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Sufco Mine
A Subsidiary of Arch Western Bituminous Group, LLC.

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April 3, 2006

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Incoming
C/041/0002
Copy Joe & Wayne H. (Letter)

Re: 2004 Annual Report Macroinvertibrate Study, Canyon Fuel Company, LLC, SUFCO Mine C/041/002

Dear Ms. ~~Grubaugh-Lit~~Pam tig:

Please replace the macroinvertibrate explanation page in the Sufco Mine 2004 Annual Report, Appendix B, with the enclosed macroinvertibrate study report. This study report 'An Assessment of the Macroinvertebrates of Box Canyon, Sevier County, Utah in October 2004' was recently completed by our consultant.

If you have any questions please give me a call at (435) 286-4421.

Sincerely,
CANYON FUEL COMPANY, LLC
SUFCO Mine

Mike Davis

Michael L. Davis,
Environmental Engineer

Enclosures

cc: Division of Oil, Gas and Mining – Price Field Office

Sufpub/govt2006/dogm-coor/Pam Grubaugh-Littig.ltr 040306.doc

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AN ASSESSMENT OF THE MACROINVERTEBRATES OF BOX CANYON, SEVIER COUNTY, UTAH IN OCTOBER 2004

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March 2006

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INTRODUCTION

Box Canyon creek on the Southeastern Wasatch Plateau, Sevier County, Utah, is a tributary to Muddy Creek, which then joins with the Fremont River to form the Dirty Devil River of the Colorado River drainage. Box Canyon creek heads at an elevation of approximately 2600 meters above sea level. Coal mining induced subsidence under the East Fork of Box Canyon in the late fall of 2003. Baseline samples of the invertebrate communities in the East Fork of Box Canyon were collected prior to subsidence, on October 20, 2003. At the same time the main stem of Box Canyon creek (which we will designate as the Main Fork Box Canyon) was sampled to establish a control where no subsidence was expected. A second set of samples, post subsidence, was collected on October 3, 2004 and the data resulting from this second sampling effort are the focus of this report.

METHODS

The Main Fork of Box Canyon was selected as a control reach but it had a lower gradient than the East Fork of Box Canyon. Flowing water was present, but moved much more slowly and in some reaches the stream bed was anoxic. No plunge pool-like habitat was found. Precipitated sulfates were seen at stream-side seeps where decomposing Blackhawk Formation shales were exposed. These factors indicated that the Main Fork of Box Canyon had a different chemical composition than the East Fork of Box Canyon. The sample site at the Main Fork of Box Canyon (Table 1) had extensive riffle habitat, consisting of rubble and cobble substrate, suggesting that, at certain times of the year, substantial flows occur in the stream channel. Yet despite the preponderance of coarse substrate, the low gradient and low flows during the fall sampling period resulted in retention of high amounts of leaf litter. The combination of a organic rich habitat and very low flows increased the likelihood of anoxic conditions in some parts of the stream bed, including the riffle habitat. This in turn will influence the composition of the invertebrate community. While the habitat in the East Fork of Box Canyon is very different from the conditions in the Main Fork of Box Canyon, the Main Fork site will be useful for appraising long term trends induced by external factors (droughts, El Nino - Southern Oscillation, etc.) so that such influences can be considered when interpreting data from the East Fork of Box Canyon.

The bed of the stream channel in the East Fork of Box Canyon included several habitat types, ranging from mobile sand bottom, to exposed bedrock. A number of short plunge pools developed where the stream had downcut through Castlegate Sandstone to shales at the top of the underlying Blackhawk Formation. The plunge pools had sand bottoms, but short riffles existed at the outflow of the plunge pools. These riffles consisted of gravel-rubble accumulations embedded in sand. Because the habitat types in the East Fork of Box Canyon were quite discrete, each would contain different invertebrate communities and random sampling would likely result in significant variations in the composition of the community measured at each station. For this reason sampling focused on riffles at the outflow of the plunge pools. That habitat type is most likely to contain a diverse invertebrate assemblage and it would be expected to be more sensitive to changes in flows. Sampling in the East Fork of Box Canyon began in the downstream-most station (Site 1). We progressively sampled upstream where adequate plunge pool/riffle habitats were found (Table 1).

Table 1. Sampling station locations.

	Station	Station Code	Zone	East	North
Main Fork of Box Creek	Site 1	SBXM01	Z12S	E 0469490	N 4316829
East Fork of Box Creek	Site 1	SEFM01	Z12S	E 0471321	N 4317506
East Fork of Box Creek	Site 2	SEFM02	Z12S		
East Fork of Box Creek	Site 3	SEFM03	Z12S	E 0471336	N 4317420
East Fork of Box Creek	Site 4	SEFM04	Z12S	E 0471333	N4317378

Conductivity, pH, alkalinity, and hardness were measured to characterize the stations. Three samples were taken at each site. Since the data are being used to monitor changes in the stream over time, each site in the East Fork of Box Canyon is being treated as a replicate. The individual samples taken from within each site are therefore subsamples which give estimates of the density at the individual site (Jordan et al 1999). Thus the samples were bulked together in the field. A modified Surber-type sampler based on the dimensions of the box sampler developed by Shiozawa (1986), with a net mesh of 250 microns, was used to collect the samples. The substrate was stirred to a depth of approximately 5 cm. All rocks within the area of the sampler were removed and individually washed to insure quantitative collection of the invertebrates. The samples were concentrated on a screen with a mesh of 64 microns and field preserved in ethyl alcohol. A GPS unit was used to both locate and record the positions of the sample stations which were also marked with plastic flagging..

In the laboratory the samples were sorted in illuminated pans. All invertebrates were removed and identified to the lowest possible taxonomic level using the keys of Merritt and Cummins (1996). We took sub-samples from the samples after they were visually sorted. The remaining sample material was placed in a beaker with a total volume of 200 ml and five 2 ml subsamples were removed and processed under magnification with a dissecting scope. The mean density per subsample was used to estimate the total density of organisms remaining in the sample after it had been visually sorted. These projections were added to the total count from the visual sorting. The data were then used to determine the density of taxa per square meter. Mean biomass estimates were also generated so that trends in standing crop could be documented.

