

# BIOLOGICAL INTEGRITY OF TRIBUTARIES TO THE SWAN RIVER BASED ON THE STRUCTURE AND COMPOSITION OF THE BENTHIC ALGAE COMMUNITY

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## Summary

In early September 2002, 9 periphyton samples were collected from 4 tributaries of the Swan River in northwest Montana for the purpose of assessing whether these streams are water-quality limited and in need of TMDLs. The samples were collected following MDEQ standard operating procedures, processed and analyzed using standard methods for periphyton, and evaluated following modified USEPA rapid bioassessment protocols for wadeable streams.

Goat Creek, Elk Creek, Jim Creek and Piper Creek all supported a mix of cyanobacteria, green algae, and diatoms. In addition, all streams but Jim Creek supported the red alga *Audouinella* and only Jim Creek supported the xanthophyte *Tribonema*. The non-diatom algae of these streams indicated cool water of good quality.

Seven of the major diatom species in tributaries of the Swan River are sensitive to organic pollution and four are somewhat tolerant of organic pollution. The tolerant species tended to be more abundant at the downstream stations and in Jim Creek. Jim Creek also had the lowest pollution index value and the highest siltation index value of any site, indicating that this stream supported larger sediment and organic nutrient loads than the other sites. Nevertheless, values for these metrics were still within the range of excellent biological integrity for a mountain stream.

The dominant diatom species at all of the sites was either *Achnanthes biasolettiana* or *Achnantheidium minutissimum*. Both are small, attached (non-motile) species that are adapted to living in fast currents. Their abundance here is a consequence of the steep gradient and fast current velocities of these streams. Both species prefer cool water temperatures and low nutrient concentrations.

Although diatom community metrics at several sites indicated moderate to severe stress, these stresses appear to be natural in origin and related to the high gradients, cold temperatures, and low nutrient concentrations of these streams. High values for the pollution index and low values for the siltation index and percent abnormal cells indicate that organic enrichment, sedimentation, and toxic metals had little or no effect on the benthic algae of these streams.

Several ecological attributes of the diatoms were examined to characterize water quality tendencies at the sampling sites. The four tributaries and stations within each tributary are fairly uniform in their general water quality characteristics, which may be described as circumneutral, fresh-brackish (TDS <900 mg/L), and mesotrophic, with continuously high concentrations of dissolved oxygen. Diatoms living in these streams are mostly attached (non-motile), autotrophic with respect to nitrogen, tolerate a wide range of nutrient concentrations, and live mainly in water bodies, but regularly in wet places. They indicate some organic loading, which may be natural, but zones where the oxidation of biodegradable organic matter is mostly complete.

## Introduction

This report evaluates the biological integrity<sup>1</sup>, support of aquatic life uses, and probable causes of stress or impairment to aquatic communities in tributaries of the Swan 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 aquatic life use support in this report is based on the species composition and structure of periphyton (benthic algae, phytobenthos) communities at 9 sites on 4 streams that were sampled in early September 2002. Periphyton is a diverse assortment of simple photosynthetic organisms called algae that live attached to or in close proximity of the stream bottom. Some algae form long filaments or large colonies and are conspicuous to the unaided eye. But most, including the ubiquitous diatoms, can be seen and identified only with the aid of a microscope. 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 Barbour et al. (1999) list several advantages of using periphyton in biological assessments.

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<sup>1</sup> *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).

## **Project Area and Sampling Sites**

The Swan River TMDL planning area is located within the Northern Rockies Ecoregion of Montana (Woods et al. 1999) in Lake and Missoula counties. Vegetation is mainly mixed conifer forest, with alpine tundra on the highest peaks (USDA 1976). The main land uses are recreation, logging, and wildlife production. The study streams are all tributaries of the Swan River (HUC 17010211), which heads in Gray Wolf Lake in the Mission Mountains, flows northerly through Lindbergh Lake and Swan Lake, and then into Flathead Lake. Streams in the Swan River drainage are classified B-1 in the Montana Surface Water Quality Standards.

Periphyton samples were collected at 9 sites on 4 tributaries of the Swan River (Table 1). Goat Creek heads on the west side of the Swan Range and flows westerly into the Swan River. Elk Creek, Jim Creek and Piper Creek head on the east side of the Mission Range and flow easterly into the Swan River. Sample sites are generally located between 3,000 and 4,000 feet elevation.

## **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 importance of those substrates at each 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 (IKI) solution.

The samples were examined to estimate the relative abundance and ordinal 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 Smith (1950), Prescott (1962, 1978), John et al. (2002), and Wehr and Sheath (2003). 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, potassium dichromate, and hydrogen peroxide. Then, 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 409 and 530 diatom cells (818 to 1060 valves) were counted at random and identified to species. The following were the main taxonomic references for the diatoms: Krammer and Lange-Bertalot 1986, 1988, 1991a, 1991b; Krammer 2002; Lange-Bertalot 2001. Diatom naming conventions followed those adopted by the Academy of Natural Sciences (Philadelphia) for USGS NAWQA samples (Morales and Potapova 2000). Van Dam et al. (1994) was the main ecological reference for the diatoms.

The diatom proportional counts were used to generate an array of diatom association metrics. A metric is a characteristic of the biota that changes in some predictable way with increased human influence (Barbour et al. 1999). Diatoms are particularly useful in generating metrics because there is a wealth of information available in the literature regarding the pollution tolerances and water quality preferences of common diatom species (e.g., Lowe 1974, Beaver 1981, Lange-Bertalot 1996, Van Dam et al. 1994).

Values for selected metrics were compared to biocriteria (numeric thresholds) developed for streams in the Rocky Mountain ecoregions of Montana (Table 2). These criteria are based on metric values measured in least-impaired reference streams (Bahls et al. 1992) and metric values measured in streams that are known to be impaired by various sources and causes of pollution (Bahls 1993). The biocriteria in Table 2 are valid only for samples collected during the summer field season (June 21-September 21).

The criteria in Table 2 distinguish among four levels of stress or impairment and three levels of aquatic life use support: (1) no impairment or only minor impairment (full support); (2) moderate impairment (partial support); and (3) severe impairment (nonsupport). These impairment levels correspond to excellent, good, fair, and poor biological integrity, respectively. In cold, high-gradient mountain streams, natural stressors will often mimic the effects of man-caused impairment on some metric values.

## Quality Assurance

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

Upon receipt of the samples, station and sample attribute data were recorded in the Montana Diatom Database and the samples were assigned a unique number, e.g., 2611-01. The first part of this number (2611) designates the sampling site (Goat Creek Reach 16) and the second part (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 information on the sample label. A portion of the raw sample was used to make duplicate diatom slides. The slide used for the diatom proportional count will be deposited in the Montana Diatom Collection at the University of Montana Herbarium in Missoula. The other slide will be retained by *Hannaea* in Helena. Diatom proportional counts have been entered into the Montana Diatom Database.

## Results and Discussion

Results are presented in Tables 3, 4 and 5, which are located near the end of this report following the references section. The Appendix contains a series of diatom reports, one for each sample. Each diatom report contains an alphabetical list of diatom species and their percent abundances, and values for 65 different diatom metrics and ecological attributes.

### Sample Notes

**Goat Creek.** The sample from Reach 16 contained moss, was very silty, and was partially decomposed (smelled of H<sub>2</sub>S). The sample from Reach 9 contained some silt and consisted mostly of *Schizothrix* colonies. The sample from Reach 7 was silty, partly decomposed, and comprised mostly of *Schizothrix* crusts. The sample from Reach 3 contained moss, was decomposing, and was very silty. Stalks of *Didymosphenia* (a diatom) in this sample appeared as tufts of dirty cotton.

**Elk Creek.** Algae were sparse in the sample from Reach 13 and the sample contained some silt and a little moss. Algae were also sparse in the sample from Reach 3 and the sample was a bit more silty.

**Jim Creek.** The sample from Jim Creek Reach 5 contained mostly moss.

**Piper Creek.** The sample from Reach 14 was silty. Moss was present and diatoms were sparse. Diatoms were also sparse in the sample from Reach 2.

## **Non-Diatom Algae**

**Goat Creek.** Diatoms and cyanobacteria dominated the benthic algal flora of Goat Creek (Table 3). *Schizothrix*, a filamentous cyanophyte that forms rubbery crusts on rocks, was particularly abundant here. The pollution-sensitive filamentous red alga *Audouinella* was also common in Goat Creek. Green algae were not abundant and appeared only at the two lower stations.

**Elk Creek.** The tufted filamentous cyanophyte *Amphithrix* was the most common alga at the upper site on Elk Creek (Table 3). *Audouinella* ranked second in biovolume at this site. The semi-aquatic green alga *Protoderma* was the most common alga at the lower station. Diatoms were sparse in Elk Creek.

