SENTAR

A BENTHIC INVERTEBRATE MONITORING STUDY ON THE ATHABASCA RIVER, WHITECOURT, ALBERTA, 1995

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July 1996

Project No.: 09-834-00

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ACKNOWLEDGEMENTS

We would like to thank Brian Steinback and Dan Moore of Alberta Newsprint Company for their assistance and cooperation during this study.

We wish to thank Ken Duncan for providing jet boat transportation.

We wish to acknowledge the assistance of SENTAR staff members Dave Huggill for his assisstance with the field survey, Kevin Brayford for his assistance with data analysis and computer graphics, and Karen McNabb for word processing. We also wish to acknowledge Gordon Pritchard and Ela Grygorasz for the sorting of the benthic invertebrate samples; Jack Zloty for the re-sort check and the identification of the benthic invertebrates; and Nathan McLoughlin for assisstance with statistical analyses.

EXECUTIVE SUMMARY

Alberta Newsprint Company (ANC) operates an integrated thermomechanical pulp (TMP), de-inked pulp (DIP) and paper mill near Whitecourt, Alberta. A benthic invertebrate monitoring program is included as part of the environmental program for the mill, as required under the Clean Water Act by Alberta Environmental Protection. Baseline (pre-operational) benthic invertebrate monitoring programs were conducted during the spring and fall of 1989 and the spring of 1990 in the Athabasca River. The mill became operational in August 1990. Water is obtained from the Athabasca River for process use and following treatment, effluent is discharged to the river at a rate of about 15,000 m^3/day. During the fall of 1990, a benthic monitoring program was conducted to establish start-up conditions and from 1991 to 1994, to establish operational conditions in the river.

The monitoring program was continued during the fall of 1995. The objectives of this program were to determine if there were any differences in benthic invertebrate community structure between sites, to evaluate the general water quality conditions of the Athabasca River as reflected by the benthic invertebrate community structure and to determine if there were any differences between pre-operational and operational conditions in the Athabasca River.

Seven sites, which were established in 1989, were sampled for this survey. Two sites were located upstream of the ANC effluent outfall as background sites and five sites were located downstream of the effluent outfall to a distance of 34 km as potential impact and recovery sites. Three of these downstream sites were located between the effluent outfall and the confluence of the McLeod River with the Athabasca River. The two sites farther downstream were located downstream of the Millar Western Pulp Ltd. (Millar Western) effluent outfall and the farthest site was also located downstream of the Whitecourt sewage treatment plant outfall.

Benthic invertebrate sampling was conducted from 7 to 10 October 1995. Five replicate benthic samples were collected at each site using a modified Neill-Hess cylinder sampler enclosing an area of 0.0892 m^2. All sampling sites were in run areas and as similar as possible with regard to physical characteristics. The physical characteristics of water velocity, water depth and substrate composition were documented at each sampling location. Water quality sampling consisting of standard field measurements and laboratory analyses, and periphytic chlorophyll *a* sampling was conducted at each site.

Each benthic sample was sorted by a combination of a whole sort and a subsampling method and enumerated in the laboratory. All organisms were identified to the lowest practical taxonomic level (genus where possible).

The basic computations of total number of taxa, number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, total number of organisms, total standing crop (number/m^2), standing crop of each major taxonomic group and Shannon-Weaver species diversity were calculated for each sample, along with statistical analyses. Any differences in benthic community structure (using reciprocal averaging ordination (RA)) and feeding group structure (using a trophic guild analysis) between sites were determined for the data. A statistical comparison was made between the pre-operational (1989) and operational (1990 to 1995) fall data using a repeated measures design, to assess the effects of the pulp mill effluent.

A Quality Assurance and Quality Control (QA/QC) program was implemented during this study and Standard Operating Procedures (SOPs) were used for all field and laboratory procedures and reporting of data.

Many factors can regulate the occurrence and distribution of benthic invertebrates, including river flow conditions and physical habitat factors. Athabasca River flows during the survey were stable and lower than historically recorded flows. Although benthic sampling sites were chosen to be as similar as possible with regard to physical habitat factors, some minor differences were present. There were some variations in water velocity and substrate composition, but very little in water depth between sites. Water velocity differences between sites resulted from hydraulic and minor habitat differences between reaches of the river. Substrates at all sites consisted mainly of cobbles and pebbles, with a few gravels. Generally, these minor differences in physical characteristics do not cause any detectable differences in benthic community structure between sites.