Results and Discussion

The Main Fork of Box Creek clearly differed in water chemistry from that recorded for the East Fork of Box Creek in both 2003 and 2004 (Table 2). The Main Fork site had lower pH, conductivity, alkalinity and hardness. In particular, alkalinity in the Main Fork, was about a third of that in the East Fork, and hardness was about half that of the East Fork sites. Alkalinity, a measure of carbonate, bicarbonate, and hydroxide ions should reflect the concentration of calcium/magnesium carbonate and calcium/magnesium bicarbonate ions. If total alkalinity equals hardness, the standard interpretation is that carbonates comprise the main anion constituents in the system. However, if hardness exceeds alkalinity, then other anions are present as well (Boyd 1990). In the case of these two streams it is probable that the difference is made up of sulfate ions. While we did not measure the sulfate concentrations, the presence of sulfur in the Main Fork were noted in the 2003 report. Assuming that the majority of the missing anions were composed of sulfates and that these were largely tied to divalent cations, the Main Fork sulfate levels were probably in the range of about 80 to 90 mg/l in 2003 and 40 mg/l in 2004. The East Fork sulfate levels were likely to be about 40 mg/l in 2003. In 2004 the East Fork of Box Creek sulfate levels varied from about 40 mg/l in the upstream station (site 4) to 0 mg/l in the downstream most station (site 1). The basis behind this difference in 2004 is unclear. Both the Main Fork and the East Fork samples showed a 55% to 100% increase in alkalinity from 2003 to 2004. But the East Fork, unlike the Main Fork, also increased in hardness by about 25% at all East Fork stations, indicating an increase in divalent cations in the system. The hardness levels were approximately the same at all East Fork stations in 2004. The upstream-most station (site 4) had the lowest alkalinity (200 mg/l) and the downstream stations were all about 20% higher.

Conductivity in the Main Fork of Box Canyon increased about 15% between 2003 and 2004. This increase is probably associated with the 2004 increase in alkalinity. The conductivity levels of the East Fork of Box Canyon stations are not as easily understood. The downstream-most station was approximately 15% lower in conductivity than in 2003. The other three sites (stations 2, 3, and 4) were 60% to 66% higher in conductivity when compared to their 2003 measurements. The increase in conductivity is, in part, associated with the increase in divalent ions as detected with the hardness and alkalinity measurements, but the conductivity readings are not responding proportionally at each station. Further, the usual trend is for conductivity to increase progressively downstream, but in this case the conductivity dropped at the downstream-most station. A significant slump occurred at the lower end of site 2 sometime between the 2003 and 2004 sampling periods. This could have altered the inflow of water from the seep which could have impacted the ion concentration in the stream. The discrepancy suggests that something has changed the stream water chemistry both in the composition and concentrations of dissolved solids. The cause of the abrupt change between the downstream-most station, site 1, and the station immediately upstream from it (site 2), is confounded with factors such as the subsidence and fracturing of the stream bed, changing water percolation paths due to rock fractures, the slump of materials from a spring seep into the stream channel, and the injection of bentonite clay into fractures in the Blackhawk Formation. Clays are known to impact ion concentrations in water due to their high ion exchange capacity. Compacted clays can preferentially adsorb sodium and when suspended these same clays can preferentially adsorb calcium (Hem 1970). However those effects should be acute (short term) rather than chronic (long term) and the injection

of bentonite was completed in late September, 2004, while our samples were taken on the 3rd of October. The bentonite may have no longer been a factor by the time our samples were taken.

Table 2. Water Chemistry

	Main Fork Box Canyon		East Fork Box Canyon Site 1		East Fork Box Canyon Site 2		East Fork Box Canyon Site 3		East Fork Box Canyon Site 4	
	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004
Conductivity (uS/cm)	170	202	300	260	270	435	290	445	280	466
pH	7.83	7.76	8.52	8.28	8.39	8.31	8.43	8.06	8.44	7.94
Alkalinity mg/L $CaCO_3$	34	80	154	240	137	220	137	240	154	200
Hardness mg/L $CaCO_3$	120	120	188	240	188	240	171	260	188	240

Invertebrate Taxa

The Main Fork of Box Canyon had 24 taxa and 36,572 organisms per square meter (Table 3). The number of taxa increased by over 75% and the density of organisms had increased by 60% over the 2003 levels. The increase in density was due to increased numbers of chironomid larvae, *Heterlimnius* (Coleoptera) larvae, and a major increase in ostracods. Chironomids made up just over 50% of the numbers and ostracods accounted for about a third of the invertebrates. The omnivorous caddisfly, *Hesperophylax*, was the dominant shredder at the Main Fork site in 2004 and early instar stoneflies were also collected. These factors suggest an increase in stream flow in 2004 over that preceding the collections in 2003.

The four East Fork of Box Canyon stations all showed an increase in the number of taxa in 2004 with an average of 17 per station, compared to an average of 11 per site in 2003. This is still lower than the 24 taxa found in the Main Fork station, and none of the East Fork of Box Canyon sites had over 18 taxa. Given the trend seen in the Main Fork of Box Canyon, the increases in number of taxa in the East Fork would be expected without any impact from the subsidence, and the higher sand embeddedness of the East Fork of Box Canyon riffles should constrain those stations to fewer taxa than would be found in the Main Fork of Box Canyon samples. So the increase in taxa between 2003 and 2004 is notable. Site 1 had about 25% more taxa, site 2 increased by about 21%, and sites 3 and 4 increased their taxa counts by over 60%.

