4	14	20	12	11	3	6	14	6	81

Figure 1. Discharge profile Eccles Creek 1980-1984.

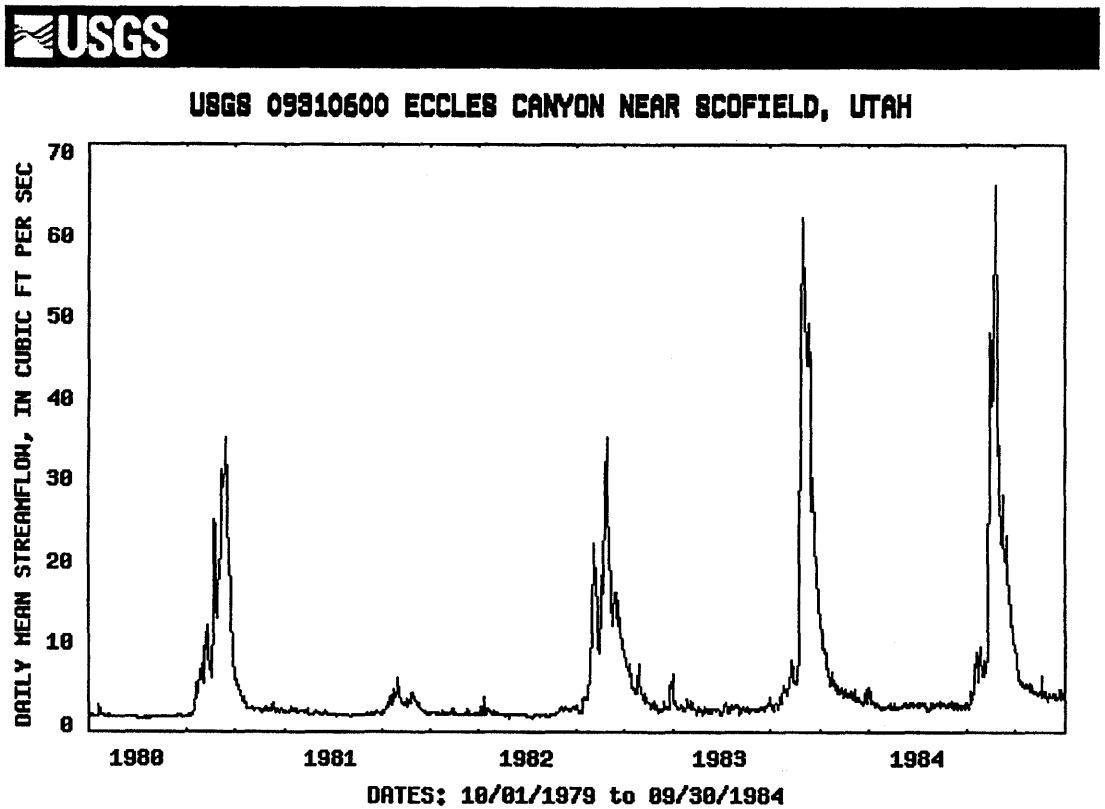

Figure 2. Sediment profile, Eccles Creek 1990 (Ecosystems Research Institute)