The water quality data indicated that the ANC treated effluent discharge did not affect pH, conductivity, dissolved oxygen or biochemical oxygen demand at downstream sites. True color, total suspended solids, total phosphorus and total Kjeldahl nitrogen concentrations were slightly higher at downstream sites than at background sites, likely as a result of effluent inputs. Metal concentrations, which are not generally a major component of pulp mill effluent, were below detection limits, except for iron and manganese which were slightly above background values, but below the provincial (AASWQIG) and federal (CWQG) guidelines. Neither resin or fatty acids were detected in the river. Total resin and fatty acid concentrations in the ANC treated effluent were well below the AASWQIG of 0.1 mg/L.

A total of 143 taxa of benthic invertebrates has been identified from the 1989 to 1995 samples collected from the Athabasca River. Of these, 78 taxa were identified from the October 1995 samples, of which two were new taxa not collected previously.

The total number of taxa and number of EPT taxa were significantly higher at far-field sites than at near-field sites. The total standing crop of organisms, standing crop of EPT and standing crop of Chironomidae were significantly higher at downstream sites than at background sites, and were significantly higher at near-field sites than at far-field sites. Species diversity was similar between downstream sites and background sites, but was slightly lower at near-field sites than at far-field sites.

Chironomidae was the dominant major taxonomic group at all sites, followed by Ephemeroptera. Plecoptera, Trichoptera, Oligochaeta and the other (remaining) taxa were present in smaller numbers.

The ANC effluent discharge appeared to increase periphytic chlorophyll *a* in the river, particularly at near-field sites. The highest chlorophyll *a* value was found at Site 4, which also had the highest standing crop of benthic invertebrates. The relationship between the amount of chlorophyll *a* and the standing crop of organisms (i.e. the higher the chlorophyll *a*, the higher the standing crop) occurred at most sites, except at Sites 2 and 3.

The RA analysis indicated that there were four sample clusters. Cluster I consisted of Site 1, Cluster II of Sites 2, 3, 5 and 6, Cluster III of Site 4 and Cluster IV of Site 7.

A number of taxa have been found to respond to organic enrichment by increasing in numbers as a response to an increase in food availability, if oxygen is not limiting. The dominant taxa identified by RA, such as *Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., *Micropsectra* sp., *Baetis* sp. and *Ephemerella inermis*, have been found to respond to organic enrichment from either natural or anthropogenic sources.

All sites were dominated by detritivore/herbivores and detritivores, followed by carnivores, which is a common natural trait of most streams in North America. The trophic analysis indicated that there were some differences in feeding group structure between sites. Changes in the numbers of detritivore/herbivores, detritivores and carnivores caused shifts in the feeding group structure between sites.

The dominant benthic community structure of the background sites, especially Site 2, indicated the presence of some mild organic enrichment. The ANC effluent appeared to contribute additional organic enrichment to the river mainly at Sites 3 and 4 (as indicated by significant increases in standing crops compared to background sites), and there was a shift in the benthic community structure at Site 4. The slight increase in standing crop and the shift in the benthic community structure at Site 7 indicated that the Millar Western and Whitecourt sewage treatment effluents appeared to also contribute some mild organic enrichment to the river.

Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera, Trichoptera and Plecoptera), increased significantly in standing crop, particularly in the near-field, as a response to the organic enrichment. There was no decrease in the number of taxa at downstream sites, and in fact, there was an increase in the number of taxa at some downstream sites, indicating that only mild enrichment was occurring in the river as a result of organic loading from the ANC effluent. Shifts in the feeding group structure between sites occurred as a result of the change in the nature of the food supply caused by the mild organic enrichment. Mild organic enrichment, due to nutrient addition (phosphorus) from the ANC effluent, has apparently over the years caused an increase in the abundance of tolerant taxa, such as Chironomidae, but oxygen depletion has not been sufficient to cause a decrease in the more sensitive EPT taxa, which have also increased.

There was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the one pre-operational and six operational years and when far-field effects were compared between the pre-operational and operational years, except an increased number of Chironomidae at near-field sites during operational years. A comparison between the operational years of 1994 and 1995 indicated that there were no differences in the benthic community between the two years when the impact over all downstream sites and when far-field effects were compared between the two years.