Table 3. Summary of densities per square meter and total taxa for Box Canyon, 2003-2004

	Main Fork Box Canyon		East Fork Box Canyon Site 1		East Fork Box Canyon Site 2		East Fork Box Canyon Site 3		East Fork Box Canyon Site 4	
	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004
Ephemeroptera: *Baetis*	20.2	20.2	3312.8	363.6	2009.9	1949.3	2242.2	0	3333	1828.1
Ephemeroptera: *Cinygmula*	0	0	0	0	0	0	0	0	0	20.2
Ephemeroptera: early instar	0	0	0	0	0	313.1	0	0	0	0
Plecoptera: *Alloperla*	0	0	0	20.2	0	161.6	0	0	0	0
Plecoptera: early instar	0	646.3	414.1	2211.9	1353.4	1919	50.5	323.2	0	1878.6
Plecoptera: *Hesperoperla pacifica*	0	0	0	0	0	0	0	10.1	0	0
Plecoptera: *Malenka californica*	10.1	0	0	60.6	0	50.5	797.9	949.4	444.4	414.1
Plecoptera: *Paraperla*	191.1	10.1	0	0	0	0	2514.9	0	1484.7	0
Plecoptera: *Zapada*	0	10.1	151.5	151.5	171.7	373.7	60.6	292.9	0	0
Trichoptera: *Brachycentrus*	0	0	10.1	0	10.1	0	0	0	0	0
Trichoptera: *Dicosmoecus*	262.6	0	0	0	0	0	0	0	10.1	0
Trichoptera: *Hesperophylax*	0	202	0	90.9	0	10.1	0	90.9	0	40.4
Trichoptera: *Hydropsyche*	0	0	30.3	0	171.7	0	1353.4	0	0	0
Trichoptera: *Lepidostoma*	0	0	0	0	0	10.1	0	0	0	0
Trichoptera: *Limnephilus*	0	0	0	0	10.1	0	0	0	0	0
Trichoptera: *Neothremma alicia*	0	10.1	0	0	0	0	0	0	0	0
Trichoptera: *Psychomyia flavida*	0	0	10.1	0	646.4	0	0	0	0	0
Trichoptera: pupae	0	10.1	0	0	0	0	0	0	0	0

Trichoptera: *Rhyacophila*	0	0	0	0	0	0	20.2	0	0	0
Coleoptera: Dytiscidae (larvae)	0	293	0	0	0	10.1	0	0	0	20.2
Coleoptera: Dytiscidae (adult)	0	0	0	20.2	0	0	0	0	0	0
Coleoptera: *Helichus*	0	111.1	0	0	0	0	0	0	0	0
Coleoptera: *Heterlimnius* (larvae)	10.1	1131.2	0	10.1	0	0	0	10.1	0	0
Coleoptera: *Heterlimnius* (adult)	20.2	10.1	0	0	0	0	0	0	0	0
Coleoptera: *Optioservus* (larvae)	0	50.5	0	0	0	0	0	0	0	0
Coleoptera: *Optioservus* (adult)	525.2	0	0	0	0	0	0	0	0	0
Diptera: *Atherix*	0	20.2	0	0	0	0	0	0	0	0
Diptera: *Caloparyphus*	0	0	0	0	0	10.1	0	0	0	0
Diptera: Ceratopogonidae	10.1	373.7	0	0	40.4	0	0	0	10.1	0
Diptera: *Chelifera*	0	0	30.3	0	60.6	0	0	0	0	10.1
Diptera: Chironomidae (larvae)	16089.3	18543.6	2636.1	1292.8	2656.3	5787.3	2030.1	3393.6	1181.7	9292
Diptera: Chironomidae (pupae)	10.1	20.2	0	303	40.4	0	0	40.4	40.4	434.3
Diptera: *Dicranota*	0	70.7	0	20.2	0	111.1	0	90.9	0	474.7
Diptera: *Dixa*	0	10.1	10.1	0	0	10.1	0	0	0	0
Diptera: *Hexatoma*	0	10.1	0	0	0	0	0	0	0	0
Diptera: *Limnophora*	0	0	0	0	0	0	0	10.1	0	20.2
Diptera: *Limnophila*	0	20.2	0	0	0	0	0	10.1	0	0
Diptera: *Pedicia*	0	20.2	0	0	0	0	0	10.1	0	30.3
Diptera: *Pericoma*	10.1	0	0	60.6	10.1	40.4	0	20.2	10.1	10.1
Diptera: Scleroprocta tetonica	0	10.1	0	0	0	0	0	0	0	0

Diptera: *Simulium* (larvae)	0	0	1010	40.4	5847.9	343.4	1888.7	20.2	999.9	808
Diptera: *Tipula*	60.6	20.2	90.9	30.3	232.3	343.4	70.7	323.2	90.9	393.9
Crustacea: Copepoda	303	0	535.3	303	0	0	0	606	0	303
Crustacea: Ostracoda	1686.7	12685.6	0	303	0	0	0	616.1	10.1	1212
Arachnida: Hydracarina	20.2	1525.1	0	0	10.1	303	0	303	0	0
Mollusca: *Sphaerium*	30.3	90.9	0	0	0	0	0	0	0	0
Annelida: Oligochaeta	1302.9	636.3	0	303	0	0	606	575.7	1343.3	434.3
Planaria	0	10.1	0	0	0	30.3	0	10.1	0	20.2
Collembola	0	0	0	0	0	10.1	0	0	0	10.1
Hemiptera	70.7	0	0	0	0	0	0	0	0	0
Nematoda	0	0	0	0	0	303	0	0	0	0
Total	**20633.5**	**36572.1**	**8241.6**	**5585.3**	**13271.4**	**12089.7**	**11635.2**	**7706.3**	**8958.7**	**17654.8**
Total taxa	**15**	**24**	**12**	**15**	**14**	**17**	**11**	**18**	**11**	**18**

