SUPPORT OF AQUATIC LIFE USES IN THE UPPER BLACKFOOT RIVER AND TRIBUTARIES BASED ON THE COMPOSITION AND STRUCTURE OF THE BENTHIC ALGAE COMMUNITY

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SUMMARY

In June of 2001, 12 periphyton samples were collected from the Blackfoot River above Nevada Creek and from four tributaries of the upper Blackfoot River in western Montana for the purpose of assessing whether these streams are water-quality limited and in need of TMDLs. The samples were collected following DEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Diatoms with deformities were found in periphyton samples collected from all 12 sites on the upper Blackfoot River and tributaries. In samples from two sites--**BlckftR-01 and SbrC-02**--teratological diatoms accounted for more than 10% of the cells that were counted, indicating **severe impairment and nonsupport of aquatic life uses.** At five sites--**BlckftR-02, SbrC-01, AraC-01, PoorC-02, and PoorC-01**--the percentage of teratological cells indicated **moderate impairment and partial support of uses**. The most likely cause of this impairment is elevated concentrations of heavy metals. The remaining 5 sites suffered only minor impairment and fully supported their aquatic life uses.

In addition to having large percentages of teratological cells, the two sites on Sandbar Creek also supported very large populations of individual diatom species. At SbrC-02, *Achnanthidium minutissimum* accounted for 86% of the cells in the diatom association. Streams receiving mining wastes in western Montana often support very large numbers of *Achnanthidium minutissimum*, an indicator of chemical disturbance and elevated concentrations of heavy metals. The upstream site on Sandbar Creek (SbrC-01) supported a large number of *Diatoma mesodon*, a cold-water stenotherm that is common in streams receiving mine adit discharge water and flows recharged by groundwater.

INTRODUCTION

This report evaluates the biological integrity, support of aquatic life uses, and probable causes of impairment to those uses, in the upper Blackfoot River and in four tributaries of the upper Blackfoot River in western Montana. The purpose of this report is to provide information that will help the State of Montana determine whether these streams are water-quality limited and in need of TMDLs.

The federal Clean Water Act directs states to develop water pollution control plans (Total Maximum Daily Loads or TMDLs) that set limits on pollution loading to water-quality limited waters. Water-quality limited waters are lakes and stream segments that do not meet water-quality standards, that is, that do not fully support their beneficial uses. The Clean Water Act and USEPA regulations require each state to (1) identify waters that are water-quality limited, (2) prioritize and target waters for TMDLs, and (3) develop TMDL plans to attain and maintain water-quality standards for all water-quality limited waters.

Evaluation of use support in this report is based on the species composition and structure of the periphyton (benthic algae, phytobenthos) community at 12 sites that were sampled from mid to late June in 2001. The periphyton community is a basic biological component of all aquatic ecosystems. Periphyton accounts for much of the primary production and biological diversity in Montana streams (Bahls et al. 1992).

Plafkin et al. (1989) and Stevenson and Bahls (1999) list several advantages of using periphyton in biological assessments:

- Algae are universally present in large numbers in all streams and unimpaired periphyton assemblages typically support a large number (>30) of species;

- Algae have rapid reproduction rates and short life cycles, making them useful indicators of short-term impacts;

- As primary producers, algae are most directly affected by physical and chemical factors, such as temperature, nutrients, dissolved salts, and toxins;

- Sampling is quick, easy and inexpensive, and causes minimal damage to resident biota and their habitat;

- Standard methods and criteria exist for evaluating the composition, structure, and biomass of algal associations;

- Identification to species is straightforward for the diatoms, for which there is a large body of taxonomic and ecological literature;

- Excessive algae growth in streams is often correctly perceived as a problem by the public.

- Periphyton and other biological communities reflect the *biological integrity*[1] of waterbodies; restoring and maintaining the biological integrity of waterbodies is a goal of the federal Clean Water Act;

- Periphyton and other biological communities integrate the effects of different stressors and provide a measure of their aggregate impact; and

- Periphyton and other biological communities may be the only practical means of evaluating impacts from non-point sources of pollution where specific ambient criteria do not exist (e.g., impacts that degrade habitat or increase nutrients).

Periphyton is a diverse assortment of simple photosynthetic organisms called algae, and other microorganisms that live attached to or in close proximity of the stream bottom. Most algae, such as the diatoms, are microscopic. Diatoms are distinguished by having a cell wall composed of opaline glass--hydrated amorphous silica. Diatoms often carpet a stream bottom with a slippery brown film.

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[1] *Biological integrity* is defined as "the ability of an aquatic ecosystem to support and maintain a balanced, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of natural habitats within a region" (Karr and Dudley 1981).

Some algae, such as the filamentous greens, are conspicuous and their excessive growth may be aesthetically displeasing, deplete dissolved oxygen, interfere with fishing and fish spawning, clog water filters and irrigation intakes, create tastes and odors in drinking water, and cause other problems.

PROJECT AREA AND SAMPLING SITES

The project area is located in Lewis & Clark and Powell Counties in western Montana. The surface geology of the upper Blackfoot River watershed consists mostly of Precambrian Belt Series rocks in the uplands and Quaternary basin fill in the valleys (Renfro and Feray 1972).

The Blackfoot River heads near Rogers Pass (elevation 5,610 feet) north of Helena. Most tributaries arise at elevations ranging from 5,000 to 9,000 feet. At 4,300 feet, the Blackfoot River above Nevada Creek is the lowest site in the study area. Vegetation is mainly mixed conifer forest with alpine tundra on the highest peaks and open parks of fescue grassland near the mouth of Poorman Creek and near the mouth of Nevada Creek at the lower end of the study area (USDA 1976).

The upper Blackfoot River watershed is within the Northern Rockies Ecoregion of Montana (Woods et al. 1999). The main land uses are recreation, livestock grazing, logging, and mining. The Blackfoot River is popular for fishing and floating, mainly below the study area. The upper Blackfoot River drainage has many abandoned mine sites and a long history of hardrock mining.

Periphyton samples were collected at 12 sites on the Blackfoot River and four of its tributaries (Maps 1-7, Table 1). Most sampling sites are on public (USFS, BLM, or State) land. The Blackfoot River and its tributaries are classified B-1 in the Montana Surface Water Quality Standards.

METHODS

Periphyton samples were collected following standard operating procedures of the MDEQ Planning, Prevention, and Assistance Division. Using appropriate tools, microalgae were scraped, brushed, or sucked from natural substrates in proportion to the rank of those substrates at the study site. Macroalgae were picked by hand in proportion to their abundance at the site. All collections of microalgae and macroalgae were pooled into a common container and preserved with Lugol's solution.

The samples were examined to estimate the relative abundance and rank by biovolume of diatoms and genera of soft (non-diatom) algae according to the method described in Bahls (1993). Soft algae were identified using Dillard (1999), Prescott (1978), Smith (1950), and Whitford and Schumacher (1984). These books also served as references on the ecology of the soft algae, along with Palmer (1969, 1977).

After the identification of soft algae, the raw periphyton samples were cleaned of organic matter using sulfuric acid, and permanent diatom slides were prepared using Naphrax, a high refractive index mounting medium, following *Standard Methods for the Examination of Water and Wastewater* (APHA 1998). Between 400 and 494 diatom cells (800 to 988 valves) were counted at random and identified to species. The following were used as the main taxonomic and autecological references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Patrick and Reimer 1966, 1975. Lowe (1974) was also used as an ecological reference for the diatoms.

The diatom proportional counts were used to generate an array of diatom association metrics (Table 2). A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999).

Metric values from the Blackfoot River and tributaries were compared to numeric biocriteria or threshold values developed for streams in the Rocky Mountain Ecoregions of Montana (Table 3). These criteria are based on metric values measured in least-impaired reference streams (Bahls et al. 1992) and on metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993).

The criteria in Table 3 distinguish among four levels of impairment and three levels of aquatic life use support: no impairment or only minor impairment (full support); moderate impairment (partial support); and severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor *biological integrity*, respectively.

Quality Assurance. Several steps were taken to assure that the study results are accurate and reproducible.

Upon receipt of the samples, station and sample information were recorded in a laboratory notebook and the samples were assigned a unique number compatible with the Montana Diatom Database, e.g., 2156-01. The first part of this number (2156) designates the sampling site (Blackfoot River at Flesher Pass Road); the second part of this number (01) designates the number of periphyton samples that have been collected at this site for which data have been entered into the Montana Diatom Database.

Sample observations and analyses of soft (non-diatom) algae were recorded in a lab notebook along with station and sample information provided by MDEQ. A portion of the raw sample was used to make duplicate diatom slides. After completing the diatom proportional count, the slide used for the count will be deposited in the Montana Diatom Collection at University of Montana Herbarium in Missoula. The other slide will be retained by *Hannaea* in Helena.

On completion of the project, station information, sample information, and diatom proportional count data will be entered into the Montana Diatom Database.

RESULTS AND DISCUSSION

Results are presented in Figure 1 and Tables 4 through 7, which are located near the end of this report following the Literature Cited section. Spreadsheets containing completed diatom proportional counts, with species' pollution tolerance classes (PTC) and percent abundances, are attached as Appendix A.

SAMPLE NOTES

Blackfoot River. Deformed diatom valves were noted in all three of the periphyton samples from the upper Blackfoot River.

Arrastra Creek. Algae were very sparse in the sample from AraC-01, and the usually colonial alga *Hydrurus* was present only as individual cells. This implies that algal colonization and succession at this site were at a very early stage.

Poorman Creek. All three of the samples from Poorman Creek were dominated by moss. *Spirogyra* in the sample from PoorC-03 was senescent.

Willow Creek. The sample collected at WilC-01 was dominated by moss. *Ulothrix zonata* was the species of *Ulothrix* present at WilC-02.

Sandbar Creek. The sample from SbrC-01 was dominated by moss. Algae were sparse and diatoms were very sparse in the sample from SbrC-02.

NON-DIATOM ALGAE

Blackfoot River. Filamentous green algae dominated the periphyton community at all three sites on the upper Blackfoot River, and a different genus dominated at each site (Table 4).

Zygogonium dominated at the upstream site (Flesher Pass Road). This unusual alga, which is rare in periphyton samples, is primarily aerial and grows on moist acid soils, rocks, and peat (Smith 1950). When growing on soil, it may develop in patches several yards in diameter. "The remarkable capacity of *Zygogonium* for taking up and returning large quantities of water plays no inconsiderable role in colonization of bare soil by the smaller phanerogams" (Smith 1950).

Diatoms ranked second in biovolume at BlckftR-01, followed by *Tolypothrix*, a cyanobacterium that requires cool water. In total, 12 genera of green, blue-green, and golden nondiatom algae were found in the sample from this site (Table 4). These algae indicate cool waters with relatively low levels of nutrients.

Stigeoclonium dominated the periphyton at BlckftR-02, above Landers Fork. This alga is often found in waters that are enriched with organic wastes (Palmer 1969). The source of this organic load may be swampy areas upstream or old pit toilets at the Forest Service campground (Aspen Grove) just above the sampling site (Michael Pipp, MDEQ, pers. comm.). Diatoms ranked 2nd in biovolume at this site, followed by the cyanobacterium *Nostoc*, which indicates cool waters where nitrogen is limiting. A total of 9 genera of non-diatom algae in three divisions were recorded at this site (Table 4).

Ulothrix dominated the periphyton community at BlckftR-03, above Nevada Creek, followed by the cyanobacterium *Oscillatoria*. These algae indicate increasing nitrogen enrichment. Diatoms ranked 3rd at this site. Ten genera of non-diatom algae were recorded here, in four different divisions, including the red alga *Audouinella* (Table 4).

Poorman Creek. Diatoms dominated the periphyton community in all three samples from Poorman Creek (Table 4). Cyanobacteria ranked second at the upper two sites: *Nostoc* at PoorC-01 and *Phormidium* at PoorC-02. These genera indicate cool waters with relatively low levels of nutrients. The filamentous green alga *Spirogyra* ranked second at PoorC-03. This alga, also known as "pond scum", indicates warmer water temperatures, which may be due to a large beaver dam complex just upstream (Michael Pipp, MDEQ, pers. comm.).