1.0 INTRODUCTION

Alberta Newsprint Company (ANC) operates an integrated thermomechanical pulp (TMP), de-inked pulp (DIP) and paper mill near Whitecourt, Alberta. A benthic invertebrate monitoring program is included as part of the environmental program for the mill, as required under the Clean Water Act by Alberta Environmental Protection. Baseline benthic invertebrate monitoring programs were conducted during the spring and fall of 1989 and the spring of 1990 to establish pre-operational conditions in the Athabasca River (Luoma and Shelast 1990, 1991). The pulp and paper mill became operational in August 1990. Water is obtained from the Athabasca River for process use and following treatment, effluent is discharged to the Athabasca River at a rate of about 15,000 m^3/day. During the fall of 1990, the benthic monitoring program was conducted to establish start-up conditions (Luoma and Shelast 1991) and from 1991 to 1994, to establish operational conditions (Luoma and Shelast 1992, 1993, 1994, 1995). The monitoring of operational conditions was continued during the fall of 1995 and is documented in this report.

Benthic invertebrates are a useful monitoring tool since their community structure can reflect general water quality conditions over time. Benthic invertebrates are good indicators of disturbance primarily because of the long term stability of their populations and because they constitute an easily sampled community which is abundant and diverse enough to be responsive to both gross and subtle environmental changes (Hynes 1960, Gaufin 1973, Kovalak 1981). If the physical characteristics (substrate, water velocity and depth) of the sampling sites are standardized, then the water quality can be used to determine the potential causes for any changes in the benthic community structure.

The objective of the fall 1995 benthic invertebrate monitoring program was to assess the effects of the ANC pulp and paper mill effluent on the benthic invertebrate community and water quality of the Athabasca River, specifically:

- to determine if there were any differences in benthic invertebrate community structure between sampling sites in 1995,
- to evaluate the general water quality conditions of the Athabasca River as reflected by the benthic invertebrate community structure, and

- to determine if there were any differences between pre-operational and operational conditions in the Athabasca River.

All requirements of the federal Environmental Effects Monitoring (EEM) benthic invertebrate program (Environment Canada and Department of Fisheries and Oceans 1992) were incorporated into the annual monitoring program, including Quality Assurance and Quality Control (QA/QC) methods.

2.0 METHODOLOGY

2.1 SITE LOCATIONS

The study area consisted of approximately 36.5 km of the Athabasca River, extending 2.5 km upstream and 34 km downstream of the ANC effluent outfall. Seven sites, which were established in 1989 (Luoma and Shelast 1990) within the study area, were sampled for benthic invertebrates during the fall 1995 survey (Figure 1). Sites 1 and 2 were located on the north side of a mid-channel gravel bar, 2.5 and 1.2 km, respectively, upstream of the effluent outfall as background sites. Sites 3, 4 and 5 were located between the effluent outfall and the confluence of the McLeod River with the Athabasca River as potential impact sites. Sites 3 and 4 were located on the north bank of the river, 1.1 and 3.3 km, respectively, downstream of the effluent outfall and Site 5 on the south bank, 9.3 km downstream. Sites 6 and 7 were located on the south bank, 13.9 and 34 km, respectively, downstream of the effluent outfall, also as potential impact or recovery sites. These two sites were located downstream of the confluence of the McLeod River and the Millar Western Pulp Ltd. (Millar Western) effluent outfall, and Site 7 was also located downstream of the Whitecourt sewage treatment plant outfall.

The site positions were located in the field using a Magellan Field NAV™ GPS (Global Positioning System). The accuracy of the GPS unit was 15 m. However, this accuracy is subject to the United States Department of Defense 100 m Selective Availability policy. The site locations are provided in Table 1.

A plume delineation study was conducted during the low flow period in May 1993 (125 m^3/s) (Webb 1993). This study indicated that Sites 3 and 4 were exposed to a range of 0.1 to 0.2% effluent and less than 0.05% effluent by Site 5.

2.2 PHYSICAL AND CHEMICAL SAMPLING

Field sampling for physical and chemical parameters and for benthic invertebrates was conducted between 7 and 10 October 1995.