The four sites in the East Fork of Box Canyon had total densities of 5585, 12,090, 7706, and 17,655 respectively. The East Fork of Box Canyon site 4 was the only site that showed an increase for both total number of organism and number of taxa. East Fork of Box Canyon sites 1, 2, and 3 showed declines in total numbers of organisms of 10 to 40% when compared to the 2003 data. In three of the East Fork sites (#s 2, 3, and 4), chironomids were the dominant taxon, comprising 48%, 44%, and 55% of the total organisms, respectively. Early instar Plecoptera also composed a large percentage of the organisms in the three sites and were also the dominant taxa in site 1, accounting for 40% of the total organisms. *Baetis* mayfly nymphs were collected in lower densities in the 2004 samples at all sites, although at site 2 the numbers were only slightly below the 2003 densities. Yet at site 1 *Baetis* were significantly lower in density, falling from 3313, in 2003, to 364 per square meter in 2004, and at site 2 their numbers fell from 2242 per meter square to 0. These two sites clearly were more strongly impacted by something between the two years. This could be the effects of changes in water chemistry (influenced by subsidence and bentonite clay) or the influence of increased sedimentation from stream-side slumps. Two taxa appear to be responding to gradient/current differences between the Main Fork of Box Canyon and the East Fork of Box Canyon. Simuliids, which require flowing water to feed, were present at all four East Fork stations yet they were absent at the Main Fork site. Ostracods, which are weak swimmers, were much lower in density in the East Fork of Box Canyon stations than in the Main Fork of Box Canyon. Early instar Plecoptera, with chironomids accounting for only 23%. However the total density at this site was about 30% less than was recorded in 2003.

Filter feeders in the East Fork of Box Canyon, represented by Simuliidae and Hydropsychidae, clearly show changes in abundance from 2003 to 2004. Hydropsychids which occurred in greatest abundance at site 3 (1353/square meter) and in much lower numbers in sites 1 and 2 (30 and 172 per sq. meter respectively), were completely absent in the 2004 samples. Simuliids were in densities of 1010, 5848,1889,and 1000 per square meter in sites 1, 2, 3, and 4 respectively in 2003, were collected in densities of 40, 343, 20, and 808 in the same four stations in 2004. The filter feeder thus did not change substantially in site 4, the upstream-most station, but they were drastically reduced in the other stations. Such reductions can be generated by increased sediment flow, including fine particles which can plug feeding appendages and nets. Thus the injection of clay into the fractured substrate appears to be a potential cause. While a slump also occurred in the stream, it was below stations 3 and 4, so its effects on simuliids should have not been apparent at station 3. However the slump did block the stream, pooling water into station 2. Substantial reduction in current would have resulted in the immigration of hydropsychids which require current for feeding. The pool was breached by the crew repairing the stream bed in late September. The resulting increase in discharge would have impacted station 1. If the current disturbed rubble at station 1 (which is likely), the hydropsychids would have been flushed from the station in what is known as catastrophic drift. Simuliids tend to be more migratory, drifting even under normal flow conditions, and thus re-colonize habitats rapidly, while hydropsychids are most prevalent in the drift when newly hatched (Shiozawa personal observations).

Table 4. Biomass, comparisons for Oct 2003- Oct 2004

	Main Fork		East Fork Site 1		East Fork Site 2		East Fork Site 3		East Fork Site 4	
Sample	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004	Oct 2003	Oct 2004
1	2.389g	0.3722g	0.3501g	0.0000g	1.4155g	0.2254g	0.8783g	0.2311g	1.3890	0.5828g
2	---	0.4156g	---	0.8244g	---	0.1643g	---	0.1698g	---	0.8661g
3	---	0.3078g	---	0.7631g	---	0.2172g	---	0.2965g	---	0.8539g
total	2.389g	1.0956g	0.3501g	1.5875g	1.4155g	0.6069	0.8783g	0.6974g	1.3809	2.3028g
per m^2	24.12 g/m^2	11.07 g/m^2	3.54 g/m^2	16.03 g/m^2	14.30 g/m^2	6.13 g/m^2	8.87 g/m^2	7.04 g/m^2	13.95 g/m^2	23.26 g/m^2

Biomass

Despite the increase in density and numbers of taxa in the Main Fork of Box Canyon, biomass (Table 4) at that station fell by 64% in 2004. This is due to the substantial increase in small organisms such as ostracods and chironomids. Site 3 of the East Fork of Box Canyon fell only slightly in biomass, but the other sites underwent dramatic shifts. The East Fork sites 1 and 4 both showed increases in biomass over the 2003 values. East Fork of Box Canyon, site 1, was 450% and site 4 was167% of their respective 2003 values. The East Fork of Box Canyon, site 2, in contrast was just 43% of its 2003 biomass. This is the same station where the *Baetis* were absent in the 2004 sampling. Biomass levels between the Main Fork and East Fork are not as easily interpreted as are the number of taxa and the densities. What is clear is that the East Fork of Box Canyon, site 2, station was impacted by the time of the 2004 sampling period.

Diversity Indices

While all five sites increased in the number of taxa between 2003 and 2004, diversity did not always mirror this change (Table 5). The Main Fork of Box Canyon experienced an increase from 0.897 to 1.237, this can be attributed to the increase in total taxa and the decrease of the percentage chironimids. East Fork of Box Canyon site 1 also increased in diversity, from 1.505 in 2003 to 2.059 in 2004. The remaining sites, East Fork of Box Canyon site 2, 3, and 4, despite increases in total number of taxa, declined in their diversity values. Site 2 had a doubling of chironomids and while a few other taxa increased, the overall total numbers of organisms decreased, thus resulting in the chironomids becoming proportionally more abundant. Filter feeders, simuliids and hydropsychids both decreased in density. Site 2 had the lowest diversity value of the sites examined. Site 3 also had a major drop in the total density of organisms while chironomids increased. Several taxa abundant in 2003 (simuliids, *Baetis*, plecoptera and hydropsychids) were absent or almost so in 2004. Again two of these (simuliids and hydropsychids) are filter feeders indicating that stream conditions had changed such that filter feeding was unprofitable at that site. Site 4, the upstream most site had a large increase in chironomids, but many other taxa stayed at or below the 2003 levels. This station had an increase in the density of small plecopterans, suggesting an accumulation of food and cover at that site but it was not as diverse as it was the previous year. It again appears that site 2 was the one that had the greatest evidence of impacts in 2004, but the loss of filter feeders at site 3 also suggests that something had happened to that stream reach. One possible factor is the injection of clay into the stream bed since mobilized clay particles would tend to obstruct the feeding of filter feeding invertebrates.