The number of non-diatom genera was lower in Poorman Creek than in the upper Blackfoot River: only 2 to 6 genera of non-diatom algae were recorded at each site (Table 4). This may be due to the smaller size of Poorman Creek and natural stresses associated with shading and cool waters of low mineral content. Diatoms, green algae, and cyanobacteria were present at PoorC-01, whereas only diatoms and cyanobacteria were present at PoorC-02. Cyanobacteria were absent at the downstream site (PoorC-03), but green algae and red algae were present here (Table 4).

Arastra Creek. On average, Arrastra Creek supported even fewer non-diatom algae than did Poorman Creek (Table 5). Only diatoms and the cold-water chrysophyte *Hydrurus foetidus* were found with regularity in the sample from AraC-01. *Hydrurus* dominated the sample from AraC-02, followed by diatoms and the filamentous green alga *Ulothrix*. These algae indicate cold waters with relatively low levels of nutrients.

Sandbar Creek. Diatoms dominated the periphyton sample collected at SbrC-01 and the cyanobacterium *Phormidium* accounted for the most biovolume at SbrC-02 (Table 5). Among the non-diatom algae, both sites supported a mix of green algae and cyanobacteria, and a single genus of chrysophyte (*Tribonema*). Ten genera of non-diatom algae were found at the upstream site and seven genera at the downstream site (Table 5). As with the other streams in this study, the algal flora of Sandbar Creek indicated cool waters of low mineral content.

Willow Creek. Diatoms accounted for most of the biovolume in the periphyton sample collected at WilC-01 and the chrysophyte *Tribonema* ranked second at this site (Table 5). Nine other genera of green algae and cyanobacteria, most of them indicating cool waters of low nutrient and low mineral content, made up the rest of the flora.

The filamentous green alga *Ulothrix* dominated the periphyton sample from WilC-02, followed by *Chaetophora* (filamentous green), *Audouinella* (filamentous red), and *Tolypothrix* (filamentous cyanobacterium) (Table 5). These algae also indicate cool waters with relatively low nutrient and mineral content.

DIATOMS

Blackfoot River. Most of the major diatom species in samples from the upper Blackfoot River are sensitive to organic enrichment (Table 6). However, *Synedra rumpens*, the dominant species at the Flesher Pass Road, is somewhat tolerant of organic loading (Lange-Bertalot 1979). Organic loading at this site, which is also reflected by the borderline pollution index (2.50), may be internal and due to the naturally swampy nature of the stream at and above this location.

Aside from minor organic loading and disturbance, and a slightly elevated percent dominant species value at the upstream site, the most serious problem in the upper Blackfoot River appears to be chronic metals toxicity resulting in large percentages of abnormal diatom valves (Table 6). The largest of these percentages (11.40%) is comparable to that found in the Eagle River of Colorado, a federal superfund site (McFarland et al. 1997). Large percentages of teratological diatom valves have also been observed in Tenmile Creek near Helena (Bahls 1998) and in Elkhorn Creek near Wise River (Bahls 2001). Both sites have elevated heavy metals associated with historic mining activities.

The percentage of abnormal diatom valves in the upper Blackfoot River decreases in a downstream direction (Figure 1, Table 6). This likely indicates dilution of heavy metals by cleanwater tributaries and/or an increase in buffering capacity as the river becomes more alkaline. The percentage of abnormal valves at the Flesher Pass Road (BlckftR-01) indicates severe impairment and nonsupport of aquatic life uses. The percentage above the Landers Fork (BlckftR-02) indicates moderate impairment and partial support of aquatic life uses, and the percentage above Nevada Creek (BlckftR-03) indicates minor impairment but full support of aquatic life uses.

Other than unusually large percentages of teratological diatoms at the two upstream sites, diatom metrics indicate good to excellent biological integrity and full support of aquatic life uses in the upper Blackfoot River. Diatom diversity, species richness, and the pollution index all increased in a downstream direction, indicating a decrease in organic loading and heavy metals concentrations. Except for small increases in the siltation index, the diatoms indicate that biological integrity improved from upstream to downstream in the upper Blackfoot. Adjacent sites in the upper Blackfoot River had about 40% of their diatom floras in common (Table 6), indicating that moderate environmental change (recovery) occurred between them.

Poorman Creek. The upper two sites on Poorman Creek also had an elevated number of teratological diatom valves, but the percentages here were much smaller than they were at the upper two sites on the Blackfoot River (Table 6). These resulted in ratings of moderate impairment and fair biological integrity at PoorC-01 and PoorC-02. This impairment is probably due to elevated concentrations of heavy metals. Otherwise, diatom metrics indicated only minor impairment and full support of aquatic life uses in Poorman Creek.

Diatom diversity and species richness in Poorman Creek increased in a downstream direction, perhaps in response to a decline in concentrations of heavy metals. Slowing current velocities and warmer water temperatures may also contribute to an increase in diatom diversity. A slightly elevated siltation index indicates minor impairment from sedimentation at PoorC-02 (Table 6).

Most of the major diatom species in Poorman Creek are sensitive to pollution (Table 6). Pollution index values for Poorman Creek were relatively low for a mountain stream and were about the same at all three sites. The one major species present that is somewhat tolerant of organic enrichment--*Synedra ulna*--was most abundant at the upstream site (PoorC-01). In Table 6, the similarity index indicates a much greater floristic change occurred between the upper and middle sites (26% similar floras) than between the middle and lower sites (52% similar floras).

Arastra Creek. The upper site on Arrastra Creek had a high percentage of abnormal diatom valves (3.67%) that indicates moderate impairment and partial support of aquatic life uses (Table 7). As with Poorman Creek and the upper Blackfoot River, this impairment was likely due to elevated concentrations of heavy metals. The percentage of teratological diatom valves dropped to an acceptable level at AraC-02.

Diatom species diversity and species richness also declined from AraC-01 to AraC-02 (Table 7). This decline in diversity was due mainly to an abundance of *Hannaea arcus* at AraC-02. This diatom and *Hydrurus foetidus*, which dominated the periphyton at this site, both indicate cold waters of high quality. Hence the low diatom diversity and species richness values at this site are likely due to natural stressors, such as cold water temperatures, low concentrations of dissolved solids, and moderate current velocities.

Sandbar Creek. Both sites on Sandbar Creek had elevated percentages of abnormal diatoms (Table 7). The percentage at SbrC-01 (3.71%) indicated moderate impairment and partial support of aquatic life uses; the percentage at SbrC-02 (10.26) indicated severe impairment and nonsupport of aquatic life uses.

In addition, both sites on Sandbar Creek had depressed diatom diversity and species richness values, indicating moderate to severe stress (Table 7). *Diatoma mesodon*, the dominant diatom species at the upstream site, is a cold water stenotherm (Lowe 1974). I have recorded large numbers of this species in mine adit discharges and in streams that receive mine adit discharges (unpublished data). It appears to be a good indicator of stream sites that are fed primarily by groundwater.

The dominant diatom species at the downstream site (SbrC-02) was *Achnanthidium minutissimum* (synonym: *Achnanthes minutissima*) (Table 7). This is a pioneer species which, when present in very large numbers, indicates some form of chemical, physical or biological disturbance (Barbour et al. 1999). Although diatom associations in unpolluted streams in Montana may be composed of up to 70% *Achnanthidium minutissimum*, much larger percentages of this diatom almost always occur in streams that receive mining wastes (unpublished data). The large percentage of this diatom

(86.5%) at SbrC-02 and the resulting low diversity index (0.96) both indicate severe impairment and nonsupport of uses.

The two sites on Sandbar Creek shared only about a quarter of their diatom floras (Table 7). This indicates that a moderate amount of environmental change (impairment) occurred between the two sites.

Willow Creek. Willow Creek was the only one of the study streams where diatoms indicated that both sites suffered only minor impairment and fully supported their aquatic life uses (Table 7). The upstream site (WilC-01) had a slightly elevated siltation index and a few abnormal diatom valves. The lower site (WilC-02) had somewhat depressed pollution index, indicating some organic loading. This organic loading may be natural and due to the swampy nature of this stream.

Both sites supported relatively large numbers of small, free-living Fragilariaceae (*Fragilaria vaucheriae, Staurosira construens, Synedra rumpens)* (Table 7). These diatoms indicate highly stable stream flows and reflect the low gradient and stable flows of Willow Creek. The two sites on Willow Creek had almost half of their diatom floras in common, indicating only minor environmental change occurred between them.

Both sites on Willow Creek supported a few abnormal diatom valves (Table 7) but these sites had two of the three lowest percentages of abnormal valves of all the sites in the study area (Figure 1). The upper Blackfoot River and the tributaries sampled for this study are unusual in that abnormal valves were recorded at all study sites (Figure 1). This probably indicates the influence of elevated heavy metals in these waters.