Many factors can regulate the occurrence and distribution of benthic invertebrates, including river flow conditions and physical habitat factors. River flow conditions were monitored prior to and during the field survey using the Environment Canada

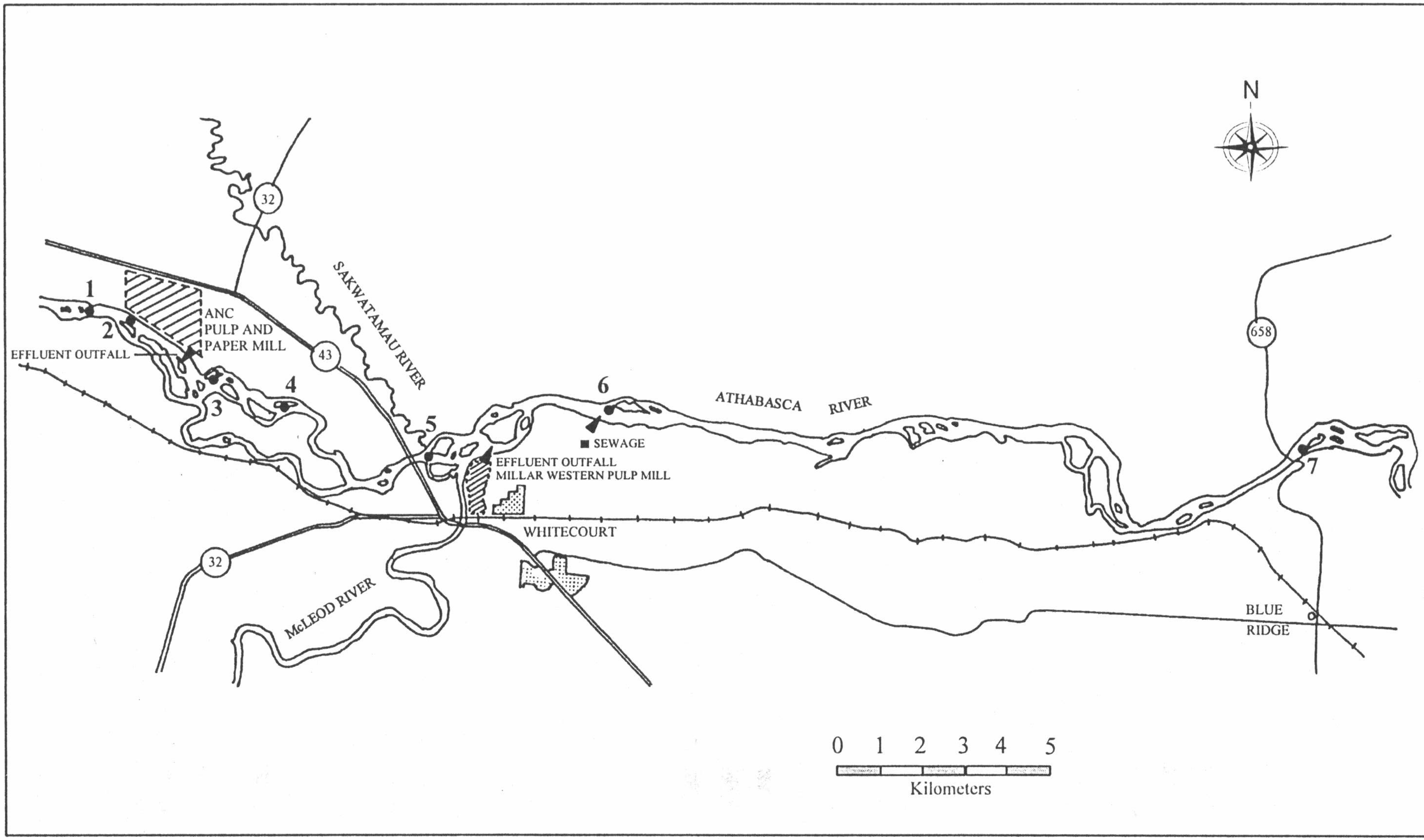

Figure 1. Benthic invertebrate sampling sites on the Athabasca River.

Table 1. Site locations on the Athabasca River for the benthic invertebrate survey.