**Jim Creek.** The filamentous cyanophyte *Oscillatoria* was the most abundant alga in Jim Creek Reach 5 (Table 3). This genus contains many species, some of which are tolerant of organic pollution. Diatoms ranked second in biovolume in Jim Creek, which also supported the filamentous green alga *Ulothrix* and the filamentous xanthophyte *Tribonema*.

**Piper Creek.** This stream supported a mix of diatoms, red algae, green algae, and cyanobacteria (Table 3). *Audouinella* was most abundant at the upstream site and *Oscillatoria* was most abundant at the downstream site. Diatoms were common here.



## Diatoms

Seven of the major diatom species in tributaries of the Swan River are sensitive to organic pollution and four are somewhat tolerant of organic pollution (Table 4). The tolerant ones tended to be more abundant at the downstream stations and in Jim Creek. The dominant diatom species at all of the sites was either *Achnanthes biasolettiana* or *Achnantheidium minutissimum*. Both are small, attached (non-motile) species that are adapted to living in fast currents. Their abundance here is a consequence of the steep gradient and fast current velocities of these streams. Both species prefer cool water temperatures and low nutrient concentrations.

Although diatom community metrics at several sites indicated moderate to severe stress, these stresses appear to be natural in origin and related to the high gradients, cold temperatures, and low nutrient concentrations of these streams. High values for the pollution index and low values for the sedimentation index and percent abnormal cells indicate that organic enrichment, sedimentation, and toxic metals did not have a significant effect on the benthic algae of these streams.

**Goat Creek.** Low species diversity, high percent dominant species, and a high disturbance index indicate minor to moderate stress in Goat Creek (Table 4). The dominant species here—*Achnanthes biasolettiana* and *Achnantheidium minutissimum*—indicate that this stress was likely natural in origin. High similarity index values between adjacent stations in Goat Creek indicate little or no change in the diatom associations from station to station, hence little or no intervening input of pollutants or habitat alterations.

**Elk Creek.** Both sites on Elk Creek had very low diatom diversity and species richness and very high values for the disturbance index and percent dominant species (Table 4). Again, *Achnantheidium minutissimum* was the dominant species, indicating a natural origin of the stressors operating in Elk Creek. The pollution index, siltation index, and percent abnormal cells all indicate good water quality here. The two sites on Elk Creek had very similar diatom floras, indicating that little or no perturbation occurred between them.

**Jim Creek.** The diatom association of Jim Creek indicated the lowest amount of stress of any of the sites that were sampled (Table 4). However, Jim Creek also had the lowest pollution index and the highest sedimentation index of any site, indicating that this stream supported larger sediment and organic nutrient loads than any of the other sites. Nevertheless, values for these metrics were still in the range of excellent biological integrity for a mountain stream (Table 2). Jim Creek also supported the largest number of diatom species and the highest diversity of any site. These metrics tend to increase in mountain streams in response to small to moderate increases in sediments and nutrients (unpublished observation).

**Piper Creek.** Like Elk Creek, Piper Creek had very low diatom diversity and species richness and very high values for the disturbance index and percent dominant species (Table 4). And like Elk Creek, *Achnantheidium minutissimum* was the dominant diatom species in Piper Creek, indicating natural stress from cold, fast waters of low nutrient content. Values for the pollution index and sedimentation index indicate very little loading of sediment or organic nutrients in Piper Creek. The two sites on Piper Creek had virtually identical diatom assemblages, indicating little or no perturbation occurred between them.

Several ecological attributes were selected from the diatom reports in the appendix and modal categories of these attributes were extracted to characterize water quality tendencies in the four streams (Table 5). The four tributaries and stations within each tributary are fairly uniform in their general water quality characteristics, which may be described as circumneutral, fresh-brackish (TDS <900 mg/L), and mesotrophic, with continuously high concentrations of dissolved oxygen. Diatoms living in these streams are mostly attached (non-motile), autotrophic with respect to nitrogen, tolerate a wide range of nutrient concentrations, and live mainly in water bodies, but regularly in wet places. They indicate some organic loading, which may be natural, but zones where the oxidation of biodegradable organic matter is mostly complete (Van Dam et al. 1994).

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Table 1. Location of periphyton sampling stations in the Swan River TMDL planning area, 2002.

Station	MDEQ Station Code	Hannaea Sample Number	Latitude	Longitude	Sample Date
Goat Creek Reach 16	C10GOATC04	2611-01	47 - 46.128	113 - 44.208	9/4/02
Goat Creek Reach 9	C10GOATC03	2612-01	47 - 45.504	113 - 46.872	9/5/02
Goat Creek Reach 7	C10GOATC02	2613-01	47 - 45.126	113 - 47.892	9/4/02
Goat Creek Reach 3	C10GOATC01	2614-01	47 - 44.958	113 - 49.344	9/4/02
Elk Creek Reach 13	C10ELKC02	2615-01	47 - 29.628	113 - 46.326	9/4/02
Elk Creek Reach 3	C10ELKC01	2616-01	47 - 31.932	113 - 44.586	9/4/02
Jim Creek Reach 5 (lower)	C10JIMC01	2617-01	47 - 37.680	113 - 48.324	9/5/02
Piper Creek Reach 14	C10PIPRC02	2618-01	47 - 38.328	113 - 51.000	9/5/02
Piper Creek Reach 2	C10PIPRC01	2619-01	47 - 40.296	113 - 49.128	9/5/02

Table 2. Diatom association metrics used by the State of Montana to evaluate biological integrity in mountain streams: references, range of values, expected response to increasing impairment or natural stress, and criteria for rating levels of biological integrity. The lowest rating for any one metric is the rating for that site.

Biological Integrity/ Impairment or Stress/ Use Support	No. of Species Counted <sup>1</sup>	Diversity Index <sup>2</sup> (Shannon)	Pollution Index <sup>3</sup>	Siltation Index <sup>4</sup>	Disturbance Index <sup>5</sup>	% Dominant Species <sup>6</sup>	% Abnormal Cells <sup>7</sup>
Excellent/None Full Support	>29	>2.99	>2.50	<20.0	<25.0	<25.0	0
Good/Minor Full Support	20-29	2.00-2.99	2.01-2.50	20.0-39.9	25.0-49.9	25.0-49.9	>0.0, <3.0
Fair/Moderate Partial Support	19-10	1.00-1.99	1.50-2.00	40.0-59.9	50.0-74.9	50.0-74.9	3.0-9.9
Poor/Severe Nonsupport	<10	<1.00	<1.50	>59.9	>74.9	>74.9	>9.9
References	Bahls 1979 Bahls 1993	Bahls 1979	Bahls 1993	Bahls 1993	Barbour et al. 1999	Barbour et al. 1999	McFarland et al. 1997
Range of Values	0-100+	0.00-5.00+	1.00-3.00	0.0-90.0+	0.0-100.0	-5.0-100.0	0.0-30.0+
Expected Response	Decrease <sup>a</sup>	Decrease <sup>b</sup>	Decrease	Increase	Increase	Increase	Increase

<sup>1</sup>Based on a proportional count of 400 cells (800 valves)

<sup>2</sup>Base 2 [bits] (Weber 1973)

<sup>3</sup>Composite numeric expression of the pollution tolerances assigned by Lange-Bertalot (1979) to the common diatom species

<sup>4</sup>Sum of the percent abundances of all species in the genera *Navicula*, *Nitzschia* and *Surirella*

<sup>5</sup>Percent abundance of *Achnanthes minutissimum* (synonym: *Achnanthes minutissima*)

<sup>6</sup>Percent abundance of the species with the largest number of cells in the proportional count

<sup>7</sup>Cells with an irregular outline or with abnormal ornamentation, or both

<sup>8</sup>Species richness and diversity may increase somewhat in mountain streams in response to slight to moderate increases in nutrients or sediment

Table 3. Relative abundance of cells and ordinal rank by biovolume of diatoms (Division Bacillariophyta) and genera of non-diatom algae in periphyton samples collected from tributaries of the Swan River in 2002: d = dominant; a = abundant; f = frequent; c = common; o = occasional; r = rare.

Taxa	Station									
	Goat 16	Goat 9	Goat 7	Goat 3	Elk 13	Elk 3	Jim 5	Piper 14	Piper 2	
<b>Cyanophyta</b>										
<i>Amphithrix</i>		f/4	a/2		c/1	o/3		f/2		
<i>Chamaesiphon</i>					c/4					
<i>Oscillatoria</i>	c/3	o/5	o/6				a/1		a/1	
<i>Phormidium</i>					o/6			o/5		o/8
<i>Rivularia</i>										
<i>Schizothrix</i>	c/4	d/1	d/1	a/2						
<b>Rhodophyta</b>										
<i>Audouinella</i>	f/2	c/3	o/5		o/2			a/1		f/4
<b>Chlorophyta</b>										
<i>Botryococcus</i>			c/4							
<i>Closterium</i>				o/6						c/5
<i>Mougeotia</i>				c/3						
<i>Oedogonium</i>										
<i>Protoderma</i>					o/5	c/1		o/6		f/3
<i>Spirogyra</i>				r/7						
<i>Stigeoclonium</i>								c/4		
<i>Ulothrix</i>				o/5			c/3		a/2	
<i>Zygnema</i>				o/4					c/6	
<b>Xanthophyta</b>										
<i>Tribonema</i>								o/4		
<b>Bacillariophyta</b>	a/1	a/2	f/3	a/1	o/3	c/2	f/2	c/3	c/7	
# Non-Diatom Genera	3	4	5	6	5	2	3	5	7	

Table 4. Percent abundance of major diatom species<sup>1</sup> and values of selected diatom association metrics for periphyton samples collected from tributaries of the Swan River in 2002. Underlined values indicate minor stress; **bold values** indicate moderate stress; **underlined and bold** values indicate severe stress; all other values indicate no stress and full support of aquatic life uses when compared to criteria for mountain streams in Table 2. Stress may be natural or anthropogenic (see text).