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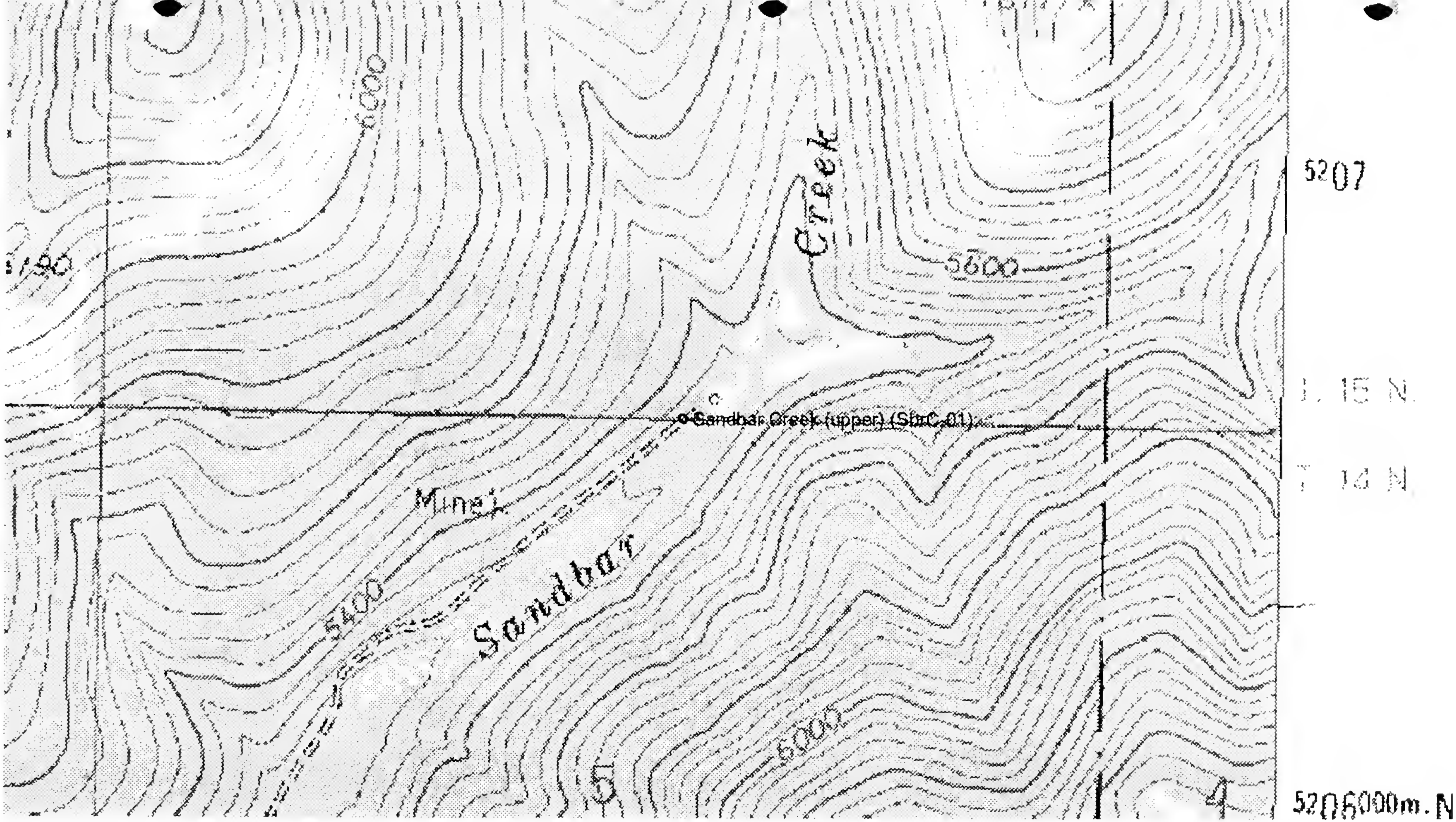
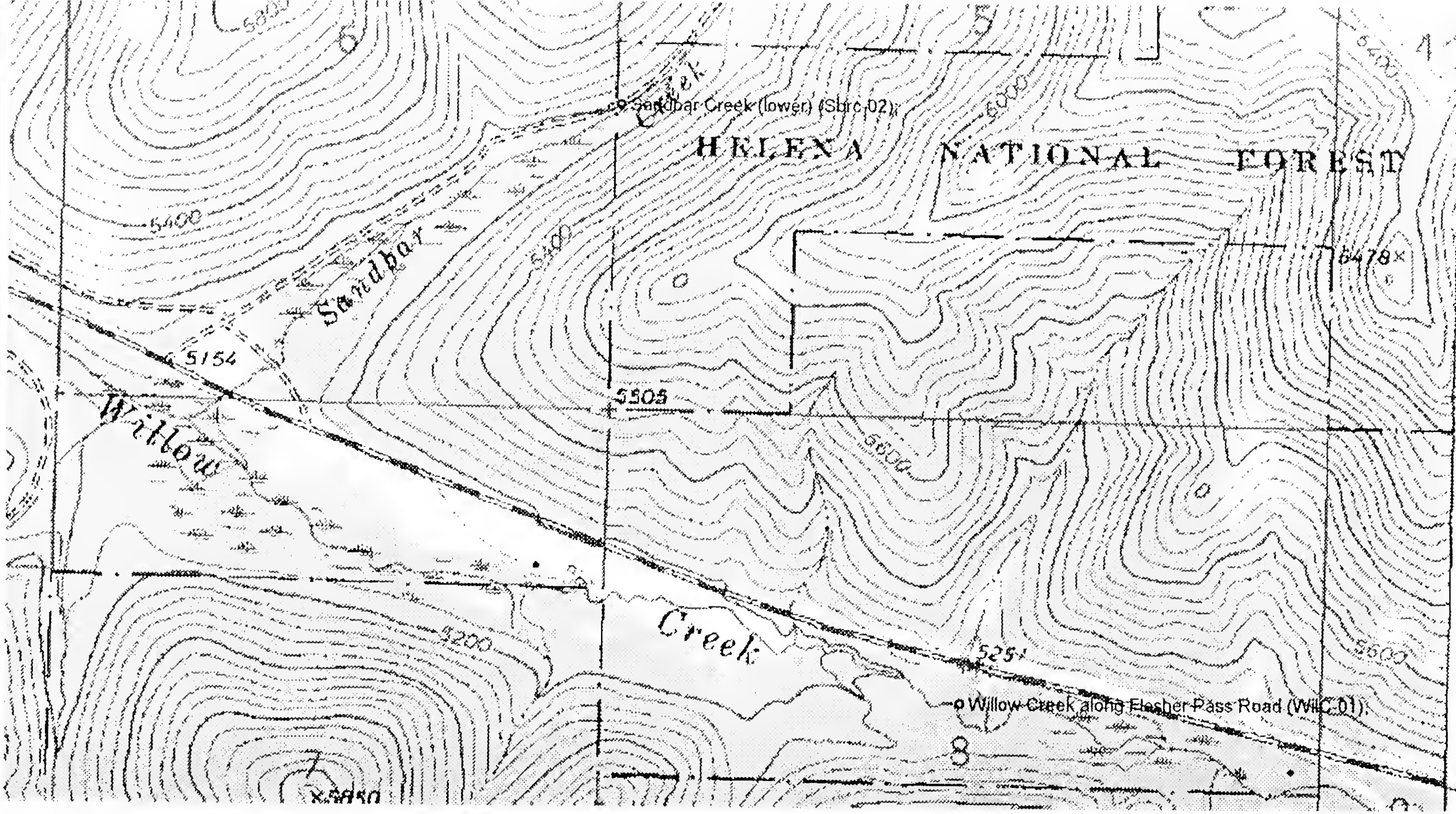


o Sandbar Creek (lower) (Sbrc-02);

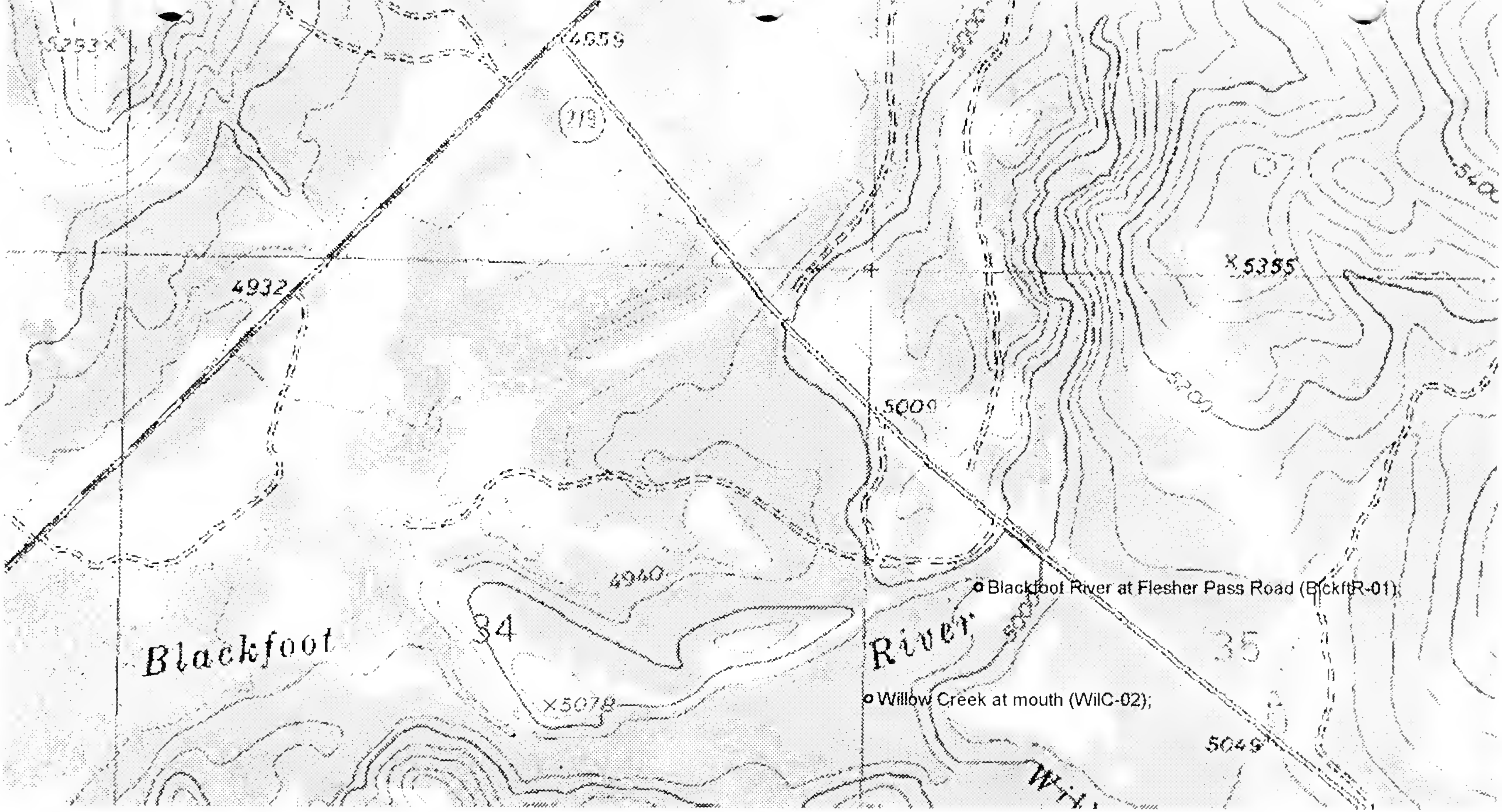
MAP 1

'Cadotte Creek; MT'; Scale 1" = 0 143Mi 230Mt 755Ft, 1 Mi = 6 996" , 1 cm = 91Mt



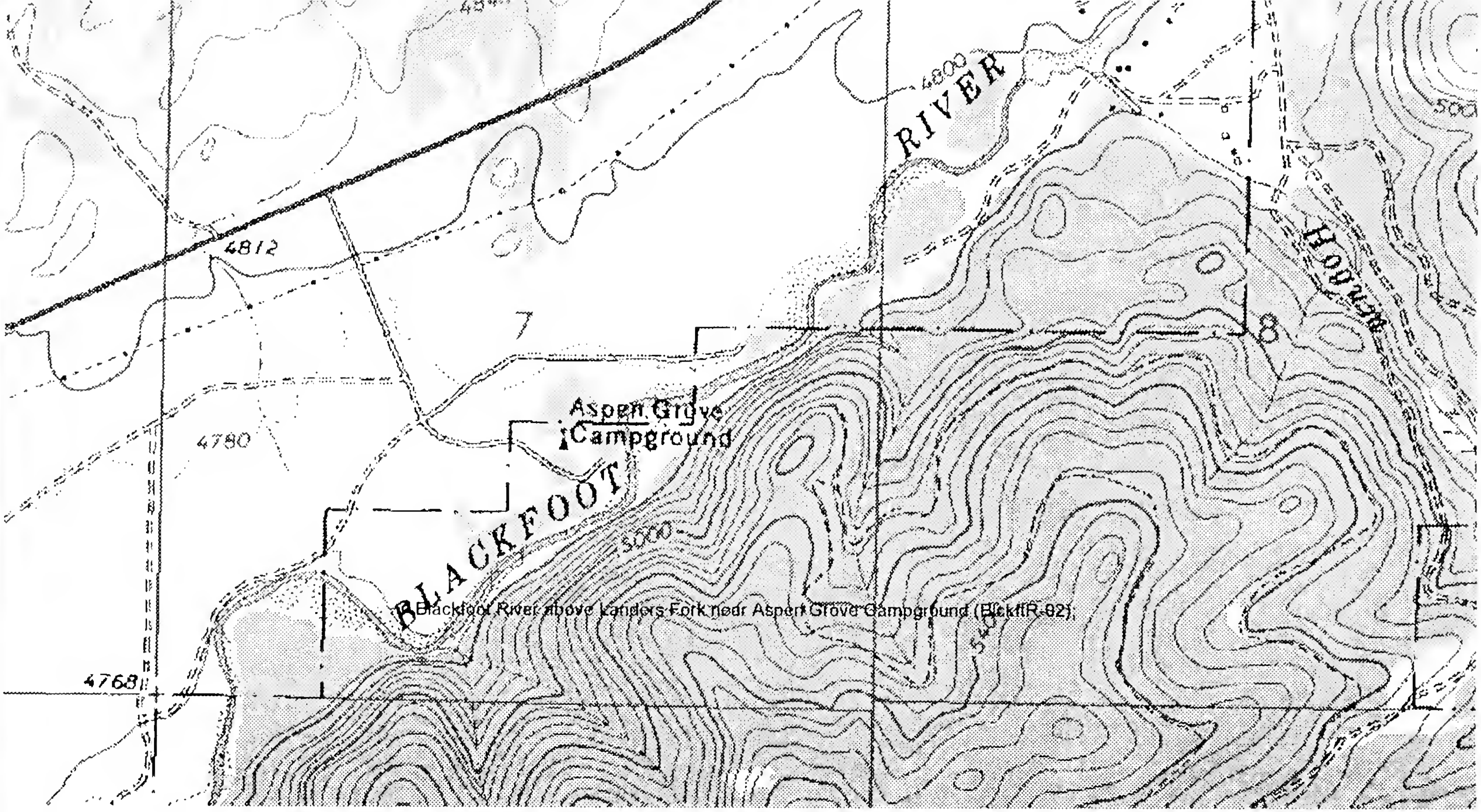
MAP 2

'Stemple Pass; MT'; Scale: 1" = 0.191Mi 307Mt 1,006Ft, 1 Mi = 5.247" , 1 cm = 121Mt