Table 5. Diversity indices, based on natural logs for Box Canyon Oct 2003-Oct 2004

	Main Fork Box Canyon	East Fork Box Canyon Site 1	East Fork Box Canyon Site 2	East Fork Box Canyon Site 3	East Fork Box Canyon Site 4
Oct 2003	0.897	1.505	1.614	1.929	1.713
Oct 2004	1.237	2.059	1.337	1.852	1.553

The Biotic Condition Index

The actual Community Tolerance Quotient (CTQa) was determined from the presence-absence of taxa (Table 6), and was used to generate the Biotic Condition Index for each of the stations

Table 6. Tolerance quotients for Box Canyon, Fall 2004

	Main Fork Box Canyon	East Fork Box Canyon Site 1	East Fork Box Canyon Site 2	East Fork Box Canyon Site 3	East Fork Box Canyon Site 4	Ideal Stream
Ephemeroptera: Baetidae: *Baetis spp.*	72	72	72		72	72
Ephemeroptera: early instar			72			72
Ephemeroptera: Heptageniidae: *Cinygmula*					21	21
Plecoptera: early instar	36	36	36	36	36	36
Plecoptera: Chloroperlidae: *Alloperla*		24	24			24
Plecoptera: Chloroperlidae: *Paraperla*	24					24
Plecoptera: Nemouridae: *Malenka californica*		36	36	36	36	36
Plecoptera: Nemouridae: *Zapada*	16	16	16	16		16
Plecoptera: Perlidae: *Hepseroperla pacifica*				18		18
Trichoptera: Brachycentridae: *Brachycentrus*						24
Trichoptera: Hydropsychidae: *Hydropsyche*						108
Trichoptera: Lepidostomatidae: *Lepidostoma*			18			18
Trichoptera: Limnephilidae: *Dicosmoecus*						24
Trichoptera: Limnephilidae: Hesperophylax	108	108	108	108	108	108
Trichoptera: Limnephilidae: *Limnephilus*						108
Trichoptera: Psychomyidae: *Psychomyia*						108
Trichoptera: pupae	108					108
Trichoptera: Rhyacophilidae: *Rhyacophila*						18

Trichoptera: Uenoidae: Neothremma alicia	8					8
Coleoptera: Dryopidae: *Helichus*	54					54
Coleoptera: Dytiscidae	72	72	72		72	72
Coleoptera: Elmidae: *Heterlimnius*	108	108		108		108
Coleoptera: Elmidae: *Optioservus*	108					108
Diptera: Athericidae: *Atherix*	24					24
Diptera: Ceratopogonidae	108					108
Diptera: Chironomidae	108	108	108	108	108	108
Diptera: Dixidae: *Dixa*	108		108			108
Diptera: Empimidae: *Chelifera*					108	108
Diptera: Muscidae: *Limnophora*				108	108	108
Diptera: Psychodidae: *Pericoma*		36	36	36	36	36
Diptera: Simuliidae: *Simulium*		108	108	108	108	108
Diptera: Stratiomyidae: *Caloparyphus*			108			108
Diptera: Tipulidae: *Dicranota*	24	24	24	24	24	24
Diptera: Tipulidae: *Hexatoma*	36					36
Diptera: Tipulidae: *Limnophila*	72			72		72
Diptera: Tipulidae: *Pedicia*	72			72	72	72
Diptera: Tipulidae: *Scleroprocta tetonica*	72					72
Diptera: Tipulidae: *Tipula*	36	36	36	36	36	36
Copepoda		108		108	108	108
Ostracoda	108	108		108	108	108
Acari: Hydracarina	108		108	108		108
Mollusca: Gastropoda: *Sphaerium*	108					108
Tricladida: Planariidae	108		108	108	108	108
Oligochaeta	108	108		108	108	108
Collembola			108		108	108
Nematoda			108			108
Total	**1914**	**1108**	**1414**	**1426**	**1485**	**3285**
n	**26**	**16**	**20**	**19**	**19**	**46**
CTQa	**73.615**	**69.25**	**70.7**	**75.053**	**78.158**	**71.41**

sampled. The highest CTQa value was obtained from the East Fork of Box Canyon site 4 (CTQa of 78.2), followed by the East Fork of Box Canyon Site 3 (75.1), the Main Fork (73.6), East Fork Site 2 (70.7) and East Fork Site 1 (69.3). The CTQa value is higher for those communities that represent a more stressful environment (Winget and Mangum 1979). This ranking indicates that Site 4, the upstream-most site in the East Fork of Box Canyon is the most stressed while the downstream most site in that same drainage is the least stressed (has the fewest stress indicator taxa). These values represent an average generated from a list provided by Winget and Mangum (1979) and are based on presence-absence of taxa. Thus a single individual per square meter is equal in weight to an other taxa that is represented by thousands of individuals in the same area. Relative abundance is not considered in this index. It can give us a picture of how conditions have changed over time when compared to previous samples (table 7) or when adjusted by the ideal (CTQp) for the stream. This adjusted value is the BCI, or Biotic Condition Index.

Community Tolerance Quotient and Biotic Condition Indices

The CTQp values are estimated from a combination of gradient, substrate, and water chemistry in accordance with a key provided by Winget and Mangum (1979). One of the chemical factors that is important, sulfate, was not measured in this study so it must be estimated (see Shiozawa 2004). The estimates were 40 mg/l for the East Fork of Box Canyon and 90 mg/l for the Main Fork of Box Canyon. The gradients of both sites, estimated from topographical maps, are less than 1.2%. The Main Fork of Box Canyon was a gravel-rubble substrate while the stations on the East Fork were sorted gravels or rubble substrates. The estimated CTQp for the Main Fork of Box Canyon was 51 while the East Fork Stations had a CTQp of 53.