Species/Metric	PTC <sup>2</sup>	Station										
		Goat 16	Goat 9	Goat 7	Goat 3	Elk 13	Elk 3	Jim 5	Piper 14	Piper 2		
<i>Achnanthes biasolettiana</i>	3	21.97	51.64	33.40	9.83	0.11	0.24	4.61	3.31	0.98		
<i>Achnantheidium minutissimum</i>	3	44.90	25.70	38.49	55.92	84.69	73.23	34.83	80.85	81.68		
<i>Cymbella laevis</i>	3	6.31	3.88	5.09	0.47			6.81	0.24	0.12		
<i>Ecnyonema silesiacum</i>	2			0.85	1.18					0.61		
<i>Ecnyonopsis microcephala</i>	2	5.95	9.58	2.45	5.21	0.79	0.84					
<i>Fragilaria capucina</i>	2			0.94	0.47			8.30	0.24			
<i>Gomphonema dichotomum</i>	3	1.94	1.09	1.04	1.90	1.02	9.12	3.81	1.42	7.94		
<i>Gomphonema olivaceoides</i>	3			0.47	0.47	2.38	5.16		8.63	1.47		
<i>Reimeria sinuata</i>	3			0.47	0.47	0.57	7.08	1.04	0.12	1.22		
<i>Staurosira construens</i>	3			0.47	0.47	0.23		7.27	0.83	0.12		
<i>Synedra rumpens</i>	2		0.48	3.87	6.04		0.24	1.15		1.10		
Number of Species Counted		24	19	31	42	20	17	47	14	20		
Shannon Species Diversity		2.73	2.14	2.69	2.84	1.13	1.54	3.87	1.20	1.26		
Pollution Index		2.88	2.87	2.88	2.82	2.98	2.99	2.65	3.00	2.96		
Siltation Index		5.58	2.06	4.15	3.20	0.57	0.24	11.30	0.00	0.12		
Disturbance Index		44.90	25.70	38.49	55.92	84.69	73.23	34.83	80.85	81.68		
Percent Dominant Species		44.90	51.64	38.49	55.92	84.69	73.23	34.83	80.85	81.68		
Percent Abnormal Cells		0.36	0.48	0.47	0.47	0.00	0.24	0.00	0.35	0.24		
Similarity Index <sup>3</sup>			63.06	71.20	65.04		80.01			86.15		

<sup>1</sup>A major diatom species accounts for 5.0% or more of the cells at one or more stations in a sample set.

<sup>2</sup>Pollution Tolerance Class (Lange-Bertalot 1979): 1 = most tolerant; 2 = tolerant; 3 = sensitive to organic pollution

<sup>3</sup>Percent Community Similarity (Whittaker 1952) when compared to the diatom assemblage at the adjacent upstream station



Table 5. Modal categories for selected ecological attributes of diatom species in tributaries of the Swan River.

Ecological Attribute	Goat Creek	Elk Creek	Jim Creek	Piper Creek
Motility <sup>1</sup>	Not Motile	Not Motile	Not Motile	Not Motile
pH <sup>2</sup>	Circumneutral/ Alkaliphilous	Circumneutral	Circumneutral	Circumneutral
Salinity <sup>2</sup>	Fresh-brackish	Fresh-brackish	Fresh-brackish	Fresh-brackish
Nitrogen Uptake <sup>2</sup>	Not Classified/ Autotroph	Nitrogen Autotroph (high organics)	Nitrogen Autotroph (high organics)	Nitrogen Autotroph (high organics)
Oxygen Demand <sup>2</sup>	Not Classified/ Continuously High	Continuously High	Continuously High	Continuously High
Saprobity <sup>2</sup>	Not Classified/ beta-Mesosaprobous	beta-Mesosaprobous	beta-Mesosaprobous	beta-Mesosaprobous
Trophic State <sup>2</sup>	Mesotraphentic/ Variable	Variable	Variable	Variable
Moisture <sup>2</sup>	Not Classified/ Mainly in Waterbodies	Mainly in Waterbodies	Mainly in Waterbodies	Mainly in Waterbodies

<sup>1</sup>Dr. R. Jan Stevenson, Michigan State University, personal communication.

<sup>2</sup>Van Dam et al. 1994

Appendix: Diatom Reports

# Hannaea

1032 12th Avenue Helena, MT 59601 (406) 443-2196  
hannaea@montana.com

## Diatom Report

Sample: 261801

Client ID: C10PIPRC02

Sample Location: Piper Creek Reach 14

Sample Date: 9/5/02

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### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	3.31
<i>Achnanthes pusilla</i>	0.12
<i>Achnantheidium minutissimum</i>	80.85
<i>Cocconeis placentula</i>	0.95
<i>Diatoma hyemalis</i>	0.47
<i>Diatoma mesodon</i>	0.47
<i>Encyonema silesiacum</i>	0.24
<i>Eucoconeis flexella</i>	0.12
<i>Fragilaria capucina</i>	0.24
<i>Gomphonema dichotomum</i>	1.42
<i>Gomphonema minusculum</i>	2.25
<i>Gomphonema olivaceoides</i>	8.63
<i>Reimeria sinuata</i>	0.12
<i>Staurosira construens</i>	0.83

---

### Diatom Metrics

Metric	Category	Value
Valves Counted	--	846
Cells Counted	--	423
Total Number of Species	--	18
Total Number of Species Counted	--	14
Percent Dominant Species	--	80.85
Shannon's Diversity Index	--	1.2
Pollution Index	--	3
Pollution Tolerance (% by Category)	Most Tolerant	0
Pollution Tolerance (% by Category)	Tolerant	0.47
Pollution Tolerance (% by Category)	Sensitive	99.53

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## Diatom Report

Siltation Index	--	0
Disturbance Index	--	80.85
Stability Index	--	2.01
Percent Epithemiaceae	--	0
Percent Aerophiles	--	0
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	0
Motility (% by Category)	Moderately Motile	0.12
Motility (% by Category)	Not Motile	99.65
Motility (% by Category)	Variable Motility	0.24
pH (% by Category)	Not Classified	2.25
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	90.78
pH (% by Category)	Alkaliphilous	6.97
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	2.25
Salinity (% by Category)	Fresh	9.69
Salinity (% by Category)	Fresh-brackish	88.06
Salinity (% by Category)	Brackish-fresh	0
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	5.79
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	12.06
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	82.15
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	5.79
Oxygen Demand (% by Category)	Continuously High	93.03
Oxygen Demand (% by Category)	Fairly High	0
Oxygen Demand (% by Category)	Moderate	1.18
Oxygen Demand (% by Category)	Low	0
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	5.56
Saprobity (% by Category)	Oligosaprobous	9.81
Saprobity (% by Category)	beta-Mesosaprobous	84.4
Saprobity (% by Category)	alpha-Mesosaprobous	0.24

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## Diatom Report

Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	0
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	2.72
Trophic State (% by Category)	Oligotraphentic	0.24
Trophic State (% by Category)	Oligo-mesotraphentic	8.63
Trophic State (% by Category)	Mesotraphentic	4.14
Trophic State (% by Category)	Meso-eutraphentic	2.25
Trophic State (% by Category)	Eutraphentic	0.95
Trophic State (% by Category)	Hypereutraphentic	0
Trophic State (% by Category)	Variable	81.09
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	5.91
Moisture (% by Category)	Rarely Outside Waterbodies	1.06
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	1.89
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	91.13
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	0
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261901	86.15