Site	Area	Latitude	Longitude	Distance From Effluent Outfall
1	Background	54° 10.81′N	115° 50.73′W	2.5 km upstream
2	Background	54° 10.57′N	115° 49.24′W	1.2 km upstream
3	Downstream	54° 09.80′N	115° 48.13′W	1.1 km downstream
4	Downstream	54° 09.52′N	115° 46.49′W	3.3 km downstream
5	Downstream	54° 09.07′N	115° 43.13′W	9.3 km downstream
6	Downstream	54° 09.64′N	115° 39.68′W	13.9 km downstream
7	Downstream	54° 09.44′N	115° 23.40′W	34 km downstream

discharge station at Windfall (Station No. 07AE001) on the Athabasca River. The most important of the physical habitat factors are water velocity and substrate (Hynes 1972). All sampling sites were in run areas and were as similar as possible with regard to water velocity, water depth and substrate composition to reduce inter-site variability. The physical characteristics of each sampling location were documented so that any habitat differences could be taken into account when interpreting differences in benthic invertebrate distribution patterns and community structure between sites.

Substrates at each sample location were classified using a modification of the Wentworth classification system (Cummins 1962). All loose substrates contained within the benthic sampler were removed, put into size categories using standard Tyler geologic screens, and weighed with a portable spring scale. These size category weights were then converted into percentages of the total substrate weight. Water velocity was measured 2 cm from the bottom with a Price AA current meter and water depth with a metre stick at each sample location. Three measurements were taken within the sampler area, from which an average was calculated for each sample. All sites were photographed.

Water quality sampling, consisting of field measurements of pH using a pHep$^+$ Hanna Instruments pH meter ($\pm$ 0.1 unit), conductivity using a Myron L Model EP-10 conductivity meter ($\pm$ 10 µmhos/cm), dissolved oxygen using a YSI Model 54A dissolved oxygen meter ($\pm$ 0.2 ppm), and water temperature using a pocket thermometer ($\pm$ 0.5^{o}C) was conducted at each benthic site. Water samples were collected at each site taking grab samples about 20 cm below the water surface. All bottles used for water samples were received from the analytical laboratory. Bottles were rinsed three times with site water prior to filling and standard preservatives were added, where required. All samples were kept cool on ice, until delivered to the laboratory. Water samples were analyzed by Alpha Laboratory Services Ltd. of Edmonton for true color, total phosphorus, total Kjeldahl nitrogen (TKN), total suspended solids (TSS) and biochemical oxygen demand (5 day) (BOD_5) using standard methods (APHA-AWWA-WEF 1992) and approved Alberta Environment methods (Alberta Environment 1987). All BOD samples were shipped to the laboratory for analysis within 24 hours of sampling.

A more detailed water chemistry analysis was conducted for Site 2 (just upstream of the effluent outfall) and Site 3 (just downstream of the effluent outfall). Parameters analyzed at these sites included total phenols, total organic carbon, total metals, and resin and fatty acids. These parameters were analyzed using standard methods by Alpha Laboratories Services Ltd., except for resin and fatty acids which were analyzed by Enviro-Test Laboratories of Edmonton.

The periphytic algae (epilithic algae which are attached to rocks) were sampled for chlorophyll *a* at each benthic site. Epilithic chlorophyll *a* can be used as an indirect measure of algal biomass (Anderson 1989). Three replicate samples of randomly selected submerged rocks (cobbles or pebbles) from the river were delineated by a template and the area scraped clean using a scalpel. Each replicate consisted of a composite scraping with a 4 cm^2 template from two rocks, so that each replicate represented a total of 8 cm^2 area scraped. This provided a total of three 8 cm^2 area replicate samples for each site. Each replicate was filtered onto a Whatman GF/C filter with a porosity of 0.45 μm, wrapped in aluminum foil and then frozen on dry ice. These samples were analyzed by Chemex Labs Alberta Inc. of Calgary for chlorophyll *a* using the spectrophotometric method outlined in Standard Methods (APHA-AWWA-WEF 1992).

All samples were labelled with a site number, date of collection and project number and name. Chain-of-custody forms were provided with all samples delivered to the laboratory.