The Biotic Condition Index is the ratio of CTQp/CTQa expressed as a percent. This ratio effectively reverses the reading of the relationships so that instead of low values being indicative of higher quality waters, high BCI values indicate better water quality. The ideal is a BCI of 100 or higher, meaning that the station meets or exceeds the predicted level. The BCIs for 2004 (table 7) ranged from 67-76. The BCI of the Main Fork of Box Canyon increased by about 10% from 2003 to 2004. The East Fork of Box Canyon sites 1 and 2 also increased approximately the same amount. However the BCI of site 3 in the East Fork of Box Canyon decreased by17%. Site 4 dropped only 2 points. The average BCI for the four East Fork sites in 2003 was 71.5. In 2004 that average was 72.5. This suggests that the BCI of the East Fork has not changed since the subsidence in 2003.

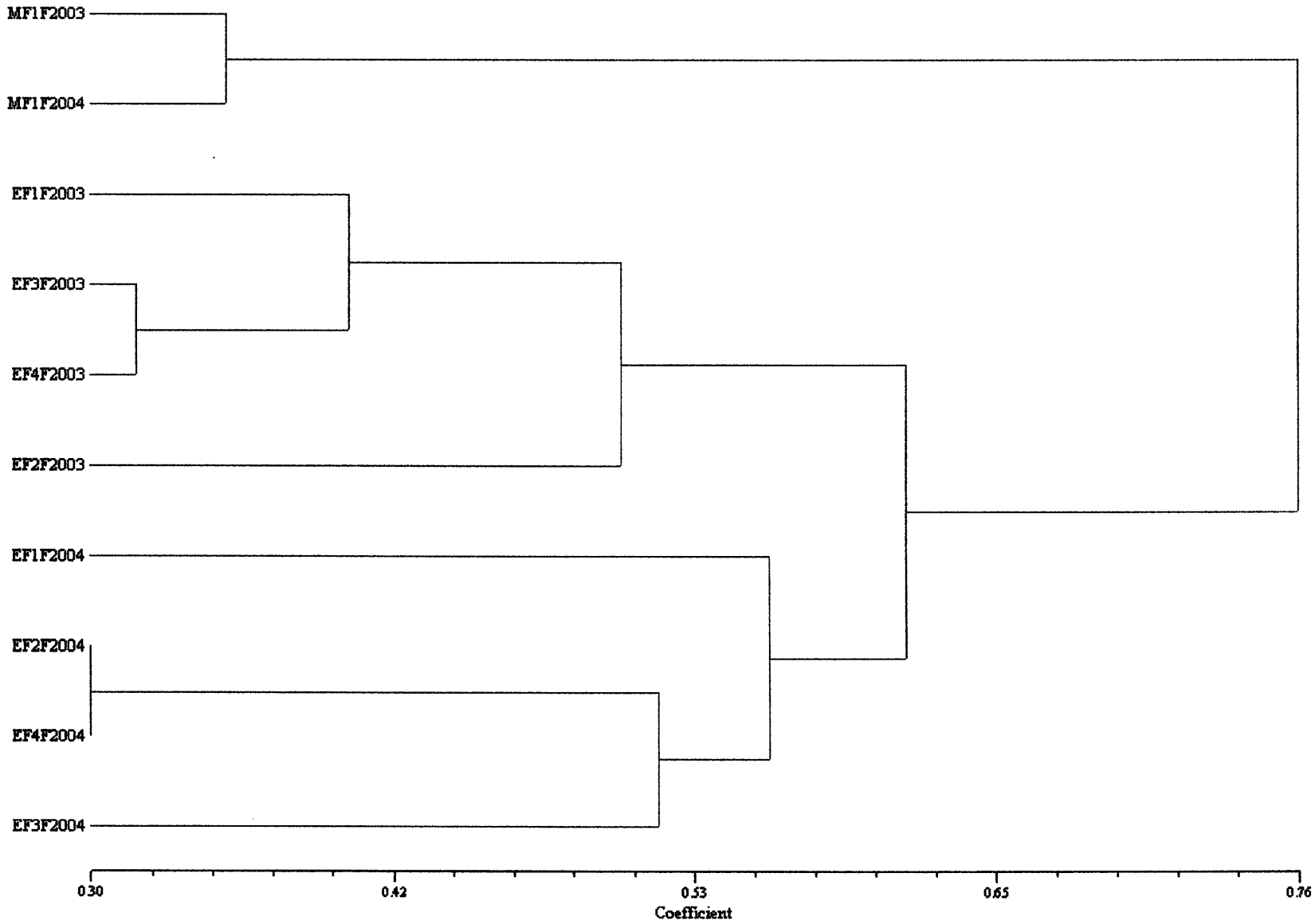
Table 7. CTQa and BCI values for Box Canyon Oct 2003- Oct 2004

	Main Fork	East Fork Site 1	East Fork Site 2	East Fork Site 3	East Fork Site 4
	CTQa/BCI	CTQa/BCI	CTQa/BCI	CTQa/BCI	CTQa/BCI
Oct 2003	84.8/ 60.14	78.33/ 67.66	85.57/ 61.94	60.91/ 87.01	76.36/ 69.41
Oct 2004	73.62/ 69.27	69.25/ 76.53	70.7/ 74.96	75.05/ 70.62	78.16/ 67.81
Average	79/ 65	74/ 72	78/ 68	68/ 79	77/ 69

Cluster Analysis

The cluster analysis of the data utilized the Bray-Curtis dissimilarity index (Poole 1974, Krebs 1989) with the unweighted pairs group averaging algorithm (UPGMA) (NTSYS; Rolf 2000).
The analysis (Figure 1) resulted in two principle clusters separating at a dissimilarity level of 0.76. One cluster consisted of the Main Fork of Box Canyon samples for 2003 and 2004. The other included all of the East Fork of Box Canyon samples. Within the East Fork of Box Canyon cluster the sites clustered by year, indicating that the stations sampled in 2004 were quite dissimilar to the same sites in 2003. If no changes had taken place in the stream between 2003 and 2004, the clusters would have been expected to lack the segregation into discrete 2003 and 2004 groupings.