---



# Hannaea

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## Diatom Report

Sample: 261901

Client ID: C10PIPRC01

Sample Location: Piper Creek Reach 2

Sample Date: 9/5/02

---

### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	0.98
<i>Achnanthidium minutissimum</i>	81.68
<i>Cocconeis placentula</i>	0.24
<i>Cymbella laevis</i>	0.12
<i>Diatoma hyemalis</i>	0.73
<i>Encyonema minutum</i>	0.12
<i>Encyonema silesiacum</i>	0.61
<i>Fragilaria vaucheriae</i>	0.73
<i>Gomphonema cuneolus</i>	0.24
<i>Gomphonema dichotomum</i>	7.94
<i>Gomphonema kobayasii</i>	0.61
<i>Gomphonema minusculum</i>	0.24
<i>Gomphonema olivaceoides</i>	1.47
<i>Hannaea arcus</i>	0.37
<i>Navicula cryptotenella</i>	0.12
<i>Reimeria sinuata</i>	1.22
<i>Staurosira construens</i>	0.12
<i>Staurosirella pinnata</i>	0.24
<i>Synedra rumpens</i>	1.1
<i>Synedra ulna</i>	1.1

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### Diatom Metrics

Metric	Category	Value
Valves Counted	--	819
Cells Counted	--	409.5
Total Number of Species	--	20
Total Number of Species Counted	--	20

# Hannaea

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## Diatom Report

Percent Dominant Species	--	81.68
Shannon's Diversity Index	--	1.26
Pollution Index	--	2.96
Pollution Tolerance (% by Category)	Most Tolerant	0
Pollution Tolerance (% by Category)	Tolerant	3.79
Pollution Tolerance (% by Category)	Sensitive	96.21
Siltation Index	--	0.12
Disturbance Index	--	81.68
Stability Index	--	4.4
Percent Epithemiaceae	--	0
Percent Aerophiles	--	0.73
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	0
Motility (% by Category)	Moderately Motile	1.34
Motility (% by Category)	Not Motile	97.8
Motility (% by Category)	Variable Motility	0.85
pH (% by Category)	Not Classified	1.59
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	86.2
pH (% by Category)	Alkaliphilous	12.21
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	1.59
Salinity (% by Category)	Fresh	2.2
Salinity (% by Category)	Fresh-brackish	96.21
Salinity (% by Category)	Brackish-fresh	0
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	3.79
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	10.26
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	85.96
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	3.79
Oxygen Demand (% by Category)	Continuously High	93.41
Oxygen Demand (% by Category)	Fairly High	0
Oxygen Demand (% by Category)	Moderate	2.81



# Hannaea

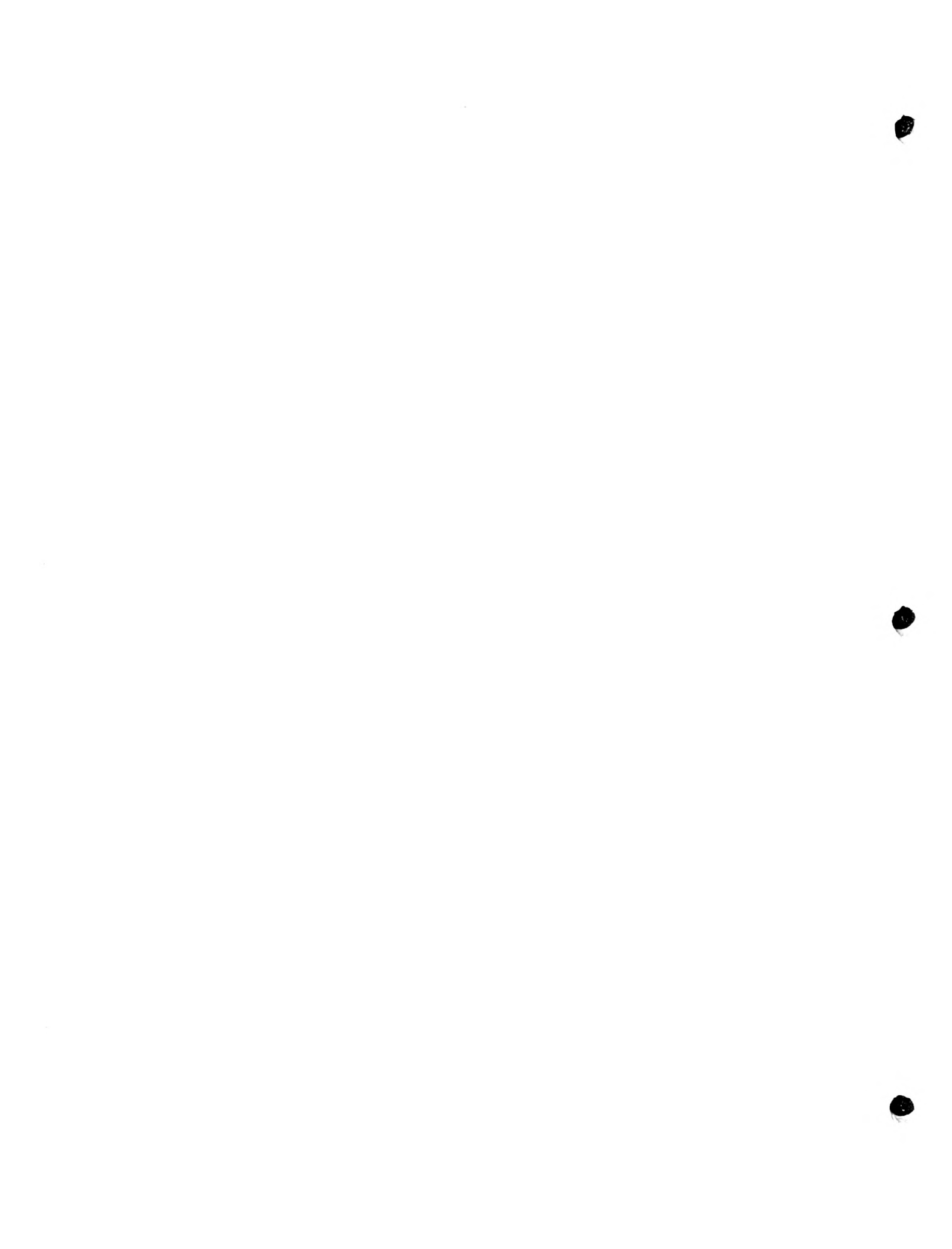
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## Diatom Report

Oxygen Demand (% by Category)	Low	0
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	3.66
Saprobity (% by Category)	Oligosaprobous	2.2
Saprobity (% by Category)	beta-Mesosaprobous	91.58
Saprobity (% by Category)	alpha-Mesosaprobous	1.47
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	1.1
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	2.32
Trophic State (% by Category)	Oligotraphentic	0
Trophic State (% by Category)	Oligo-mesotraphentic	2.56
Trophic State (% by Category)	Mesotraphentic	2.2
Trophic State (% by Category)	Meso-eutraphentic	8.06
Trophic State (% by Category)	Eutraphentic	0.98
Trophic State (% by Category)	Hypereutraphentic	0
Trophic State (% by Category)	Variable	83.88
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	3.66
Moisture (% by Category)	Rarely Outside Waterbodies	0.85
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	2.2
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	93.28
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	0
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261801	86.15

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# Hannaea

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## Diatom Report

Sample: 261701

Client ID: C10JIMC01

Sample Location: Jim Creek Reach 5 (lower)

Sample Date: 9/5/02

---

### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	4.61
<i>Achnanthes exigua</i>	0.12
<i>Achnanthes lanceolata</i>	0.92
<i>Achnanthes lauenbergiana</i>	0.12
<i>Achnanthes sp.</i>	0.23
<i>Achnantheidium minutissimum</i>	34.83
<i>Amphipleura pellucida</i>	0.69
<i>Amphora inariensis</i>	0.92
<i>Amphora pediculus</i>	1.85
<i>Caloneis bacillum</i>	0.23
<i>Cocconeis pediculus</i>	0.12
<i>Cocconeis placentula</i>	2.08
<i>Cymbella affinis</i>	0.12
<i>Cymbella cistula</i>	0.23
<i>Diatoma hyemalis</i>	1.85
<i>Diploneis oblongella</i>	0.12
<i>Encyonema silesiacum</i>	6.81
<i>Eucoconeis laevis</i>	0.35
<i>Eunotia sp.</i>	0.12
<i>Fragilaria capucina</i>	8.3
<i>Gomphoneis herculeana</i>	0.23
<i>Gomphonema acuminatum</i>	0.46
<i>Gomphonema dichotomum</i>	3.81
<i>Gomphonema micropus</i>	0.23
<i>Gomphonema minutum</i>	0.23
<i>Gomphonema olivaceum</i>	0.12
<i>Gomphonema parvulum</i>	1.85
<i>Gomphonema sp.</i>	0.46
<i>Meridion circulare</i>	1.15

# Hannaea

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## Diatom Report

<i>Navicula antonii</i>	0.23
<i>Navicula cari</i>	0.23
<i>Navicula menisculus</i>	0.23
<i>Navicula minima</i>	0.35
<i>Navicula minuscula</i>	0.12
<i>Navicula radiosiola</i>	0.23
<i>Navicula reichardtiana</i>	2.88
<i>Navicula tripunctata</i>	0.69
<i>Nitzschia dissipata</i>	1.04
<i>Nitzschia pura</i>	4.27
<i>Nitzschia recta</i>	0.35
<i>Nitzschia sublinearis</i>	0.69
<i>Reimeria sinuata</i>	1.04
<i>Stausira construens</i>	7.27
<i>Stausirella leptostauron</i>	0.92
<i>Stausirella pinnata</i>	2.08
<i>Synedra rumpens</i>	1.15
<i>Synedra ulna</i>	3.11