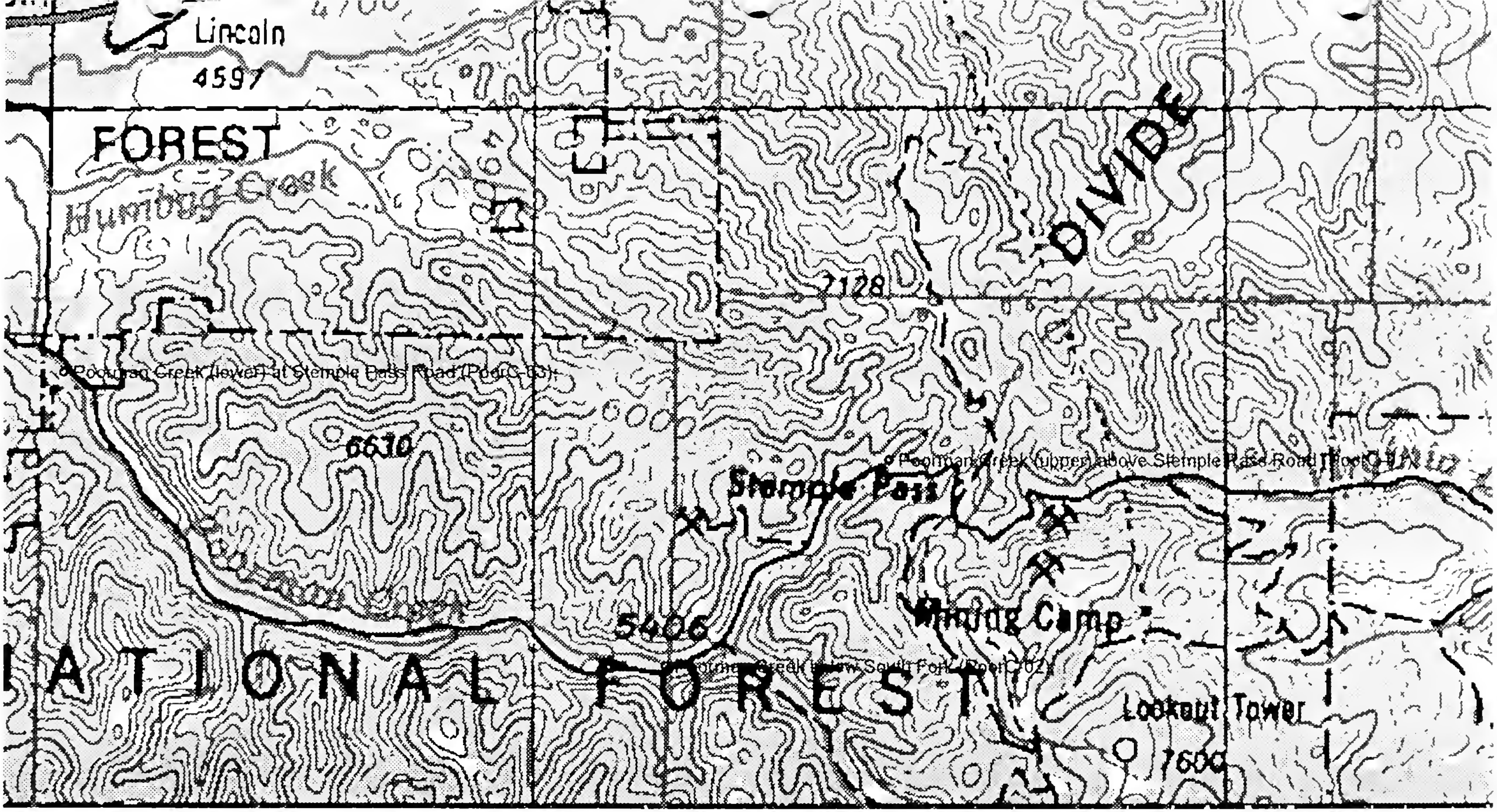
MAP 3

'Cadotte Creek; MT', Scale 1" = 0.191Mi 307Mt 1,006Ft, 1 Mi = 5 247" , 1 cm = 121Mt



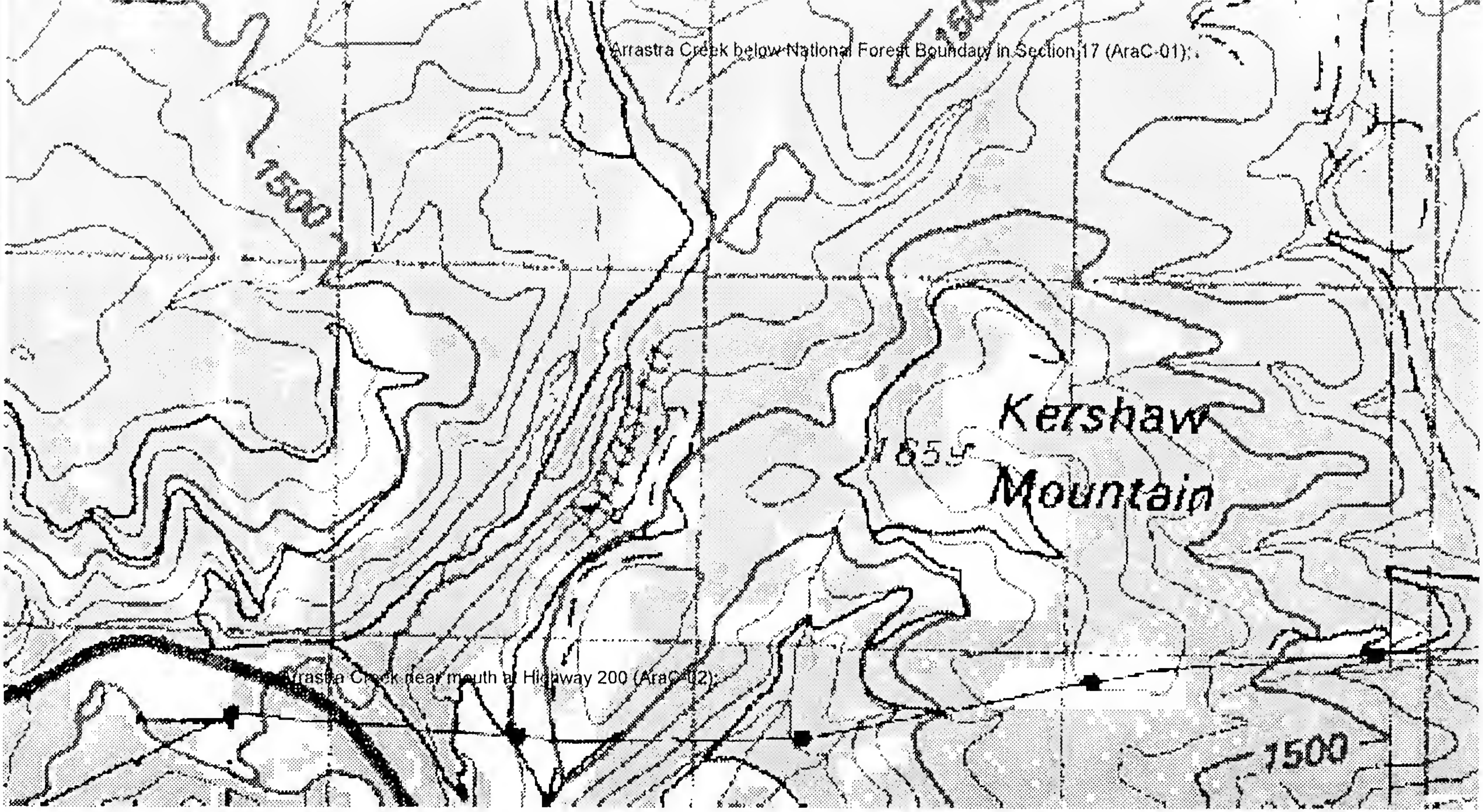
MAP 4

'Swede Gulch; MT'; Scale: 1" = 0.191Mi 307Mt 1,006Ft, 1 Mi = 5.247" , 1 cm = 121Mt



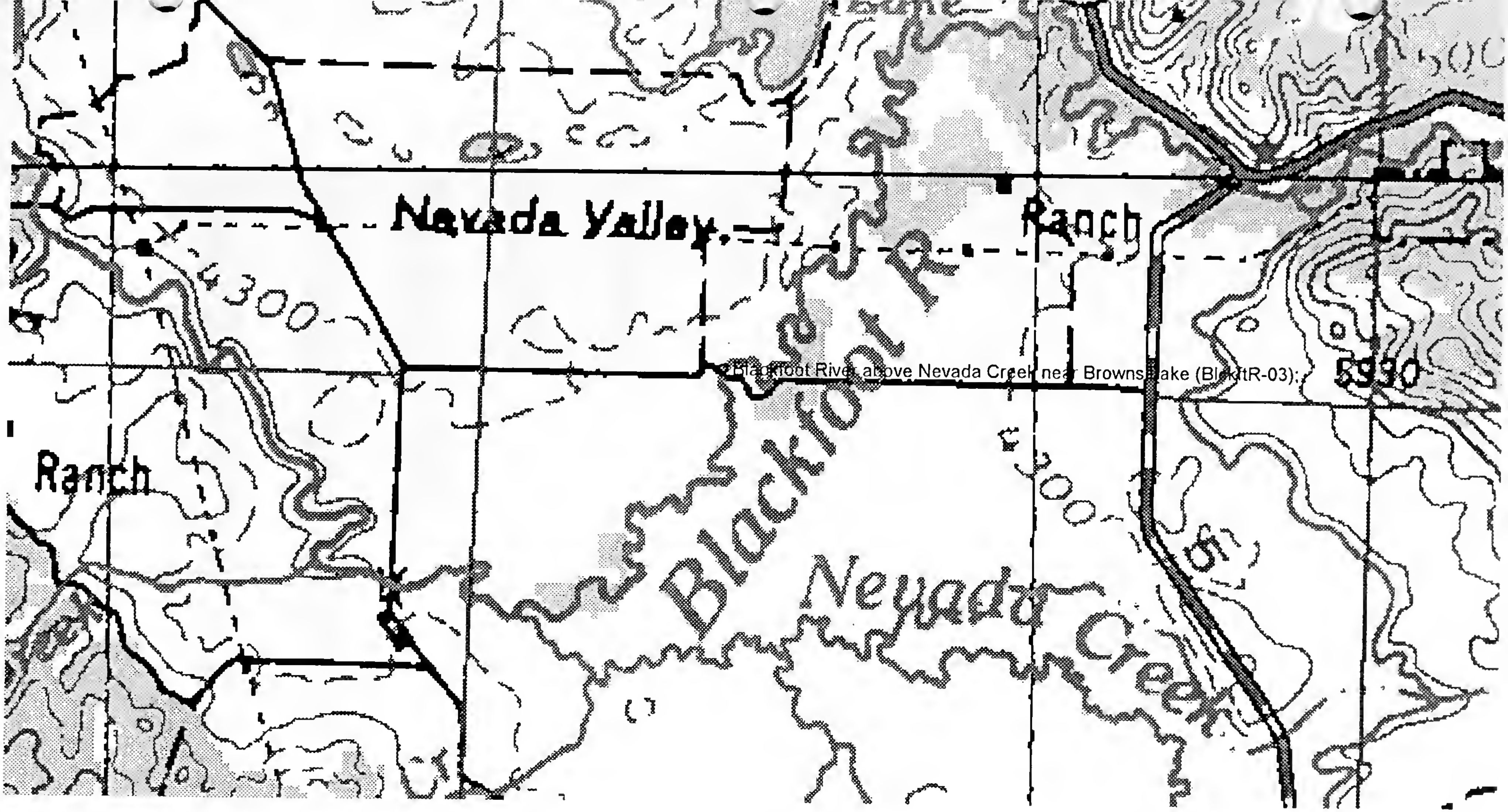
MAP 5

'Butte 250K, MT'; Scale: 1" = 1.271Mi, 2,045Mt, 6,709Ft, 1 Mi = 0.787", 1 cm = 805Mt



MAP 6

'Elliston 100K; MT'; Scale: 1" = 0.381Mi 613Mt 2,013Ft, 1 Mi = 2.624" , 1 cm = 242Mt



MAP 7

'Butte 250K; MT'; Scale: 1" = 0.953Mi 1,534Mt 5,031Ft, 1 Mi = 1.049" , 1 cm = 604Mt

Figure 1. Percent abnormal diatom valves in periphyton samples from the upper Blackfoot River and tributaries.