Figure 1. Cluster dendrogram for the Box Canyon samples.



CONCLUSIONS

The East Fork of Box Canyon sites in 2004, as in 2003, were again different from the Main Fork of Box Canyon station. This confirms the visual assessment of the two stream channels. The strength of the difference between the two forks of Box Canyon limits the use of the Main Fork of Box Canyon site to that of assessing annual trends in the region, thus giving a general template with which to base the interpretation of changes in the East Fork sample sites. The Main Fork of Box Canyon cannot be used as the ideal endpoint in the trajectory of the East Fork of Box Canyon sites as they recover from any impacts due to subsidence. Changes in the invertebrate community and water chemistry of the Main Fork of Box Canyon site between 2003 and 2004 indicate an increase in stream discharge in 2004. A similar discharge influence would be expected in the East Fork of Box Canyon. Alkalinity and hardness in the East Fork of Box Canyon increased in 2004, suggesting increased leaching. This could be induced by increased discharge. The 2004 conductivity readings in the three upstream East Fork stations were much higher than in 2003, but were actually lower than the 2003 levels at the downstream-most station. Increased conductivity could be a result of subsidence induced fracturing or bedrock and the decrease in conductivity at the downstream station (site 1) may have been due increased seepage from the slump above the station.

In the cluster analysis, the 2003 and 2004 Main Fork of Box Canyon sites were much more similar to one another than to any of the East Fork of Box Canyon sites. The East Fork of Box Canyon sites fell into a sweparate discrete cluster. Cluster analysis also clearly showed that the four East Fork of Box Canyon sites from the 2004 samples were in a separate cluster from the 2003 series. The change in community composition in the East Fork of Box Canyon is not just induced by the discharge related differences seen between the 2003 and 2004 Main Fork Box Canyon samples. The degree of dissimilarity between the two years in the Main Fork of Box Canyon is about 0.35, while that between years in the East Fork of Box Canyon is much greater, about 0.60, suggesting that the differences between the 2003 and 2004 samples in the East Fork sites are likely to be due to more than just shifts in annual discharge. The CTQa and BCI values indicated that while the Main Fork site had improved in quality between 2003 and 2004, the East Fork stations showed no collective change. Sites 1 and 2 improved in the CTQa and BCI values while sites 3 and 4 declined.

All stations in both forks of Box Canyon had an increase in the number of taxa in 2004 but the densities of invertebrates in the East Fork of Box Canyon decreased in all but the upstream-most station, site 4. Biomass only declined at site 2. The other sites either increased in biomass or remained about the same as in 2003. Diversity in the East Fork of Box Canyon increased at site 1, but decreased at the other sites. Filter feeding invertebrates were greatly reduced in all but the uppermost station in the East Fork of Box Canyon. Their elimination was likely associated with the use of clay to seal the fractures in the Blackhawk Formation. Collectively these measures give mixed conclusions but they stem in part from the differential impacts of the subsidence and mitigation (i.e. the use of bentonite clay). The middle two stations appear to be the most impacted while the downstream-most station superficially appears to be in the best condition, except that it is missing part of the filter feeding component of the stream benthic community. Over time this component of the stream community should recover.

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Appendix A. Sample data Main Fork Box Canyon Fall 2004

Main Fork Box Canyon Fall 2004		Sample 1	Sample 2	Sample 3	Mean	Density
Ephemeroptera	*Baetis sp.*	0	0	2	0.666667	20.2
Plecoptera	Early instar Plecoptera	1	12	51	21.33333	646.4
	Paraperla frontalis	1	0	0	0.333333	10.1
	Zapada sp.	1	0	0	0.333333	10.1
Trichoptera	Trichoptera pupa	0	1	0	0.333333	10.1
	Hesperophylax	10	5	5	6.666667	202
	Neothremma alicia	0	0	1	0.333333	10.1
Coeleoptera	Dytiscidae	0	14	15	9.666667	292.9
	Helichus sp. (Dryopidae)	1	9	1	3.666667	111.1
	Heterlimnius (larvae)	0	1	111	37.33333	1131.2
	Heterlimnius (adult)	0	0	1	0.333333	10.1
	Optioservus (larvae)	0	1	4	1.666667	50.5
Diptera	*Atherix*	0	1	1	0.666667	20.2
	Ceratopogonidae	31	1	5	12.33333	373.7
	Chironomidae (larva)	927	620	289	612	18543.6
	Chironomidae (pupa)	1	1	0	0.666667	20.2
	Dicranota	5	0	2	2.333333	70.7
	Dixa	0	1	0	0.333333	10.1
	Hexatoma	0	0	1	0.333333	10.1
	Limnophila	0	2	0	0.666667	20.2
	Pedicia	0	2	0	0.666667	20.2
	Tipula sp.	1	0	1	0.666667	20.2
	Scleroprocta tetonica	0	0	1	0.333333	10.1
Crustacea	*Ostracoda*	143	603	510	418.6667	12685.6
Arachnida	*Hydracarnia*	30	61	60	50.33333	1525.1
Mollusca	*Sphaerium sp*	7	0	2	3	90.9
Misc.	Oligochaeta	0	32	31	21	636.3
	Planaria	0	1	0	0.333333	10.1
	Totals	*1159*	*1368*	*1094*		**36572.1**