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### Diatom Metrics

Metric	Category	Value
Valves Counted	--	867
Cells Counted	--	433.5
Total Number of Species	--	47
Total Number of Species Counted	--	47
Percent Dominant Species	--	34.83
Shannon's Diversity Index	--	3.87
Pollution Index	--	2.65
Pollution Tolerance (% by Category)	Most Tolerant	2.31
Pollution Tolerance (% by Category)	Tolerant	30.22
Pollution Tolerance (% by Category)	Sensitive	67.47
Siltation Index	--	11.3
Disturbance Index	--	34.83
Stability Index	--	24.68
Percent Epithemiaceae	--	0
Percent Aerophiles	--	0.58
Percent Centrics	--	0

# Hannaea

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## Diatom Report

Motility (% by Category)	Highly Motile	6.34
Motility (% by Category)	Moderately Motile	9.8
Motility (% by Category)	Not Motile	76.59
Motility (% by Category)	Variable Motility	7.27
pH (% by Category)	Not Classified	7.38
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	54.67
pH (% by Category)	Alkaliphilous	37.83
pH (% by Category)	Alkalibiontic	0.12
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	1.96
Salinity (% by Category)	Fresh	2.31
Salinity (% by Category)	Fresh-brackish	95.62
Salinity (% by Category)	Brackish-fresh	0.12
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	25.03
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	15.34
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	57.44
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	2.19
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	25.03
Oxygen Demand (% by Category)	Continuously High	52.48
Oxygen Demand (% by Category)	Fairly High	7.15
Oxygen Demand (% by Category)	Moderate	13.15
Oxygen Demand (% by Category)	Low	2.19
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	9
Saprobity (% by Category)	Oligosaprobous	7.5
Saprobity (% by Category)	beta-Mesosaprobous	66.67
Saprobity (% by Category)	alpha-Mesosaprobous	10.84
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	6
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	11.07
Trophic State (% by Category)	Oligotraphentic	1.38
Trophic State (% by Category)	Oligo-mesotraphentic	1.96
Trophic State (% by Category)	Mesotraphentic	13.96

# Hannaea

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## Diatom Report

Trophic State (% by Category)	Meso-eutraphentic	13.26
Trophic State (% by Category)	Eutraphentic	9.69
Trophic State (% by Category)	Hypereutraphentic	0
Trophic State (% by Category)	Variable	48.67
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	24.91
Moisture (% by Category)	Rarely Outside Waterbodies	16.03
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	9.69
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	49.13
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	0.23
Moisture (% by Category)	Exclusively Outside Waterbodies	0

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# Hannaea

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## Diatom Report

Sample: 261601

Client ID: C10ELKC01

Sample Location: Elk Creek Reach 3

Sample Date: 9/4/02

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### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	0.24
<i>Achnanthes bioretii</i>	0.12
<i>Achnantheidium minutissimum</i>	73.23
<i>Cocconeis placentula</i>	1.32
<i>Cymbella excisiformis</i>	0.12
<i>Cymbella leptoceros</i>	0.24
<i>Encyonopsis microcephala</i>	0.84
<i>Eucocconeis laevis</i>	0.48
<i>Gomphonema cuneolus</i>	0.84
<i>Gomphonema dichotomum</i>	9.12
<i>Gomphonema minusculum</i>	0.24
<i>Gomphonema olivaceoides</i>	5.16
<i>Gomphonema pumilum</i>	0.48
<i>Navicula brementis</i>	0.12
<i>Navicula cari</i>	0.12
<i>Reimeria sinuata</i>	7.08
<i>Synedra rumpens</i>	0.24

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### Diatom Metrics

Metric	Category	Value
Valves Counted	--	833
Cells Counted	--	416.5
Total Number of Species	--	17
Total Number of Species Counted	--	17
Percent Dominant Species	--	73.23
Shannon's Diversity Index	--	1.54
Pollution Index	--	2.99

# Hannaea

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## Diatom Report

Pollution Tolerance (% by Category)	Most Tolerant	0
Pollution Tolerance (% by Category)	Tolerant	1.32
Pollution Tolerance (% by Category)	Sensitive	98.68
Siltation Index	--	0.24
Disturbance Index	--	73.23
Stability Index	--	0.24
Percent Epithemiaceae	--	0
Percent Aerophiles	--	0
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	0
Motility (% by Category)	Moderately Motile	7.32
Motility (% by Category)	Not Motile	91.48
Motility (% by Category)	Variable Motility	1.2
pH (% by Category)	Not Classified	1.92
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	86.31
pH (% by Category)	Alkaliphilous	11.76
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	1.32
Salinity (% by Category)	Fresh	5.88
Salinity (% by Category)	Fresh-brackish	92.8
Salinity (% by Category)	Brackish-fresh	0
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	2.4
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	15.97
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	81.63
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	2.4
Oxygen Demand (% by Category)	Continuously High	96.28
Oxygen Demand (% by Category)	Fairly High	0
Oxygen Demand (% by Category)	Moderate	1.32
Oxygen Demand (% by Category)	Low	0
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	2.4



# Hannaea

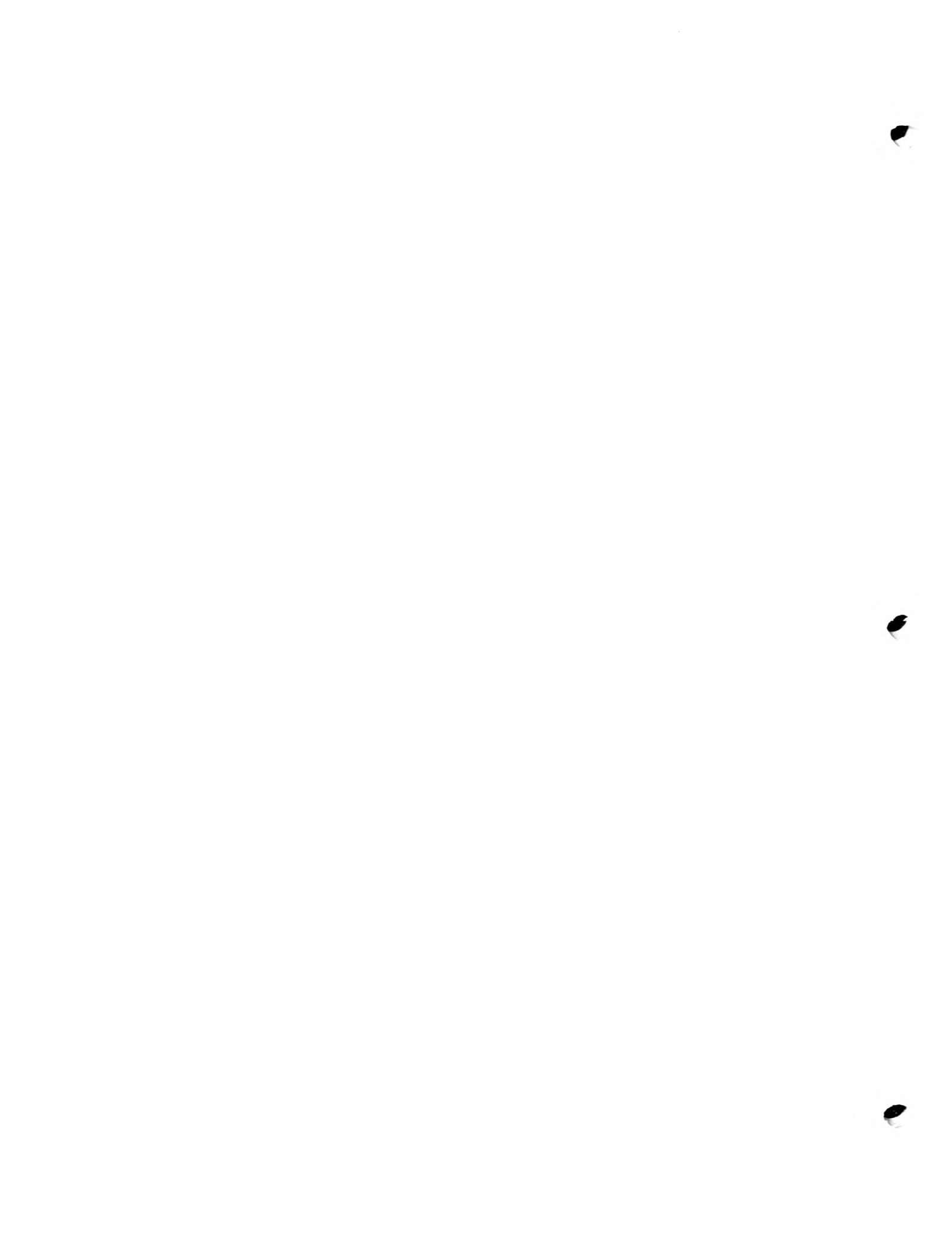
1032 12th Avenue Helena, MT 59601 (406) 443-2196

hannaea@montana.com

## Diatom Report

Saprobity (% by Category)	Oligosaprobous	6.84
Saprobity (% by Category)	beta-Mesosaprobous	90.76
Saprobity (% by Category)	alpha-Mesosaprobous	0
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	0
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	1.32
Trophic State (% by Category)	Oligotraphentic	0.72
Trophic State (% by Category)	Oligo-mesotraphentic	5.4
Trophic State (% by Category)	Mesotraphentic	7.44
Trophic State (% by Category)	Meso-eutrathentic	9.96
Trophic State (% by Category)	Eutrathentic	1.32
Trophic State (% by Category)	Hypereutrathentic	0
Trophic State (% by Category)	Variable	73.83
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	2.4
Moisture (% by Category)	Rarely Outside Waterbodies	0
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	1.32
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	96.16
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	0.12
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261501	80.01