2.3 BENTHIC INVERTEBRATE SAMPLING

Benthic invertebrate samples were collected using a modified Neill-Hess cylinder sampler with a collecting net of 250 μm mesh and enclosing a surface area of 0.0892 m^2. During sampling, the sampler was forced into the substrate to a depth of 5 to 10 cm. Large substrates were removed and scraped into a bucket to ensure that attached organisms were collected. Smaller substrates were agitated in the sampler to dislodge all other organisms which were then carried by the stream current into the collecting bottle. Samples consisting of organisms and detritus from the collecting bottle and bucket were concentrated over a 180 μm mesh standard sieve, stored in jars and preserved in 10% formaldehyde for laboratory identification and enumeration. Five replicate samples were taken at each site to ensure that all representative benthic communities were assessed and to provide an acceptable level of confidence on the data (Needham and Usinger 1956, Wilhm and Dorris 1968, Alberta Environment

1990). All samples were labelled and chain-of-custody forms provided with all samples delivered to the taxonomist.

2.4 BENTHIC INVERTEBRATE SAMPLE ANALYSIS

The benthic samples were stained with rose bengal prior to sorting in the laboratory. Each benthic sample was sorted by a combination of a whole sort and a subsampling method. The whole sort/subsampling method was used because the samples contained a large amount of detritus/algae which consisted of a fairly homogeneous mixture and/or extremely large numbers of small benthic organisms which could not be feasibly counted.

The benthic sample was initially sieved into coarse (>1 mm) and fine (0.180 to 1 mm) fractions. Sample material in the coarse fraction was sorted using the whole sort method which consisted of systematically sorting through the sample under a dissecting microscope using a gridded petri dish to pick out all organisms. Sample material in the fine fraction was sorted using the subsampling method of Wrona et al. (1982). The fine material was placed into the subsampling apparatus (an Imhoff cone) with water added to provide a total volume of 1 L. This mixture was agitated for five minutes to ensure thorough mixing. Subsamples were removed from the agitated mixture and systematically sorted under a dissecting microscope using the gridded petri dish to pick out all organisms. The size and number of subsamples taken depended on the amount of fine material and/or numbers of organisms present in the sample. All sorted organisms in both coarse and fine fractions were identified and enumerated. The numbers of each taxon occurring in the total fine fraction were obtained by multiplying the respective counts by the volumetric proportion which the subsamples represented of the total fine fraction. These counts were then added to the counts obtained from the coarse fraction for each taxon.

A re-sorting of the sample residues was conducted on 10% of the samples by a different sorter to determine the level of sorting efficiency. The number of invertebrates initially recovered from the sample was expressed as a percentage of the total number after the re-sort (total of initial and re-sort count).

All organisms were identified using dissecting or compound microscopes. Identifications were to the lowest practical taxonomic level (genus where possible) using current literature and nomenclature by an experienced taxonomist. All taxa were identified using the following references, as appropriate: Edmunds et al. (1976) and Provonsha (1990) for Ephemeroptera; Wiggins (1977) for Trichoptera; Baumann et al. (1977), and Stewart and Stark (1988) for Plecoptera; Bode (1983), Epler (1987, 1992), Grodhaus (1987a, 1987b), Jackson (1977), Oliver and Roussel (1983), Oliver et al. (1990), Roback (1985), Walker et al. (1992) and Wiederholm (1983, 1986) for Diptera (Chironomidae); McAlpine et al. (1981) for other Diptera; Brooks and Kelton (1967), Clifford (1991), Edmondson (1959), Klemm (1985), Merritt and Cummins (1984), Pennak (1989), Thorp and Covich (1991), and Usinger (1956) as general references.

Microscope slide mounts were prepared for taxa which required detailed microscopic examination for identification. In particular, samples of chironomid larvae (midges) were mounted on microscope slides using CMCP-9 mounting medium and identified to genus by mouth parts. The commonest chironomid species were distinguishable on the basis of gross morphology, requiring only a few mounts (5 to 10) as checks, while mounts were made for all rare or less commonly occurring species.

All organisms were stored in vials with 70% isopropyl alcohol for archiving. The reference collection produced from previous surveys was updated with additional species from the fall 1995 samples.

2.5 DATA AND STATISTICAL ANALYSES

All new taxa identified from the 1995 samples were added to the species list. The basic computations of total number of taxa, number of Ephemeroptera, Plecoptera and Trichoptera (EPT) taxa, total number of organisms, total standing crop (number/m^2) and standing crop of each major taxonomic group (Ephemeroptera, Trichoptera, Plecoptera, Chironomidae, Oligochaeta and remaining groups) were calculated for each sample and means were calculated for each site. Confidence limits for all means were calculated at the 95% level.