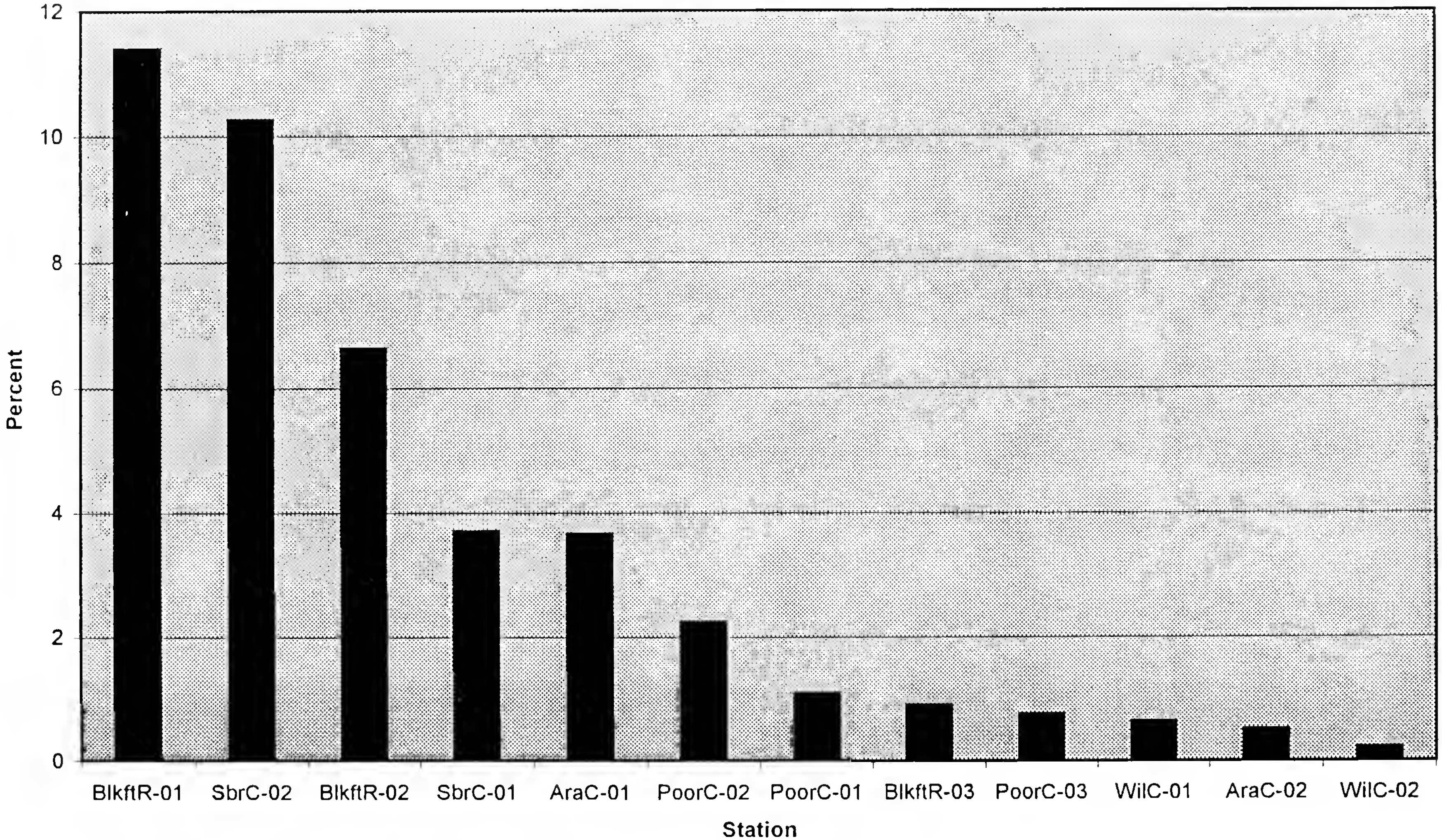


Table 1. Location of periphyton sampling stations in the upper Blackfoot R. drainage.

Station	Station Code	Sample Number	Latitude/ Longitude	Sample Date
Blackfoot River at Flesher Pass Road	BlckftR-01	2156-01	47 00 39 112 27 17	06/21/01
Blackfoot River above Landers Fork at Aspen Grove Campground	BlckftR-02	2157-01	46 58 30 112 32 05	06/21/01
Blackfoot River above Nevada Creek near Browns Lake	BlckftR-03	2158-01	46 55 08 113 00 50	06/26/01
Arrastra Creek below National Forest boundary in section 17	AraC-01	2159-01	46 58 15 112 53 09	06/21/01
Arrastra Creek at Highway 200 near mouth	AraC-02	2160-01	46 56 45 112 54 14	06/21/01
Poorman Creek (upper) above Stemple Pass road	PoorC-01	2161-01	46 54 00 112 30 27	06/26/01
Poorman Creek (middle) below South Fork	PoorC-02	2162-01	46 52 23 112 32 57	06/26/01
Poorman Creek (lower) at Stemple Pass road	PoorC-03	2163-01	46 54 33 112 39 51	06/26/01
Willow Creek along Flesher Pass road	WilC-01	2164-01	46 59 09 112 23 21	06/19/01
Willow Creek at mouth	WilC-02	2165-01	47 00 31 112 27 28	06/21/01
Sandbar Creek (upper)	SbrC-01	2166-01	47 00 22 112 23 15	06/18/01
Sandbar Creek (lower)	SbrC-02	2167-01	46 59 51 112 23 58	06/18/01

Table 2. Diatom association metrics used to evaluate biological integrity in Montana streams: reference, range of values in Montana streams, and expected direction of metric response to increasing anthropogenic perturbation or natural stress.

Metric	Reference	Range of Values	Expected Response
Shannon Species Diversity	Bahls 1979	0.00-5.00+	Decrease[1]
Pollution Index[2]	Bahls 1993	1.00-3.00	Decrease
Siltation Index[3]	Bahls 1993	0.00-90.0+	Increase
Disturbance Index[4]	Barbour *et al.* 1999	0.00-100.0	Increase
No. Species Counted	Bahls 1979, 1993	0-100+	Decrease[1]
Percent Dominant Species	Barbour *et al.* 1999	5.0-100.0	Increase
Percent Abnormal Cells	McFarland *et al.* 1997	0.0-20.0+	Increase
Similarity Index	Whittaker 1952	0.0-80.0+	Decrease
Percent Epithemiaceae	Stevenson & Pan 1999	0.0-80.0+	Decrease
Percent Aerophiles	Johansen 1999	0.0-100	Increase

[1] Shannon diversity and species richness may increase somewhat in naturally nutrient-poor mountain streams in response to slight to moderate increases in nutrients or sediment.

[2] Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species.

[3] Sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia*, and *Surirella*.

[4] Percent abundance of *Achnanthes minutissima*.

Table 3. Criteria for rating levels of biological integrity, environmental impairment or natural stress, and aquatic life use support in wadeable **mountain** streams of Montana using selected metrics for benthic diatom associations. The lowest rating for any one metric is the overall rating for the study site.

Biological Integrity/ Impairment or Natural Stress/Use Support	Diversity Index (Shannon)	Pollution Index	Siltation Index	Disturbance Index	Number of Species Counted	Percent Dominant Species	Percent Abnormal Cells	Similarity Index[1]
Excellent None/Full Support	>2.99	>2.50	<20.0	<25.0	>29	<25.0	0.0	>59.9
Good/Minor Full Support	2.00-2.99	2.01-2.50	20.0-39.9	25.0-49.9	20-29	25.0-49.9	>0.0-<1.0	40.0-59.9
Fair/Moderate Partial Support	1.00-1.99	1.50-2.00	40.0-59.9	50.0-74.9	10-19	50.0-74.9	1.0-9.9	20.0-39.9
Poor/Severe Nonsupport	<1.00	<1.50	>59.9	>74.9	<10	>74.9	>9.9	<20.0

[1] The Similarity Index or Percent Community Similarity (Whittaker 1952) may be used to compare a study site to an unimpaired upstream control site on the same stream. This metric measures the degree of floristic similarity between diatom associations at the two sites and is the sum of the smaller of the two percent abundance values for each species that is common to both sites. Adjacent riffles on the same stream, without intervening tributaries or environmental perturbations, will generally have at least 60% of their diatom floras in common (Bahls 1993). PCS may also be used to guage the relative amount of impairment or recovery that occurs between adjacent study sites: >59.9% = very similar floras, no change; 40.0-59.9% = somewhat similar floras, minor change; 20.0-39.9% = somewhat dissimilar floras, moderate change; <20.0% = very dissimilar floras, major change.

Table 4. Relative abundance of cells and ordinal rank by biovolume of diatoms (Class Bacillariophyceae) and genera of non-diatom algae in periphyton samples collected from the upper Blackfoot River and Poorman Creek in 2001: d = dominant; a = abundant; f = frequent; c = common; o = occasional; r = rare.

Taxa	Station					
	BlckftR-01	BlckftR-02	BlckftR-03	PoorC-01	PoorC-02	PoorC-03
Chlorophyta (green algae)						
Ankistrodesmus	c/8					
Chaetophora		f/5				
Closterium		r/10	r/10	o/6		r/5
Cosmarium	o/9					
Gongrosira			r/9			
Microspora						o/3
Mougeotia	f/4					o/4
Spirogyra						o/2
Staurastrum	r/13					
Stigeoclonium	f/5	d/1	o/7	o/4		
Ulothrix		f/4	d/1			
Zygogonium	d/1					
Chrysophyta (golden algae)						
Diatoms	a/2	f/2	a/3	a/1	a/1	f/1
Hydrurus		c/6				
Tribonema	o/11					o/6
Vaucheria			o/6			
Rhodophyta (red algae)						
Audouinella			o/8			o/7

Table 4. Relative abundance of cells and ordinal rank by biovolume of diatoms (Class Bacillariophyceae) and genera of non-diatom algae in periphyton samples collected from the upper Blackfoot River and Poorman Creek in 2001: d = dominant; a = abundant; f = frequent; c = common; o = occasional; r = rare.

Taxa	Station					
	BlckftR-01	BlckftR-02	BlckftR-03	PoorC-01	PoorC-02	PoorC-03
Cyanophyta (cyanobacteria)						
Amphithrix			r/11			
Anabaena	o/10	o/9				
Calothrix	c/7					
Nostoc		f/3		f/2		
Oscillatoria	c/6	c/8	a/2	o/5	o/3	
Phormidium	o/12	c/7	c/5	c/3	c/2	
Rivularia			c/4			
Tolypothrix	a/3					
No. of Genera	12	9	10	5	2	6

Table 5. Relative abundance of cells and ordinal rank by biovolume of diatoms (Class Bacillariophyceae) and genera of non-diatom algae in periphyton samples collected from Arrastra Creek, Sandbar Creek, and Willow Creek in 2001: d = dominant; a = abundant; f = frequent; c = common; o = occasional; r = rare.