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# Hannaea

1032 12th Avenue Helena, MT 59601 (406) 443-2196

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## Diatom Report

Sample: 261501

Client ID: C10ELKC02

Sample Location: Elk Creek Reach 13

Sample Date: 9/4/02

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### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	0.11
<i>Achnanthes lanceolata</i>	0.11
<i>Achnantheidium minutissimum</i>	84.69
<i>Cocconeis placentula</i>	0.34
<i>Cymbella reichardtii</i>	0.23
<i>Diatoma moniliformis</i>	0.11
<i>Diatoma tenuis</i>	0.11
<i>Encyonopsis microcephala</i>	0.79
<i>Fragilaria vaucheriae</i>	0.57
<i>Gomphonema cuneolus</i>	1.36
<i>Gomphonema dichotomum</i>	1.02
<i>Gomphonema minusculum</i>	2.38
<i>Gomphonema olivaceoides</i>	2.38
<i>Gomphonema pumilum</i>	4.2
<i>Hannaea arcus</i>	0.23
<i>Navicula cryptotenella</i>	0.11
<i>Navicula stroemii</i>	0.23
<i>Nitzschia hantzschiana</i>	0.23
<i>Reimeria sinuata</i>	0.57
<i>Staurosira construens</i>	0.23

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### Diatom Metrics

Metric	Category	Value
Valves Counted	--	882
Cells Counted	--	441
Total Number of Species	--	28
Total Number of Species Counted	--	20

# Hannaea

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## Diatom Report

Percent Dominant Species	--	84.69
Shannon's Diversity Index	--	1.13
Pollution Index	--	2.98
Pollution Tolerance (% by Category)	Most Tolerant	0
Pollution Tolerance (% by Category)	Tolerant	2.04
Pollution Tolerance (% by Category)	Sensitive	97.96
Siltation Index	--	0.57
Disturbance Index	--	84.69
Stability Index	--	1.25
Percent Epithemiaceae	--	0
Percent Aerophiles	--	0.79
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	0.23
Motility (% by Category)	Moderately Motile	0.91
Motility (% by Category)	Not Motile	97.85
Motility (% by Category)	Variable Motility	1.02
pH (% by Category)	Not Classified	8.5
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	87.87
pH (% by Category)	Alkaliphilous	3.63
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	4.31
Salinity (% by Category)	Fresh	2.61
Salinity (% by Category)	Fresh-brackish	92.97
Salinity (% by Category)	Brackish-fresh	0.11
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	8.96
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	4.65
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	86.39
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	8.73
Oxygen Demand (% by Category)	Continuously High	90.14
Oxygen Demand (% by Category)	Fairly High	0
Oxygen Demand (% by Category)	Moderate	1.13

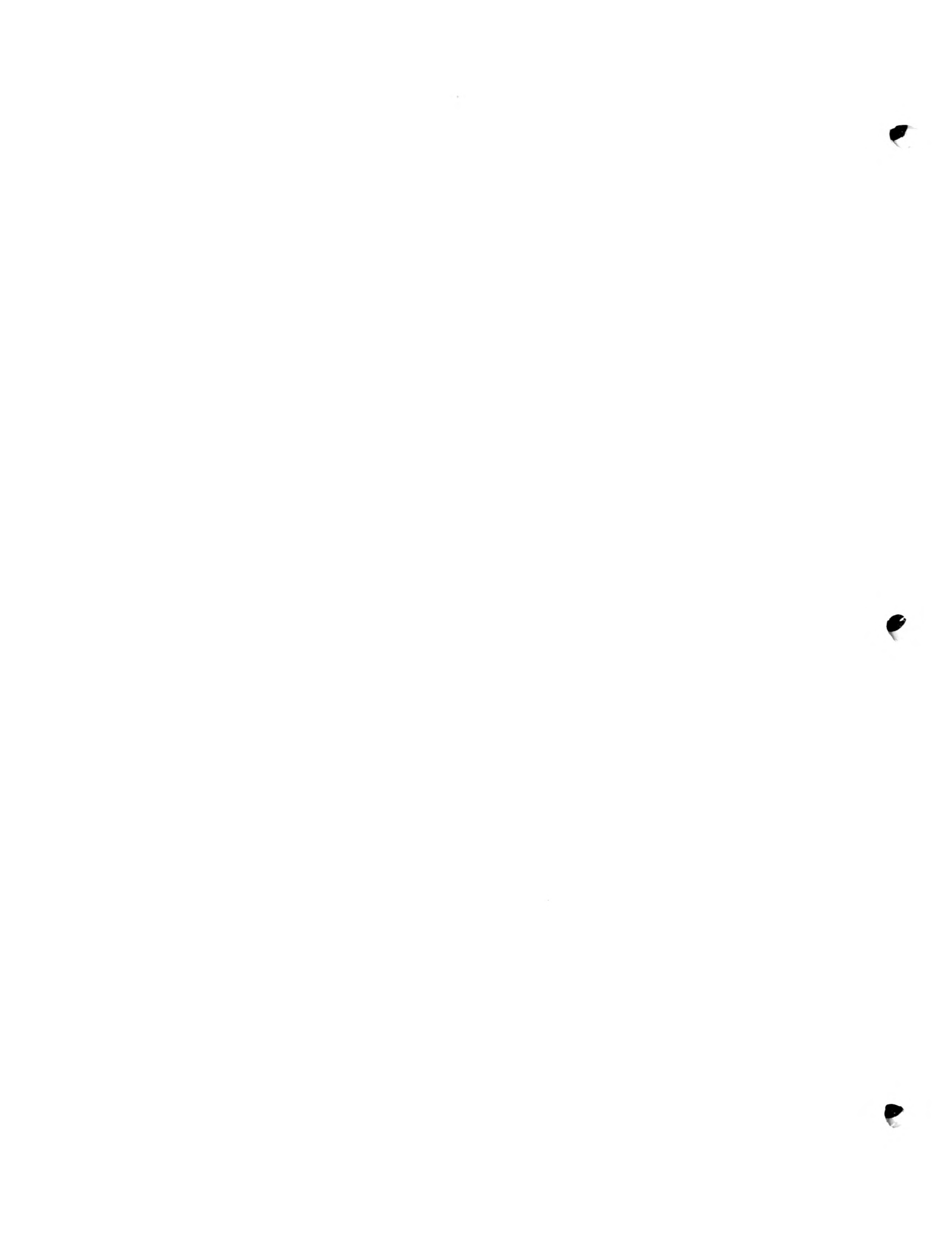
# Hannaea

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hannaea@montana.com

## Diatom Report

Oxygen Demand (% by Category)	Low	0
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	8.84
Saprobity (% by Category)	Oligosaprobous	3.4
Saprobity (% by Category)	beta-Mesosaprobous	86.96
Saprobity (% by Category)	alpha-Mesosaprobous	0.79
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	0
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	4.54
Trophic State (% by Category)	Oligotraphentic	0
Trophic State (% by Category)	Oligo-mesotraphentic	2.38
Trophic State (% by Category)	Mesotraphentic	0.91
Trophic State (% by Category)	Meso-eutraphentic	2.04
Trophic State (% by Category)	Eutraphentic	1.13
Trophic State (% by Category)	Hypereutraphentic	0
Trophic State (% by Category)	Variable	89
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	8.62
Moisture (% by Category)	Rarely Outside Waterbodies	0.34
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	0.45
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	90.14
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	0.45
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261601	80.01