Appendix B. Sample data East Fork Box Canyon Site 1, Fall 2004

Site 1 East Fork Box Canyon Fall 2004		Sample 1	Sample 2	Sample 3	Mean	Density
Ephemeroptera	*Baetis sp.*	0	34	2	12	363.6
Plecoptera	Early instar Plecoptera	60	146	13	73	2211.9
	Alloperla sp.	0	2	0	0.666667	20.2
	Malenka californica	0	6	0	2	60.6
	Zapada sp.	0	9	6	5	151.5
Trichoptera	*Hesperophylax*	0	9	0	3	90.9
Coeleoptera	Dytiscidae (adult)	0	0	2	0.666667	20.2
	Heterlimnius (larvae)	0	1	0	0.333333	10.1
Diptera	*Chironomidae (larva)*	30	36	62	42.66667	1292.8
	Chironomidae (pupa)	0	30	0	10	303
	Dicranota	0	2	0	0.666667	20.2
	Pericoma	0	5	1	2	60.6
	Simulium	0	3	1	1.333333	40.4
	Tipula sp.	0	0	3	1	30.3
Crustacea	*Copepoda*	0	0	30	10	303
	Ostracoda	0	0	30	10	303
Misc.	Oligochaeta	0	0	30	10	303
	Totals	*90*	*283*	*180*		**5585.3**

Appendix C. Sample data East Fork Box Canyon Site 2, Fall 2004

Site 2 East Fork Box Canyon Fall 2004		Sample 1	Sample 2	Sample 3	Mean	Density
Ephemeroptera	*Baetis sp.*	2	191	0	64.33333	1949.3
	Early instar Ephemeroptera	0	30	1	10.33333	313.1
Plecoptera	Early instar Plecoptera	66	73	51	63.33333	1919
	Alloperla sp.	0	15	1	5.333333	161.6
	Malenka californica	3	1	1	1.666667	50.5
	Zapada sp.	13	22	2	12.33333	373.7
Trichoptera	*Hesperophylax*	1	0	0	0.333333	10.1
	Lepidostoma	0	0	1	0.333333	10.1
Coeleoptera	Dytiscidae	0	1	0	0.333333	10.1
Diptera	*Caloparyphus*	0	0	1	0.333333	10.1
	Chironomidae (larva)	248	168	157	191	5787.3
	Dixa	1	0	0	0.333333	10.1
	Dicranota	7	4	0	3.666667	111.1
	Pericoma	1	0	3	1.333333	40.4
	Simulium	10	23	1	11.33333	343.4
	Tipula sp.	32	1	1	11.33333	343.4
Arachnida	*Hydracarina*	0	0	30	10	303
Misc.	Collembola	1	0	0	0.333333	10.1
	Nematoda	30	0	0	10	303
	Planaria	0	3	0	1	30.3
	Totals	*415*	*532*	*250*		**12089.7**

Appendix D. Sample Data East Fork Box Canyon Site 3, Fall 2004

Site 3 East Fork Box Canyon Fall 2004		Site 1	Site 2	Site 3	Mean	Density
Plecoptera	Early instar Plecoptera	16	13	3	10.66667	323.2
	Hesperoperla pacifica	1	0	0	0.333333	10.1
	Malenka californica	0	27	67	31.33333	949.4
	Zapada sp.	28	1	0	9.666667	292.9
Trichoptera	*Hesperophylax*	2	1	6	3	90.9
Coeleoptera	*Heterlimnius* (adult)	1	0	0	0.333333	10.1
Diptera	Chironomidae (larvae)	42	51	243	112	3393.6
	Chironomidae (pupae)	2	1	1	1.333333	40.4
	Dicranota (Tipulidae)	4	1	4	3	90.9
	Pericoma (Psychodidae)	0	1	1	0.666667	20.2
	Simulium (Simulidae)	1	0	1	0.666667	20.2
	Tipula sp. (Tipulidae)	1	31	0	10.66667	323.2
	Pedicia (Tipulidae)	0	1	0	0.333333	10.1
	Limnophora (Tipulidae)	0	1	0	0.333333	10.1
	Limnophila (Tipulidae)	0	0	1	0.333333	10.1
Crustacea	Copepoda	0	60	0	20	606
	Ostracoda	1	30	30	20.33333	616.1
Arachnida	Hydracarina	0	30	0	10	303
Annelida	Oligochaeta	22	1	34	19	575.7
	Planaridae	0	1	0	0.333333	10.1
	Totals	*121*	*251*	*391*		**7706.3**

Appendix E. Sample data East Fork Box Canyon Site 4, Fall 2004

Site 4 East Fork Box Canyon Fall 2004		Site 1	Site 2	Site 3	Mean	Density
Ephemeroptera	*Baetis sp.*	61	60	60	60.33333	1828.1
	Cinygmula sp.	2	0	0	0.666667	20.2
Plecoptera	Early instar Plecoptera	3	1	182	62	1878.6
	Malenka californica	4	3	34	13.66667	414.1
Trichoptera	*Hesperophylax*	0	4	0	1.333333	40.4
Coeleoptera	Dytiscidae	1	1	0	0.666667	20.2
Diptera	*Limnophora* (Tipulidae)	2	0	0	0.666667	20.2
	Chironomidae (larvae)	226	336	358	306.6667	9292
	Chironomidae (pupae)	6	32	5	14.33333	434.3
	Cheliferia (Empididae)	0	0	1	0.333333	10.1
	Dicranota (Tipulidae)	44	2	1	15.66667	474.7
	Pedicia (Tipulidae)	3	0	0	1	30.3
	Pericoma (Psychodidae)	0	1	0	0.333333	10.1
	Simulium (Simulidae)	1	44	35	26.66667	808
	Tipula sp. (Tipulidae)	9	19	11	13	393.9
Crustacea	Copepoda	30	0	0	10	303
	Ostracoda	90	30	0	40	1212
Annelida	Oligochaeta	14	29	0	14.33333	434.3
Misc.	Collembola	0	0	1	0.333333	10.1
	Planaridae	1	1	0	0.666667	20.2
	Totals	*497*	*563*	*688*		**17654.8**