Shannon-Weaver species diversity was also calculated for each sample, as were means and confidence limits for each site. Species diversity (Shannon and Weaver 1949), which reflects both the number of taxa and the evenness of distribution of the individuals among the taxa, was calculated as follows:

$$H' = -\sum_{i=1}^{s} p_i \ln p_i$$

where "s" is the number of species, "p_i" is the proportion of the total number of individuals consisting of the ith species, and "ln" is the natural logarithm. The use of a diversity index (a derived variable) to describe benthic community data was used for presentation purposes only, as suggested by Kovalak (1981).

Statistical analyses were conducted using analysis of variance (ANOVA) to determine whether the variables of total number of taxa, number of EPT taxa, total standing crop of organisms, standing crop of EPT and standing crop of Chironomidae were significantly different between sites. Generally in monitoring studies, only a few impact-related comparisons are of interest and planned comparisons can be determined by orthogonal contrasts (Sokal and Rohlf 1981, Hoke et al. 1990). *A priori* testing, using orthogonal contrasts, was conducted to determine differences between groups of sites (spatial contrasts). Sites were grouped into background (Sites 1 and 2), near-field (Sites 3, 4 and 5) and far-field (Sites 6 and 7). The variation among samples (replicates) was used to test for impacts, to provide a comparison to historical analyses. Spatial contrasts consisted of: (1) the difference between the average of downstream or impact sites (all five) and the average of the background sites, which tested for the average impact over all downstream sites, and (2) the difference between the average of the near-field sites and the average of the far-field sites, which tested for far-field effects (whether impacts extend to the far-field sites). The significance of all tests was determined at $p < 0.05$.

Benthic invertebrate data are generally not normally distributed and rarely satisfy the basic assumptions of parametric statistics. However, violations of these assumptions, especially normality, do not necessarily invalidate the statistical test, since tests such as ANOVA are extremely robust (Glass et al. 1972, Green 1979). Therefore, ANOVA will generally be valid, even on extremely non-normal populations, especially when there are equal and large sample sizes (Glass et al. 1972, Harris 1975), and if appropriate transformations are used (Green 1979). Transformations are used to normalize data or homogenize variances (Green 1979). The logarithmic transformation tends to be adequate, more comprehensible and more biologically meaningful than other transformations.

Environmental stress can affect entire groups of benthic invertebrates (major taxonomic groups). Somewhat arbitrarily, benthic invertebrates have been divided into two types: "tolerant taxa" such as Chironomidae and Oligochaeta, which can withstand relatively important changes in their habitat, and "intolerant taxa" such as

Ephemeroptera, Plecoptera and Trichoptera, which can withstand minor changes only (Anderson 1989). Although these two types of benthic invertebrates commonly cohabit, a marked deterioration or a marked improvement in water quality will usually result in the numerical dominance of one type over the other. In this study, the group of "intolerant taxa" (EPT group) and a "tolerant taxa" (Chironomidae group) were included as variables in the data analyses. Although, the individual taxa from the same major group tend to respond relatively uniformly, exceptions are not uncommon and the intensity of response can vary considerably among taxa (Anderson 1989). Therefore, an analysis of the community structure was also included to assess changes of dominant taxa between sites.

The benthic data were analyzed by reciprocal averaging (RA) ordination to determine the benthic community structure of sites. RA is a computer-assisted pattern recognition technique which ordinates (aligns) sites on species by the method of successive approximation across environmental gradients (Hill 1973, Gauch et al. 1977). The result of this analysis is to group samples into biological units (clusters) determined by faunal assemblages of highest similarity. The separation and/or clustering of benthic communities indicated by RA is generally along the most significant environmental gradients (Culp 1978, Crowther 1979, Culp and Davies 1980, Crowther and Luoma 1985).