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# Hannaea

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## Diatom Report

Sample: 261401

Client ID: C10GOATC01

Sample Location: Goat Creek Reach 3

Sample Date: 9/4/02

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### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	9.83
<i>Achnanthes sp.</i>	0.24
<i>Achnantheidium affine</i>	1.66
<i>Achnantheidium minutissimum</i>	55.92
<i>Amphora inariensis</i>	0.24
<i>Cocconeis pediculus</i>	0.47
<i>Cocconeis placentula</i>	1.07
<i>Cymbella affinis</i>	0.24
<i>Cymbella excisiformis</i>	2.61
<i>Cymbella laevis</i>	0.47
<i>Cymbella leptoceros</i>	0.24
<i>Denticula tenuis</i>	0.24
<i>Diatoma hyemalis</i>	0.12
<i>Diatoma mesodon</i>	0.12
<i>Diatoma tenuis</i>	0.47
<i>Didymosphenia geminata</i>	0.24
<i>Diploneis oblongella</i>	0.12
<i>Encyonema silesiacum</i>	1.18
<i>Encyonopsis microcephala</i>	5.21
<i>Eucocconeis flexella</i>	0.47
<i>Eucocconeis laevis</i>	0.47
<i>Fragilaria capucina</i>	0.47
<i>Fragilaria vaucheriae</i>	0.95
<i>Gomphonema cuneolus</i>	0.47
<i>Gomphonema dichotomum</i>	1.9
<i>Gomphonema minusculum</i>	1.78
<i>Gomphonema sp.</i>	0.12
<i>Navicula cryptocephala</i>	0.24
<i>Navicula cryptotenella</i>	1.07

# Hannaea

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## Diatom Report

<i>Nitzschia angustata</i>	0.24
<i>Nitzschia dissipata</i>	0.36
<i>Nitzschia heufleriana</i>	0.24
<i>Nitzschia linearis</i>	0.24
<i>Nitzschia palea</i>	0.47
<i>Nitzschia pura</i>	0.24
<i>Nitzschia recta</i>	0.12
<i>Reimeria sinuata</i>	0.47
<i>Staurosira construens</i>	0.47
<i>Staurosirella leptostauron</i>	0.71
<i>Staurosirella pinnata</i>	1.07
<i>Synedra rumpens</i>	6.04
<i>Synedra ulna</i>	0.71

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### Diatom Metrics

Metric	Category	Value
Valves Counted	--	844
Cells Counted	--	422
Total Number of Species	--	42
Total Number of Species Counted	--	42
Percent Dominant Species	--	55.92
Shannon's Diversity Index	--	2.84
Pollution Index	--	2.82
Pollution Tolerance (% by Category)	Most Tolerant	0.47
Pollution Tolerance (% by Category)	Tolerant	16.82
Pollution Tolerance (% by Category)	Sensitive	82.7
Siltation Index	--	3.2
Disturbance Index	--	55.92
Stability Index	--	11.14
Percent Epithemiaceae	--	0.24
Percent Aerophiles	--	1.42
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	1.9
Motility (% by Category)	Moderately Motile	2.37
Motility (% by Category)	Not Motile	85.78
Motility (% by Category)	Variable Motility	9.95
pH (% by Category)	Not Classified	6.4



# Hannaea

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## Diatom Report

pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	66.11
pH (% by Category)	Alkaliphilous	27.49
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	5.92
Salinity (% by Category)	Fresh	1.66
Salinity (% by Category)	Fresh-brackish	91.47
Salinity (% by Category)	Brackish-fresh	0.95
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	25.71
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	10.55
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	63.27
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0.47
Oxygen Demand (% by Category)	Not Classified	25.71
Oxygen Demand (% by Category)	Continuously High	68.01
Oxygen Demand (% by Category)	Fairly High	1.18
Oxygen Demand (% by Category)	Moderate	4.62
Oxygen Demand (% by Category)	Low	0.47
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	22.04
Saprobity (% by Category)	Oligosaprobous	9.83
Saprobity (% by Category)	beta-Mesosaprobous	64.1
Saprobity (% by Category)	alpha-Mesosaprobous	2.84
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	0.71
Saprobity (% by Category)	Polysaprobous	0.47
Trophic State (% by Category)	Not Classified	8.29
Trophic State (% by Category)	Oligotraphentic	1.42
Trophic State (% by Category)	Oligo-mesotraphentic	6.04
Trophic State (% by Category)	Mesotraphentic	11.37
Trophic State (% by Category)	Meso-eutraphentic	8.89
Trophic State (% by Category)	Eutraphentic	3.2
Trophic State (% by Category)	Hypereutraphentic	0.47
Trophic State (% by Category)	Variable	60.31
Trophic State (% by Category)	Dystrophic	0

# Hannaea

1032 12th Avenue Helena, MT 59601 (406) 443-2196

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## Diatom Report

Moisture (% by Category)	Not Classified	24.64
Moisture (% by Category)	Rarely Outside Waterbodies	2.96
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	4.27
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	68.01
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	0.12
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261101	65.93

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# Hannaea

1032 .12th Avenue Helena, MT 59601 (406) 443-2196  
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## Diatom Report

Sample: 261301

Client ID: C10GOATC02

Sample Location: Goat Creek Reach 7

Sample Date: 9/4/02

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### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	33.4
<i>Achnanthes marginulata</i>	0.19
<i>Achnanthes sp.</i>	0.19
<i>Achnantheidium minutissimum</i>	38.49
<i>Cocconeis placentula</i>	0.28
<i>Cymbella excisa</i>	0.19
<i>Cymbella excisiformis</i>	1.89
<i>Cymbella laevis</i>	5.09
<i>Denticula tenuis</i>	0.09
<i>Diatoma hyemalis</i>	0.85
<i>Diploneis oblongella</i>	0.09
<i>Encyonema silesiacum</i>	0.85
<i>Encyonopsis microcephala</i>	2.45
<i>Eucocconeis flexella</i>	0.19
<i>Eucocconeis laevis</i>	0.19
<i>Fragilaria capucina</i>	0.94
<i>Frustulia rhomboides</i>	0.09
<i>Gomphonema cuneolus</i>	0.38
<i>Gomphonema dichotomum</i>	1.04
<i>Gomphonema kobayasii</i>	0.75
<i>Gomphonema minusculum</i>	3.4
<i>Navicula cryptotenella</i>	1.7
<i>Navicula radiosa</i>	0.09
<i>Navicula radiosiola</i>	0.38
<i>Navicula sp.</i>	0.19
<i>Navicula stroemii</i>	1.13
<i>Nitzschia dissipata</i>	0.66
<i>Reimeria sinuata</i>	0.47
<i>Staurosirella pinnata</i>	0.28

# Hannaea

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## Diatom Report

<i>Synedra rumpens</i>	3.87
<i>Synedra ulna</i>	0.19

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### Diatom Metrics

Metric	Category	Value
Valves Counted	--	1060
Cells Counted	--	530
Total Number of Species	--	32
Total Number of Species Counted	--	31
Percent Dominant Species	--	38.49
Shannon's Diversity Index	--	2.69
Pollution Index	--	2.88
Pollution Tolerance (% by Category)	Most Tolerant	0
Pollution Tolerance (% by Category)	Tolerant	11.7
Pollution Tolerance (% by Category)	Sensitive	88.3
Siltation Index	--	4.15
Disturbance Index	--	38.49
Stability Index	--	6.13
Percent Epithemiaceae	--	0.09
Percent Aerophiles	--	0
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	0.66
Motility (% by Category)	Moderately Motile	4.25
Motility (% by Category)	Not Motile	84.62
Motility (% by Category)	Variable Motility	10.47
pH (% by Category)	Not Classified	12.26
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0.28
pH (% by Category)	Circumneutral	45.09
pH (% by Category)	Alkaliphilous	42.36
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	12.26
Salinity (% by Category)	Fresh	1.6
Salinity (% by Category)	Fresh-brackish	86.13
Salinity (% by Category)	Brackish-fresh	0
Salinity (% by Category)	Brackish	0

# Hannaea

1032 12th Avenue Helena, MT 59601 (406) 443-2196

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## Diatom Report

Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	53.3
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	5.38
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	41.32
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	52.17
Oxygen Demand (% by Category)	Continuously High	45.75
Oxygen Demand (% by Category)	Fairly High	0.75
Oxygen Demand (% by Category)	Moderate	1.32
Oxygen Demand (% by Category)	Low	0
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	50.66
Saprobity (% by Category)	Oligosaprobous	4.15
Saprobity (% by Category)	beta-Mesosaprobous	44.15
Saprobity (% by Category)	alpha-Mesosaprobous	0.85
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	0.19
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	14.34
Trophic State (% by Category)	Oligotraphentic	0.66
Trophic State (% by Category)	Oligo-mesotraphentic	3.87
Trophic State (% by Category)	Mesotraphentic	34.91
Trophic State (% by Category)	Meso-eutraphentic	4.25
Trophic State (% by Category)	Eutraphentic	0.47
Trophic State (% by Category)	Hypereutraphentic	0
Trophic State (% by Category)	Variable	41.51
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	50.47
Moisture (% by Category)	Rarely Outside Waterbodies	0.85
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	3.3
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	43.96
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	1.42
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261401	65.04