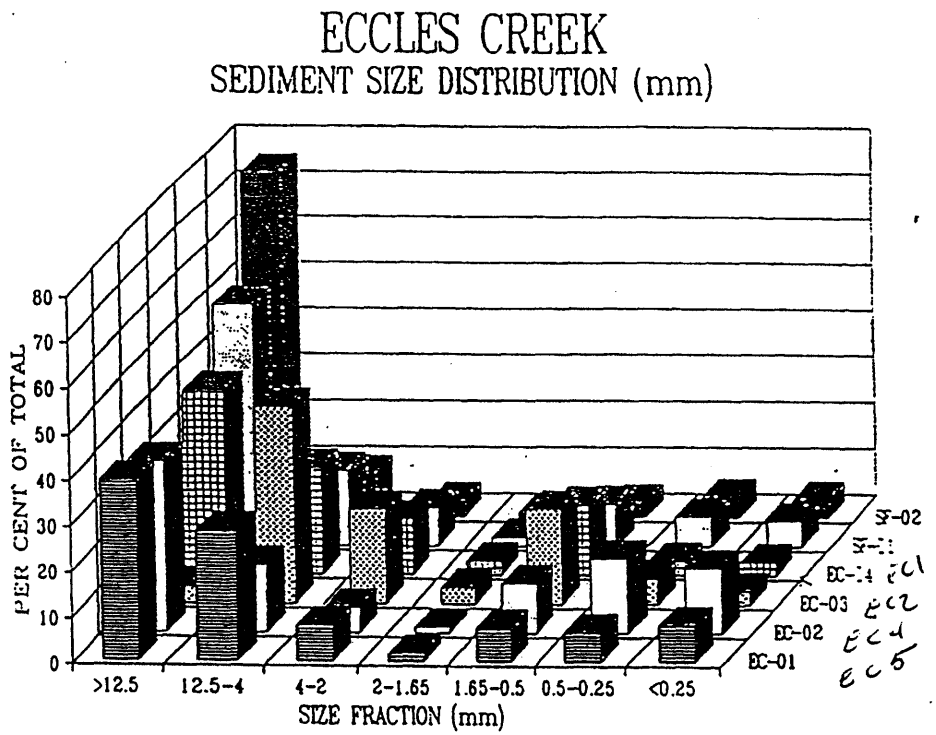

FIGURE 2-6. The size distributions of bed sediments in the Eccles Creek stations.
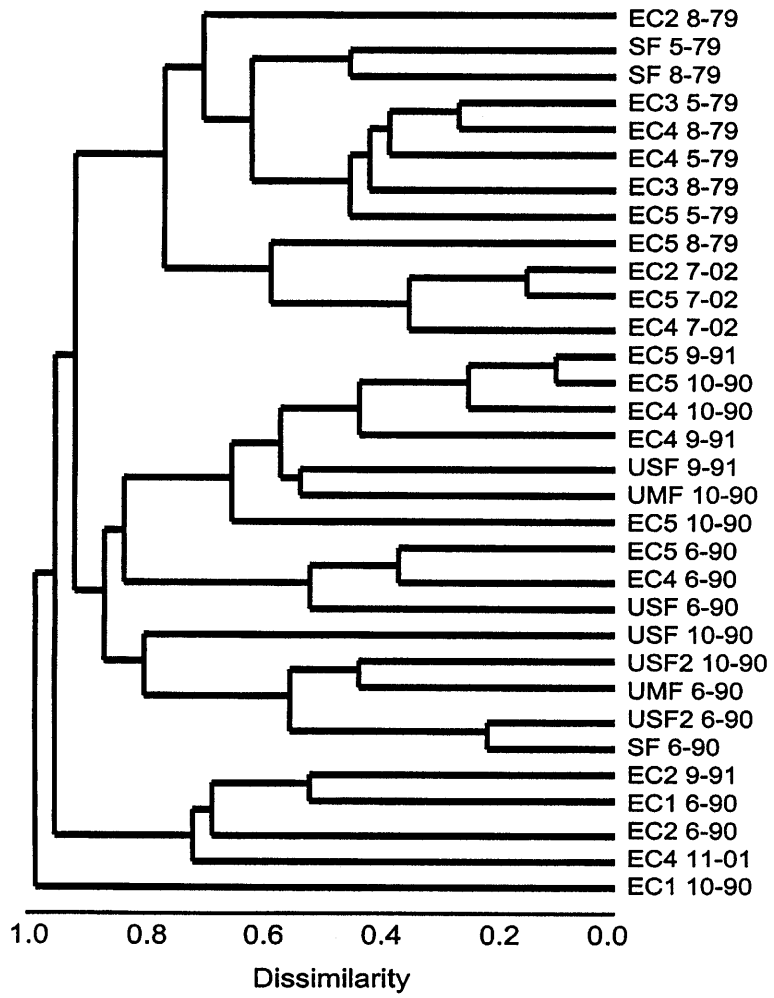
Figure 3. Cluster dendrogram of stations from the Eccles Creek Drainage.