Taxa	Station					
	AraC-01	AraC-02	SbrC-01	SbrC-02	WilC-01	WilC-02
Chlorophyta (green algae)						
Ankistrodesmus						r/12
Chaetophora						f/2
Closterium			r/11		r/11	r/11
Hormidium			c/4		c/4	
Microspora				o/6	f/3	
Microthamnion			o/8	c/3		
Mougeotia			o/9		o/6	o/10
Pediastrum					r/10	
Selenastrum			o/10			
Spirogyra					o/5	
Stigeoclonium				c/5	o/7	c/6
Ulothrix		f/3				d/1
Chrysophyta (golden algae)						
Diatoms	o/1	a/2	a/1	o/7	f/1	f/5
Hydrurus	o/2	d/1				
Tribonema			f/2	c/4	f/2	
Rhodophyta (red algae)						
Audouinella						f/3

Table 5. Relative abundance of cells and ordinal rank by biovolume of diatoms (Class Bacillariophyceae) and genera of non-diatom algae in periphyton samples collected from Arrastra Creek, Sandbar Creek, and Willow Creek in 2001: d = dominant; a = abundant; f = frequent; c = common; o = occasional; r = rare.

Taxa	Station					
	AraC-01	AraC-02	SbrC-01	SbrC-02	WilC-01	WilC-02
Cyanophyta (cyanobacteria)						
Nostoc			o/7		o/9	c/8
Oscillatoria			c/5	o/8	o/8	o/9
Phormidium		c/4		a/1		c/7
Rivularia			c/3	f/2		
Synechocystis	r/3					
Tolypothrix			o/6			f/4
No. of Genera	2	3	10	7	10	11

Table 6. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from the upper Blackfoot River and Poorman Creek in 2001. Underlined values indicate full support of aquatic life uses with minor impairment; **bold values** indicate partial support and moderate impairment; **underlined and bold values** indicate non-support and severe impairment; all other values indicate full support of aquatic life uses and no impairment when compared to criteria for mountain streams in Table 3.

Species/Metric (Pollution Tolerance Class)	Station BlkftR-01	BlkftR-02	BlkftR-03	PoorC-01	PoorC-02	PoorC-03
Achnanthidium minutissimum (3)	25.11	10.13	16.03	1.67	25.94	17.32
Diatoma vulgaris (3)			15.81			
Hannaea arcus (3)		10.13	0.00		1.72	0.98
Meridion circulare (3)	2.01	4.00		46.77	1.01	14.81
Pseudostaurosira brevistriata (3)	11.72		3.14			
Staurosira construens (3)	8.26	12.00	8.41	0.84	0.10	3.38
Synedra rumpens (2)	28.35	10.13	1.57		0.30	6.54
Synedra ulna (2)	1.12	3.13	2.02	16.75	4.86	4.47
Number of Cells Counted	448	400	446	418	494	459
Shannon Species Diversity	3.37	4.47	4.56	2.83	4.33	4.42
Pollution Index	2.50	2.57	2.72	2.55	2.56	2.56
Siltation Index	13.06	15.75	18.16	13.64	26.85	16.12
Disturbance Index	25.11	10.13	16.03	1.67	25.94	17.32
Number of Species Counted	39	46	62	27	46	54
Percent Dominant Species	28.35	12.00	16.03	46.77	25.94	17.32
Percent Abnormal Cells	**11.40**	**6.63**	0.90	**1.08**	**2.23**	0.76
Percent Epithemiaceae	0.00	1.37	1.91	0.60	0.00	0.00
Similarity Index[2]		39.86	43.56		25.73	51.74

[1] A major diatom species is here defined as one that accounts for 10.0 percent or more of the diatom cells that were counted at one or more stations in a sample set.

[2] The percent community similarity between BlkftR-01 and BlkftR-03 was 34.03; the percent community similarity between PoorC-01 and PoorC-03 was 38.13.

Table 7. Percent abundance of major diatom species[1] and values of selected diatom association metrics for periphyton samples collected from Arrastra Cr., Sandbar Creek, and Willow Creek in 2001. Underlined values indicate full support of aquatic life uses with minor impairment; **bold values** indicate partial support and moderate impairment; **underlined and bold values** indicate non-support and severe impairment; all other values indicate full support of aquatic life uses and no impairment when compared to criteria for mountain streams in Table 3.

Species/Metric (Pollution Tolerance Class)	Station AraC-01	AraC-02	SbrC-01	SbrC-02	WilC-01	WilC-02
Achnanthidium minutissimum (3)	20.23	16.33	19.74	86.48	4.03	5.14
Diatoma mesodon (3)	3.04	0.20	51.91	1.75	2.65	7.55
Fragilaria vaucheriae (2)	0.21	3.37			0.42	24.40
Gomphonema angustatum (2)	25.58	4.80	0.12		0.53	0.66
Hannaea arcus (3)	1.26	49.18			1.70	1.53
Staurosira construens (3)	2.73	2.14	0.60	4.78	27.60	3.28
Synedra rumpens (2)	0.10	2.35	9.69	2.33	13.59	14.99
Number of Cells Counted	477	490	418	429	471	457
Shannon Species Diversity	3.86	2.78	2.36	**0.96**	4.01	4.12
Pollution Index	2.59	2.77	2.73	2.92	2.55	2.35
Siltation Index	2.94	1.94	7.54	2.80	21.02	15.32
Disturbance Index	20.23	16.33	19.74	**86.48**	4.03	5.14
Number of Species Counted	51	30	23	**16**	51	46
Percent Dominant Species	25.58	49.18	**51.91**	**86.48**	27.60	24.40
Percent Abnormal Cells	**3.67**	0.51	**3.71**	**10.26**	0.64	0.22
Percent Epithemiaceae	0.21	0.00	0.24	0.00	0.00	0.00
Similarity Index	33.99		26.98		45.55	

[1] A major diatom species is here defined as one that accounts for 10.0 percent or more of the diatom cells that were counted at one or more stations in a sample set.

APPENDIX A: DIATOM PROPORTIONAL COUNTS

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
215601	Achnanthes lanceolata	2	2	0.22
215601	Achnanthidium affine	3	2	0.22
215601	Achnanthidium biasolettianum	3	0	0.00
215601	Achnanthidium minutissimum	3	225	25.11
215601	Amphipleura pellucida	2	0	0.00
215601	Aulacoseira italica	3	3	0.33
215601	Aulacoseira lirata	3	13	1.45
215601	Caloneis bacillum	2	20	2.23
215601	Caloneis tenuis	3	2	0.22
215601	Cavinula cocconeiformis	3	4	0.45
215601	Cavinula pseudoscutiformis	3	0	0.00
215601	Cyclotella meneghiniana	2	1	0.11
215601	Cymbella sp.	3	2	0.22
215601	Diatoma mesodon	3	12	1.34
215601	Diatoma tenue	2	0	0.00
215601	Encyonema minutum	2	2	0.22
215601	Epithemia adnata	2	0	0.00
215601	Epithemia sorex	3	0	0.00
215601	Fragilaria capucina	2	10	1.12
215601	Fragilaria crotonensis	3	9	1.00
215601	Fragilaria robusta	3	0	0.00
215601	Fragilaria vaucheriae	2	2	0.22
215601	Gomphonema clavatum	2	2	0.22
215601	Gomphonema intricatum	3	2	0.22
215601	Gomphonema minutum	3	1	0.11
215601	Meridion circulare	3	18	2.01
215601	Navicula arvensis	1	17	1.90
215601	Navicula cryptocephala	3	2	0.22
215601	Navicula detenta	3	0	0.00
215601	Navicula elginensis	3	2	0.22
215601	Navicula medioconvexa	3	6	0.67
215601	Navicula minima	1	33	3.68
215601	Nitzschia acicularis	2	1	0.11
215601	Nitzschia capitellata	2	0	0.00
215601	Nitzschia communis	1	0	0.00
215601	Nitzschia flexa	2	2	0.22
215601	Nitzschia fonticola	3	9	1.00
215601	Nitzschia frustulum	2	2	0.22
215601	Nitzschia gracilis	2	0	0.00
215601	Nitzschia linearis	2	2	0.22
215601	Nitzschia palea	1	4	0.45
215601	Nitzschia perminuta	3	6	0.67
215601	Nitzschia pumila	2	4	0.45
215601	Nitzschia pura	2	22	2.46
215601	Pseudostaurosira brevistriata	3	105	11.72
215601	Rhopalodia gibba	2	0	0.00
215601	Sellaphora pupula	2	0	0.00
215601	Staurosira construens	3	74	8.26
215601	Staurosirella leptostauron	3	0	0.00
215601	Staurosirella pinnata	3	8	0.89
215601	Surirella sp.	2	1	0.11
215601	Synedra rumpens	2	254	28.35
215601	Synedra ulna	2	10	1.12

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
215701	Achnanthes lanceolata	2	10	1.25
215701	Achnanthidium biasolettianum	3	2	0.25
215701	Achnanthidium minutissimum	3	81	10.13
215701	Amphipleura pellucida	2	0	0.00
215701	Amphora pediculus	3	0	0.00
215701	Aulacoseira distans	3	6	0.75
215701	Aulacoseira italica	3	1	0.13
215701	Caloneis silicula	2	2	0.25
215701	Cocconeis placentula	3	8	1.00
215701	Cyclotella meneghiniana	2	0	0.00
215701	Cymbella sp.	3	4	0.50
215701	Diatoma mesodon	3	6	0.75
215701	Encyonema auerswaldii	2	4	0.50
215701	Encyonema minutum	2	13	1.63
215701	Encyonema silesiacum	2	43	5.38
215701	Epithemia sorex	3	4	0.50
215701	Epithemia turgida	3	6	0.75
215701	Fragilaria capucina	2	10	1.25
215701	Fragilaria vaucheriae	2	22	2.75
215701	Fragilariforma bicapitata	3	2	0.25
215701	Gomphoneis eriense	3	0	0.00
215701	Gomphonema acuminatum	3	2	0.25
215701	Gomphonema angustatum	2	2	0.25
215701	Gomphonema kobayasii	3	2	0.25
215701	Gomphonema olivaceoides	3	53	6.63
215701	Gomphonema parvulum	1	2	0.25
215701	Hannaea arcus	3	81	10.13
215701	Hantzschia amphioxys	2	0	0.00
215701	Meridion circulare	3	32	4.00
215701	Navicula arvensis	1	5	0.63
215701	Navicula cryptotenella	2	4	0.50
215701	Navicula minima	1	10	1.25
215701	Navicula minuscula	1	24	3.00
215701	Navicula tripunctata	3	4	0.50
215701	Nitzschia amphibia	2	2	0.25
215701	Nitzschia archibaldii	2	22	2.75
215701	Nitzschia dissipata	3	7	0.88
215701	Nitzschia fonticola	3	33	4.13
215701	Nitzschia linearis	2	1	0.13
215701	Nitzschia palea	1	6	0.75
215701	Nitzschia perminuta	3	0	0.00
215701	Nitzschia pumila	2	2	0.25
215701	Nitzschia pura	2	6	0.75
215701	Nitzschia vermicularis	2	0	0.00
215701	Psammothidium helveticum	3	5	0.63
215701	Reimeria sinuata	3	1	0.13
215701	Rhoicosphenia curvata	3	2	0.25
215701	Rhopalodia gibba	2	1	0.13
215701	Staurosira construens	3	96	12.00
215701	Staurosirella leptostauron	3	27	3.38
215701	Staurosirella pinnata	3	38	4.75
215701	Synedra rumpens	2	81	10.13
215701	Synedra ulna	2	25	3.13