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# Hannaea

1032 12th Avenue Helena, MT 59601 (406) 443-2196  
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## Diatom Report

Sample: 261201

Client ID: C10GOATC03

Sample Location: Goat Creek Reach 9

Sample Date: 9/5/02

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### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	51.64
<i>Achnanthes</i> sp.	0.24
<i>Achnantheidium minutissimum</i>	25.7
<i>Brachysira neoexilis</i>	1.58
<i>Cymbella excisiformis</i>	1.33
<i>Cymbella laevis</i>	3.88
<i>Cymbella leptoceros</i>	0.73
<i>Denticula tenuis</i>	0.12
<i>Encyonopsis microcephala</i>	9.58
<i>Eucocconeis flexella</i>	0.48
<i>Eucocconeis laevis</i>	0.12
<i>Gomphonema dichotomum</i>	1.09
<i>Gomphonema kobayasii</i>	0.24
<i>Gomphonema minusculum</i>	0.24
<i>Navicula radiosiola</i>	0.73
<i>Navicula</i> sp.	0.24
<i>Navicula stroemii</i>	1.09
<i>Synedra rumpens</i>	0.48
<i>Synedra ulna</i>	0.48

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### Diatom Metrics

Metric	Category	Value
Valves Counted	--	825
Cells Counted	--	412.5
Total Number of Species	--	19
Total Number of Species Counted	--	19
Percent Dominant Species	--	51.64

# Hannaea

1032\_12th Avenue Helena, MT 59601 (406) 443-2196

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## Diatom Report

Shannon's Diversity Index	--	2.14
Pollution Index	--	2.87
Pollution Tolerance (% by Category)	Most Tolerant	0
Pollution Tolerance (% by Category)	Tolerant	12.61
Pollution Tolerance (% by Category)	Sensitive	87.39
Siltation Index	--	2.06
Disturbance Index	--	25.7
Stability Index	--	0.97
Percent Epithemiaceae	--	0.12
Percent Aerophiles	--	0
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	0
Motility (% by Category)	Moderately Motile	2.18
Motility (% by Category)	Not Motile	80.73
Motility (% by Category)	Variable Motility	15.52
pH (% by Category)	Not Classified	8.48
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	26.79
pH (% by Category)	Alkaliphilous	64.73
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	8.48
Salinity (% by Category)	Fresh	1.45
Salinity (% by Category)	Fresh-brackish	90.06
Salinity (% by Category)	Brackish-fresh	0
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	61.7
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	12.12
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	26.18
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0
Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	60.61
Oxygen Demand (% by Category)	Continuously High	38.91
Oxygen Demand (% by Category)	Fairly High	0
Oxygen Demand (% by Category)	Moderate	0.48
Oxygen Demand (% by Category)	Low	0



# Hannaea

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## Diatom Report

Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	61.7
Saprobity (% by Category)	Oligosaprobous	11.03
Saprobity (% by Category)	beta-Mesosaprobous	26.79
Saprobity (% by Category)	alpha-Mesosaprobous	0
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	0.48
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	9.58
Trophic State (% by Category)	Oligotraphentic	1.33
Trophic State (% by Category)	Oligo-mesotraphentic	0.48
Trophic State (% by Category)	Mesotraphentic	51.76
Trophic State (% by Category)	Meso-eutraphentic	10.67
Trophic State (% by Category)	Eutraphentic	0
Trophic State (% by Category)	Hypereutraphentic	0
Trophic State (% by Category)	Variable	26.18
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	60.61
Moisture (% by Category)	Rarely Outside Waterbodies	0
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	0.48
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	37.82
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	1.09
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261301	71.2

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# Hannaea

1032 12th Avenue Helena, MT 59601 (406) 443-2196

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## Diatom Report

Sample: 261101

Client ID: C10GOATC04

Sample Location: Goat Creek Reach 16 (upper)

Sample Date: 9/4/02

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### Diatom Species

Genus/Species/Variety	Percent Relative Abundance
<i>Achnanthes biasolettiana</i>	21.97
<i>Achnantheidium minutissimum</i>	44.9
<i>Brachysira neoexilis</i>	2.06
<i>Cocconeis placentula</i>	0.61
<i>Cymbella laevis</i>	6.31
<i>Cymbella leptoceros</i>	2.67
<i>Denticula tenuis</i>	3.4
<i>Diatoma hyemalis</i>	0.61
<i>Encyonopsis microcephala</i>	5.95
<i>Eucocconeis flexella</i>	0.12
<i>Fragilaria vaucheriae</i>	0.85
<i>Gomphonema dichotomum</i>	1.94
<i>Gomphonema kobayasii</i>	0.49
<i>Gomphonema minusculum</i>	0.85
<i>Gomphonema pumilum</i>	0.24
<i>Hannaea arcus</i>	0.61
<i>Meridion circulare</i>	0.61
<i>Navicula densilineolata</i>	0.49
<i>Navicula radiosiola</i>	0.12
<i>Navicula sp.</i>	0.24
<i>Navicula stroemii</i>	3.76
<i>Nitzschia dissipata</i>	0.49
<i>Nitzschia pura</i>	0.49
<i>Pinnularia borealis</i>	0.24

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### Diatom Metrics

# Hannaea

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## Diatom Report

Metric	Category	Value
Valves Counted	--	824
Cells Counted	--	412
Total Number of Species	--	36
Total Number of Species Counted	--	24
Percent Dominant Species	--	44.9
Shannon's Diversity Index	--	2.73
Pollution Index	--	2.88
Pollution Tolerance (% by Category)	Most Tolerant	0
Pollution Tolerance (% by Category)	Tolerant	11.65
Pollution Tolerance (% by Category)	Sensitive	88.35
Siltation Index	--	5.58
Disturbance Index	--	44.9
Stability Index	--	2.06
Percent Epithemiaceae	--	3.4
Percent Aerophiles	--	1.09
Percent Centrics	--	0
Motility (% by Category)	Highly Motile	0.97
Motility (% by Category)	Moderately Motile	8.25
Motility (% by Category)	Not Motile	73.79
Motility (% by Category)	Variable Motility	14.93
pH (% by Category)	Not Classified	11.41
pH (% by Category)	Acidobiontic	0
pH (% by Category)	Acidophilous	0
pH (% by Category)	Circumneutral	45.27
pH (% by Category)	Alkaliphilous	43.33
pH (% by Category)	Alkalibiontic	0
pH (% by Category)	Indifferent	0
Salinity (% by Category)	Not Classified	10.68
Salinity (% by Category)	Fresh	7.28
Salinity (% by Category)	Fresh-brackish	82.04
Salinity (% by Category)	Brackish-fresh	0
Salinity (% by Category)	Brackish	0
Salinity (% by Category)	Marine	0
Nitrogen Uptake (% by Category)	Not Classified	37.62
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (low organics)	14.68
Nitrogen Uptake (% by Category)	Nitrogen Autotroph (high organics)	47.69
Nitrogen Uptake (% by Category)	Facultative Nitrogen Heterotroph	0

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## Diatom Report

Nitrogen Uptake (% by Category)	Obligate Nitrogen Heterotroph	0
Oxygen Demand (% by Category)	Not Classified	33.86
Oxygen Demand (% by Category)	Continuously High	63.59
Oxygen Demand (% by Category)	Fairly High	1.09
Oxygen Demand (% by Category)	Moderate	1.46
Oxygen Demand (% by Category)	Low	0
Oxygen Demand (% by Category)	Very Low	0
Saprobity (% by Category)	Not Classified	37.14
Saprobity (% by Category)	Oligosaprobous	13.23
Saprobity (% by Category)	beta-Mesosaprobous	48.79
Saprobity (% by Category)	alpha-Mesosaprobous	0.85
Saprobity (% by Category)	alpha-Mesosaprobous/Polysaprobous	0
Saprobity (% by Category)	Polysaprobous	0
Trophic State (% by Category)	Not Classified	15.53
Trophic State (% by Category)	Oligotraphentic	3.28
Trophic State (% by Category)	Oligo-mesotraphentic	0.24
Trophic State (% by Category)	Mesotraphentic	25.36
Trophic State (% by Category)	Meso-eutraphentic	8.37
Trophic State (% by Category)	Eutraphentic	1.46
Trophic State (% by Category)	Hypereutraphentic	0
Trophic State (% by Category)	Variable	45.75
Trophic State (% by Category)	Dystrophic	0
Moisture (% by Category)	Not Classified	33.86
Moisture (% by Category)	Rarely Outside Waterbodies	0.61
Moisture (% by Category)	Mainly in Waterbodies; Sometimes Wet	1.21
Moisture (% by Category)	Mainly in Waterbodies; Regularly Wet	60.32
Moisture (% by Category)	Mainly Wet Places; Sometimes in Water	4
Moisture (% by Category)	Exclusively Outside Waterbodies	0
Similarity Index	Reference Sample ID: 261201	63.06

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