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
215801	Achnanthes lanceolata	2	5	0.56
215801	Achnanthidium biasolettianum	3	2	0.22
215801	Achnanthidium minutissimum	3	143	16.03
215801	Amphipleura pellucida	2	4	0.45
215801	Amphora inariensis	3	2	0.22
215801	Amphora pediculus	3	1	0.11
215801	Cocconeis pediculus	3	1	0.11
215801	Cocconeis placentula	3	14	1.57
215801	Cymatopleura solea	2	0	0.00
215801	Cymbella affinis	3	20	2.24
215801	Cymbella subaequalis	3	0	0.00
215801	Denticula Kuetzingii	3	2	0.22
215801	Diatoma mesodon	3	2	0.22
215801	Diatoma moniliformis	2	6	0.67
215801	Diatoma tenue	2	3	0.34
215801	Diatoma vulgaris	3	141	15.81
215801	Encyonema auerswaldii	2	2	0.22
215801	Encyonema minutum	2	9	1.01
215801	Encyonema prostratum	3	5	0.56
215801	Encyonema silesiacum	2	32	3.59
215801	Encyonopsis microcephala	2	23	2.58
215801	Epithemia adnata	2	1	0.11
215801	Epithemia sorex	3	10	1.12
215801	Epithemia turgida	3	0	0.00
215801	Fragilaria capucina	2	4	0.45
215801	Fragilaria vaucheriae	2	28	3.14
215801	Gomphoneis herculeana	3	2	0.22
215801	Gomphonema clavatum	2	4	0.45
215801	Gomphonema kobayasii	3	2	0.22
215801	Gomphonema olivaceum	3	6	0.67
215801	Gomphonema parvulum	1	1	0.11
215801	Gomphonema sarcophagus	2	2	0.22
215801	Gomphonema septata	3	2	0.22
215801	Hannaea arcus	3	0	0.00
215801	Hantzschia amphioxys	2	0	0.00
215801	Melosira varians	2	13	1.46
215801	Navicula capitatoradiata	2	10	1.12
215801	Navicula cryptotenella	2	23	2.58
215801	Navicula menisculus	2	1	0.11
215801	Navicula radiosa	3	4	0.45
215801	Navicula reichardtiana	2	11	1.23
215801	Navicula sp.	2	2	0.22
215801	Navicula tripunctata	3	13	1.46
215801	Nitzschia angustata	2	2	0.22
215801	Nitzschia archibaldii	2	1	0.11
215801	Nitzschia dissipata	3	60	6.73
215801	Nitzschia fonticola	3	1	0.11

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
215801	Nitzschia heufleriana	3	1	0.11
215801	Nitzschia inconspicua	2	2	0.22
215801	Nitzschia lacuum	3	3	0.34
215801	Nitzschia paleacea	2	7	0.78
215801	Nitzschia perminuta	3	9	1.01
215801	Nitzschia pura	2	5	0.56
215801	Nitzschia pusilla	1	2	0.22
215801	Nitzschia sociabilis	2	3	0.34
215801	Nitzschia subacicularis	2	0	0.00
215801	Pinnularia appendiculata	3	2	0.22
215801	Placoneis clementioides	3	2	0.22
215801	Placoneis exigua	3	0	0.00
215801	Psammothidium helveticum	3	0	0.00
215801	Pseudostaurosira brevistriata	3	28	3.14
215801	Reimeria sinuata	3	10	1.12
215801	Rhopalodia gibba	2	5	0.56
215801	Sellaphora pupula	2	0	0.00
215801	Staurosira construens	3	75	8.41
215801	Staurosirella lapponica	3	3	0.34
215801	Staurosirella leptostauron	3	24	2.69
215801	Staurosirella pinnata	3	57	6.39
215801	Surirella sp.	2	2	0.22
215801	Synedra rumpens	2	14	1.57
215801	Synedra ulna	2	18	2.02

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
215901	Achnanthes lanceolata	2	9	0.94
215901	Achnanthes sp.	3	3	0.31
215901	Achnanthidium biasolettianum	3	5	0.52
215901	Achnanthidium minutissimum	3	193	20.23
215901	Amphora pediculus	3	5	0.52
215901	Aulacoseira canadensis	3	1	0.10
215901	Caloneis bacillum	2	4	0.42
215901	Caloneis silicula	2	3	0.31
215901	Cocconeis pediculus	3	1	0.10
215901	Cocconeis placentula	3	90	9.43
215901	Cyclotella atomus	2	3	0.31
215901	Cymbella hebridica	3	2	0.21
215901	Diatoma hiemale	3	16	1.68
215901	Diatoma mesodon	3	29	3.04
215901	Diatoma vulgaris	3	4	0.42
215901	Diatomella balfouriana	3	2	0.21
215901	Encyonema silesiacum	2	32	3.35
215901	Epithemia adnata	2	2	0.21
215901	Fragilaria capucina	2	2	0.21
215901	Fragilaria vaucheriae	2	2	0.21
215901	Gomphonema angustatum	2	244	25.58
215901	Gomphonema clavatum	2	16	1.68
215901	Gomphonema intricatum	3	13	1.36
215901	Gomphonema kobayasii	3	14	1.47
215901	Gomphonema minutum	3	6	0.63
215901	Gomphonema parvulum	1	6	0.63
215901	Hannaea arcus	3	12	1.26
215901	Hantzschia amphioxys	2	4	0.42
215901	Meridion circulare	3	24	2.52
215901	Navicula capitatoradiata	2	2	0.21
215901	Navicula cryptotenella	2	4	0.42
215901	Navicula ignota	2	2	0.21
215901	Navicula minima	1	2	0.21
215901	Navicula seminulum	1	1	0.10
215901	Navicula sp.	2	2	0.21
215901	Navicula tripunctata	3	1	0.10
215901	Nitzschia fonticola	3	4	0.42
215901	Nitzschia inconspicua	2	2	0.21
215901	Nitzschia linearis	2	1	0.10
215901	Nitzschia perminuta	3	4	0.42
215901	Nitzschia pura	2	2	0.21
215901	Nitzschia sigmoidea	3	1	0.10
215901	Psammothidium ventralis	3	2	0.21
215901	Reimeria sinuata	3	77	8.07
215901	Rhoicosphenia curvata	3	5	0.52
215901	Staurosira construens	3	26	2.73
215901	Staurosirella leptostauron	3	5	0.52
215901	Staurosirella pinnata	3	24	2.52
215901	Stephanodiscus minutus	2	5	0.52
215901	Synedra rumpens	2	1	0.10
215901	Synedra ulna	2	34	3.56

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216001	Achnanthes lanceolata	2	5	0.51
216001	Achnanthidium biasolettianum	3	4	0.41
216001	Achnanthidium minutissimum	3	160	16.33
216001	Amphora pediculus	3	0	0.00
216001	Aulacoseira distans	3	0	0.00
216001	Cocconeis placentula	3	2	0.20
216001	Cymbella affinis	3	17	1.73
216001	Cymbella cistula	3	7	0.71
216001	Cymbella cymbiformis	3	2	0.20
216001	Cymbella hebridica	3	6	0.61
216001	Diatoma hiemale	3	2	0.20
216001	Diatoma mesodon	3	2	0.20
216001	Encyonema minutum	2	24	2.45
216001	Encyonema silesiacum	2	0	0.00
216001	Eucocconeis laevis	3	4	0.41
216001	Fragilaria capucina	2	4	0.41
216001	Fragilaria vaucheriae	2	33	3.37
216001	Gomphonema angustatum	2	47	4.80
216001	Gomphonema intricatum	3	2	0.20
216001	Gomphonema pumilum	3	0	0.00
216001	Hannaea arcus	3	482	49.18
216001	Meridion circulare	3	7	0.71
216001	Navicula cari	2	1	0.10
216001	Navicula contenta	2	2	0.20
216001	Navicula cryptotenella	2	3	0.31
216001	Navicula minima	1	2	0.20
216001	Navicula minuscula	1	2	0.20
216001	Navicula reichardtiana	2	3	0.31
216001	Nitzschia fonticola	3	6	0.61
216001	Sellaphora bacillum	3	0	0.00
216001	Staurosira construens	3	21	2.14
216001	Staurosirella lapponica	3	4	0.41
216001	Staurosirella pinnata	3	27	2.76
216001	Synedra rumpens	2	23	2.35
216001	Synedra ulna	2	76	7.76

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216101	Achnanthes lanceolata	2	50	5.98
216101	Achnanthidium biasolettianum	3	0	0.00
216101	Achnanthidium minutissimum	3	14	1.67
216101	Amphipleura pellucida	2	6	0.72
216101	Aulacoseira canadensis	3	1	0.12
216101	Aulacoseira islandica	3	1	0.12
216101	Caloneis bacillum	2	0	0.00
216101	Cocconeis placentula	3	41	4.90
216101	Diatoma mesodon	3	4	0.48
216101	Diploneis elliptica	3	1	0.12
216101	Encyonema auerswaldii	2	4	0.48
216101	Epithemia turgida	3	5	0.60
216101	Fragilaria capucina	2	13	1.56
216101	Gomphonema angustatum	2	29	3.47
216101	Gomphonema mexicanum	2	2	0.24
216101	Gomphonema pumilum	3	4	0.48
216101	Meridion circulare	3	391	46.77
216101	Navicula cryptocephala	3	3	0.36
216101	Navicula cryptotenella	2	3	0.36
216101	Navicula minima	1	59	7.06
216101	Navicula reichardtiana	2	7	0.84
216101	Navicula tripunctata	3	8	0.96
216101	Nitzschia communis	1	4	0.48
216101	Nitzschia dissipata	3	27	3.23
216101	Nitzschia fonticola	3	1	0.12
216101	Rhoicosphenia curvata	3	9	1.08
216101	Sellaphora bacillum	3	2	0.24
216101	Staurosira construens	3	7	0.84
216101	Synedra ulna	2	140	16.75

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216201	Achnanthes lanceolata	2	47	4.76
216201	Achnanthidium affine	3	6	0.61
216201	Achnanthidium biasolettianum	3	11	1.11
216201	Achnanthidium minutissimum	3	256	25.94
216201	Amphora inariensis	3	0	0.00
216201	Amphora pediculus	3	9	0.91
216201	Caloneis bacillum	2	10	1.01
216201	Cocconeis placentula	3	27	2.74
216201	Cymbella hebridica	3	24	2.43
216201	Diatoma hiemale	3	27	2.74
216201	Diatoma mesodon	3	16	1.62
216201	Encyonema lunatum	3	2	0.20
216201	Encyonema minutum	2	55	5.57
216201	Encyonema muelleri	2	2	0.20
216201	Encyonema prostratum	3	2	0.20
216201	Encyonema reichardtii	3	2	0.20
216201	Encyonema silesiacum	2	17	1.72
216201	Encyonopsis microcephala	2	2	0.20
216201	Fragilaria capucina	2	8	0.81
216201	Fragilaria vaucheriae	2	21	2.13
216201	Frustulia rhomboides	3	1	0.10
216201	Gomphonema angustatum	2	59	5.98
216201	Gomphonema kobayasii	3	2	0.20
216201	Gomphonema olivaceoides	3	2	0.20
216201	Hannaea arcus	3	17	1.72
216201	Meridion circulare	3	10	1.01
216201	Navicula acceptata	2	1	0.10
216201	Navicula cryptocephala	3	0	0.00
216201	Navicula cryptotenella	2	31	3.14
216201	Navicula menisculus	2	1	0.10
216201	Navicula minima	1	10	1.01
216201	Navicula minuscula	1	2	0.20
216201	Navicula reichardtiana	2	60	6.08
216201	Navicula tripunctata	3	69	6.99
216201	Nitzschia archibaldii	2	1	0.10
216201	Nitzschia dissipata	3	19	1.93
216201	Nitzschia fonticola	3	19	1.93
216201	Nitzschia heufleriana	3	10	1.01
216201	Nitzschia linearis	2	18	1.82
216201	Nitzschia pura	2	22	2.23
216201	Reimeria sinuata	3	5	0.51
216201	Rhoicosphenia curvata	3	6	0.61
216201	Staurosira construens	3	1	0.10
216201	Staurosirella leptostauron	3	18	1.82
216201	Staurosirella pinnata	3	6	0.61
216201	Surirella angusta	1	0	0.00
216201	Surirella minuta	2	2	0.20
216201	Synedra rumpens	2	3	0.30
216201	Synedra ulna	2	48	4.86

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216301	Achnanthes lanceolata	2	73	7.95
216301	Achnanthidium affine	3	2	0.22
216301	Achnanthidium minutissimum	3	159	17.32
216301	Amphipleura pellucida	2	2	0.22
216301	Amphora pediculus	3	4	0.44
216301	Aulacoseira distans	3	1	0.11
216301	Caloneis bacillum	2	1	0.11
216301	Caloneis silicula	2	0	0.00
216301	Cocconeis placentula	3	14	1.53
216301	Cymbella aspera	3	2	0.22
216301	Cymbella cistula	3	6	0.65
216301	Cymbella hebridica	3	5	0.54
216301	Diadesmis contenta	2	2	0.22
216301	Diadesmis perpusilla	2	8	0.87
216301	Diatoma hiemale	3	21	2.29
216301	Diatoma mesodon	3	54	5.88
216301	Encyonema minutum	2	5	0.54
216301	Encyonema silesiacum	2	25	2.72
216301	Epithemia turgida	3	0	0.00
216301	Fragilaria capucina	2	43	4.68
216301	Fragilaria vaucheriae	2	6	0.65
216301	Frustulia vulgaris	2	2	0.22
216301	Gomphonema angustatum	2	0	0.00
216301	Gomphonema brebissonii	3	0	0.00
216301	Gomphonema clavatum	2	1	0.11
216301	Gomphonema kobayasii	3	14	1.53
216301	Gomphonema micropus	2	6	0.65
216301	Gomphonema minutum	3	2	0.22
216301	Gomphonema olivaceoides	3	2	0.22
216301	Gomphonema sarcophagus	2	3	0.33
216301	Gomphonema truncatum	3	0	0.00
216301	Hannaea arcus	3	9	0.98
216301	Melosira varians	2	11	1.20
216301	Meridion circulare	3	136	14.81
216301	Navicula cryptocephala	3	5	0.54
216301	Navicula libonensis	2	2	0.22
216301	Navicula minima	1	13	1.42
216301	Navicula minuscula	1	6	0.65
216301	Navicula pelliculosa	1	2	0.22
216301	Navicula radiosa	3	1	0.11
216301	Navicula reichardtiana	2	43	4.68
216301	Navicula tripunctata	3	4	0.44
216301	Navicula trivialis	2	0	0.00
216301	Nitzschia acicularis	2	1	0.11
216301	Nitzschia archibaldii	2	9	0.98
216301	Nitzschia dissipata	3	26	2.83
216301	Nitzschia fonticola	3	5	0.54
216301	Nitzschia frustulum	2	2	0.22
216301	Nitzschia heufleriana	3	1	0.11
216301	Nitzschia linearis	2	10	1.09
216301	Nitzschia palea	1	0	0.00
216301	Nitzschia perminuta	3	2	0.22
216301	Nitzschia pura	2	4	0.44
216301	Reimeria sinuata	3	3	0.33
216301	Rhoicosphenia curvata	3	2	0.22
216301	Staurosira construens	3	31	3.38
216301	Staurosirella leptostauron	3	7	0.76
216301	Staurosirella pinnata	3	17	1.85
216301	Surirella angusta	1	0	0.00
216301	Surirella minuta	2	0	0.00
216301	Surirella sp.	2	2	0.22
216301	Synedra rumpens	2	60	6.54
216301	Synedra ulna	2	41	4.47

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216401	Achnanthes exigua	3	0	0.00
216401	Achnanthes lanceolata	2	29	3.08
216401	Achnanthes sp.	3	6	0.64
216401	Achnanthes thermalis	3	2	0.21
216401	Achnanthidium minutissimum	3	38	4.03
216401	Amphipleura pellucida	2	4	0.42
216401	Amphora pediculus	3	2	0.21
216401	Aulacoseira distans	3	0	0.00
216401	Caloneis bacillum	2	4	0.42
216401	Cocconeis placentula	3	2	0.21
216401	Diatoma mesodon	3	25	2.65
216401	Diploneis oculata	3	2	0.21
216401	Encyonema silesiacum	2	4	0.42
216401	Encyonopsis microcephala	2	2	0.21
216401	Eucocconeis laevis	3	1	0.11
216401	Eunotia bilunaris	3	5	0.53
216401	Fragilaria crotonensis	3	0	0.00
216401	Fragilaria vaucheriae	2	4	0.42
216401	Frustulia vulgaris	2	4	0.42
216401	Gomphonema angustatum	2	5	0.53
216401	Gomphonema brebissonii	3	1	0.11
216401	Gomphonema micropus	2	0	0.00
216401	Gomphonema minutum	3	2	0.21
216401	Gomphonema parvulum	1	2	0.21
216401	Gomphonema pumilum	3	4	0.42
216401	Hannaea arcus	3	16	1.70
216401	Meridion circulare	3	56	5.94
216401	Navicula acceptata	2	2	0.21
216401	Navicula arvensis	1	9	0.96
216401	Navicula cryptocephala	3	2	0.21
216401	Navicula cryptotenella	2	4	0.42
216401	Navicula medioconvexa	3	4	0.42
216401	Navicula minima	1	26	2.76
216401	Navicula protracta	2	2	0.21
216401	Navicula radiosa	3	4	0.42
216401	Navicula reichardtiana	2	4	0.42
216401	Nitzschia acicularis	2	10	1.06
216401	Nitzschia archibaldii	2	87	9.24
216401	Nitzschia dissipata	3	6	0.64
216401	Nitzschia flexoides	2	2	0.21
216401	Nitzschia fonticola	3	22	2.34
216401	Nitzschia frustulum	2	2	0.21
216401	Nitzschia graciliformis	2	0	0.00
216401	Nitzschia lacuum	3	2	0.21
216401	Nitzschia palea	1	4	0.42
216401	Nitzschia pura	2	4	0.42
216401	Psammothidium bioretii	3	3	0.32
216401	Pseudostaurosira brevistriata	3	64	6.79
216401	Rhoicosphenia curvata	3	5	0.53
216401	Sellaphora pupula	2	2	0.21
216401	Staurosira construens	3	260	27.60
216401	Staurosirella leptostauron	3	2	0.21
216401	Staurosirella pinnata	3	24	2.55
216401	Synedra parasitica	2	12	1.27
216401	Synedra rumpens	2	128	13.59
216401	Synedra tenera	2	0	0.00
216401	Synedra ulna	2	26	2.76

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216501	Achnanthes lanceolata	2	10	1.09
216501	Achnanthidium minutissimum	3	47	5.14
216501	Amphipleura pellucida	2	1	0.11
216501	Aulacoseira canadensis	3	2	0.22
216501	Aulacoseira distans	3	2	0.22
216501	Aulacoseira islandica	3	0	0.00
216501	Caloneis bacillum	2	12	1.31
216501	Caloneis hyalina	2	2	0.22
216501	Cocconeis placentula	3	5	0.55
216501	Diatoma mesodon	3	69	7.55
216501	Encyonema auerswaldii	2	8	0.88
216501	Encyonema minutum	2	2	0.22
216501	Encyonema silesiacum	2	2	0.22
216501	Encyonopsis microcephala	2	5	0.55
216501	Epithemia sorex	3	0	0.00
216501	Epithemia turgida	3	0	0.00
216501	Fragilaria capucina	2	18	1.97
216501	Fragilaria vaucheriae	2	223	24.40
216501	Gomphoneis minuta	3	1	0.11
216501	Gomphonema angustatum	2	6	0.66
216501	Gomphonema kobayasii	3	2	0.22
216501	Gomphonema mexicanum	2	4	0.44
216501	Gomphonema micropus	2	53	5.80
216501	Gomphonema pumilum	3	8	0.88
216501	Gomphonema sp.	3	22	2.41
216501	Hannaea arcus	3	14	1.53
216501	Karayevia laterostrata	3	1	0.11
216501	Melosira varians	2	0	0.00
216501	Meridion circulare	3	51	5.58
216501	Navicula arvensis	1	14	1.53
216501	Navicula cryptocephala	3	0	0.00
216501	Navicula cryptotenella	2	2	0.22
216501	Navicula minima	1	7	0.77
216501	Navicula minuscula	1	2	0.22
216501	Navicula radiosa	3	1	0.11
216501	Navicula reichardtiana	2	12	1.31
216501	Nitzschia acicularis	2	2	0.22
216501	Nitzschia archibaldii	2	21	2.30
216501	Nitzschia dissipata	3	34	3.72
216501	Nitzschia flexoides	2	6	0.66
216501	Nitzschia fonticola	3	30	3.28
216501	Nitzschia lacuum	3	2	0.22
216501	Nitzschia linearis	2	0	0.00
216501	Nitzschia perminuta	3	5	0.55
216501	Nitzschia pura	2	0	0.00
216501	Pseudostaurosira brevistriata	3	0	0.00
216501	Rhoicosphenia curvata	3	4	0.44
216501	Staurosira construens	3	30	3.28
216501	Staurosirella leptostauron	3	0	0.00
216501	Staurosirella pinnata	3	8	0.88
216501	Surirella angusta	1	2	0.22
216501	Synedra mazamaensis	3	9	0.98
216501	Synedra rumpens	2	137	14.99
216501	Synedra tenera	2	2	0.22
216501	Synedra ulna	2	14	1.53

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216601	Achnanthes biconfusa	3	8	0.96
216601	Achnanthes lanceolata	2	31	3.71
216601	Achnanthidium biasolettianum	3	3	0.36
216601	Achnanthidium minutissimum	3	165	19.74
216601	Caloneis tenuis	3	8	0.96
216601	Diatoma mesodon	3	434	51.91
216601	Encyonema minutum	2	2	0.24
216601	Encyonema silesiacum	2	4	0.48
216601	Epithemia adnata	2	2	0.24
216601	Eunotia bilunaris	3	4	0.48
216601	Eunotia minor	2	1	0.12
216601	Gomphonema angustatum	2	1	0.12
216601	Gomphonema clavatum	2	4	0.48
216601	Gomphonema pumilum	3	8	0.96
216601	Meridion circulare	3	12	1.44
216601	Navicula atomus	1	1	0.12
216601	Navicula cryptocephala	3	3	0.36
216601	Navicula minima	1	48	5.74
216601	Navicula radiosa	3	0	0.00
216601	Nitzschia archibaldii	2	5	0.60
216601	Nitzschia dissipata	3	4	0.48
216601	Nitzschia fonticola	3	2	0.24
216601	Staurosira construens	3	5	0.60
216601	Synedra rumpens	2	81	9.69

Sample	Genus/Species/Variety	Pollution Tolerance Class	Count	Percent
216701	Achnanthes lanceolata	2	2	0.23
216701	Achnanthidium biasolettianum	3	0	0.00
216701	Achnanthidium minutissimum	3	742	86.48
216701	Aulacoseira distans	3	0	0.00
216701	Caloneis tenuis	3	0	0.00
216701	Cymbella naviculiformis	3	0	0.00
216701	Diatoma mesodon	3	15	1.75
216701	Fragilaria capucina	2	2	0.23
216701	Frustulia rhomboides	3	0	0.00
216701	Gomphonema acuminatum	3	1	0.12
216701	Gomphonema clavatum	2	0	0.00
216701	Gomphonema mexicanum	2	0	0.00
216701	Gomphonema parvulum	1	2	0.23
216701	Gomphonema pumilum	3	2	0.23
216701	Meridion circulare	3	0	0.00
216701	Navicula cryptocephala	3	2	0.23
216701	Navicula minima	1	16	1.86
216701	Navicula seminulum	1	2	0.23
216701	Nitzschia acicularis	2	2	0.23
216701	Nitzschia archibaldii	2	0	0.00
216701	Nitzschia dissipata	3	0	0.00
216701	Nitzschia flexoides	2	0	0.00
216701	Nitzschia palea	1	0	0.00
216701	Nitzschia pura	2	2	0.23
216701	Pinnularia microstauron	2	1	0.12
216701	Pseudostaurosira brevistriata	3	6	0.70
216701	Sellaphora bacillum	3	0	0.00
216701	Sellaphora pupula	2	0	0.00
216701	Staurosira construens	3	41	4.78
216701	Staurosirella pinnata	3	0	0.00
216701	Surirella angusta	1	0	0.00
216701	Synedra rumpens	2	20	2.33