A trophic guild analysis was used to determine the benthic community feeding group structure of sites. Each taxon was classified into a feeding group of either carnivore, detritivore, herbivore, detritivore/herbivore, herbivore/carnivore, carnivore/detritivore, or omnivore. This trophic classification depends on the dominant food consumed and/or feeding mechanisms of the species (Table 2) (modified from Merritt and Cummins 1984). The feeding group assigned to each taxon was determined from Merritt and Cummins (1984) for the insects and from the available literature (listed in Section 2.4) for all other organisms. The percent of each feeding group of the total number was calculated for each sample and means were calculated for each site. These differences were then compared to the separation of sites indicated by RA. The limited available literature and research to date does not allow the trophic guild analysis to be accurate at the species level or to take into account that organisms may change their feeding habits during their life history. The trophic guild analysis is intended only to provide a general indication of differences in feeding group structure between sites.

Table 2. Trophic classification of benthic invertebrates (modified from Merritt and Cummins 1984).

Functional Feeding Group	Dominant Food	Feeding Mechanism
Carnivore (C)	Living animal tissue	Engulfers - whole animals or parts Piercers - attack prey and pierce tissues and cells and suck fluids
Detritivore (D)	Decomposing fine particulate organic matter	Collectors - filterers or suspension feeders-gatherers or deposit (sediment) feeders (includes surface film feeders)
	Decomposing coarse particulate organic matter or vascular plant tissue	Shredders - chewers and wood borers
Herbivore (H)	Living vascular hydrophyte plant tissue	Shredders - chewers and miners
	Periphyton - attached algae and associated material	Scrapers - grazing scrapers of mineral and organic surfaces
	Living vascular hydrophyte cell and tissue fluids or filamentous (macroscopic) algal cell fluids	Piercers - pierce tissues or cells and suck fluids
Detritivore/Herbivore (DH)	See above	See above
Herbivore/Carnivore (HC)	See above	See above
Carnivore/Detritivore (CD)	See above	See above
Omnivore (O)	All types - whatever is available	Various types

A comparison was made between the pre-operational and operational fall data from 1989 to 1995 to assess the effects of the ANC pulp and paper mill effluent on the benthic invertebrates of the Athabasca River. Spatial differences were compared before and after the mill became operational. The data were statistically analyzed using a repeated measures design with the sites divided into areas (background, near-field and far-field) and the sites used as replicates within areas, re-sampled each year (EVS 1992, Green 1993). This analysis used the means as the mean response for the site and the among site variability to determine differences between areas. The variables analyzed were total number of taxa, number of EPT taxa, total number (or standing crop) of organisms, number (or standing crop) of EPT and number (or standing crop) of Chironomidae. Species diversity was not statistically analyzed, but was graphed to determine general trends between years.

The basic computations were conducted using developed Basic programs. Statistical analyses were conducted using either Statistix (Version 4.0) (Analytical Software 1992) or SYSTAT (Wilkinson 1990). The RA (Fortran) program was run on the University of Calgary AIX/Unix system.

2.6 QUALITY ASSURANCE AND QUALITY CONTROL

A Quality Assurance and Quality Control (QA/QC) program was implemented during this study and it followed, where appropriate, the one described for conducting EEM studies (Environment Canada and Department of Fisheries and Oceans 1993). Standard Operating Procedures (SOPs) were used for all field procedures (such as sample collection, sample shipping, sample storage, chain-of-custody forms), laboratory procedures (such as benthic sample sorting, subsample size, re-sorting, reference collection, and chemical QC, duplicate and spike checks) and reporting of data (including data entry checks). Documentation regarding QA/QC is provided in Appendix A.

3.0 RESULTS AND DISCUSSION

3.1 PHYSICAL CHARACTERISTICS

River flow conditions and the physical characteristics of sites can influence the water and habitat quality of the river and therefore, the benthic invertebrate community. Athabasca River flows recorded at Windfall (Station No. 07AE001) for the fall 1995 survey, as well as previous surveys from 1989 to 1994, are shown in Figure 2 (Environment Canada 1990, 1991a, unpublished data 1991, 1992, 1993, 1994, and preliminary unpublished data 1995). The fall 1995 survey was conducted during flows which were lower than the historical mean monthly flow for October. The mean daily discharge during the survey ranged from 123 to 133 m^3/s, while the mean monthly discharge for October 1995 was 125 m^3/s (Environment Canada preliminary unpublished data 1995). The historical (1960 to 1990) mean monthly discharge for October was 179 m^3/s (Environment Canada 1991b).

The mean daily discharge in the Athabasca River during September, prior to sampling, decreased from 298 to 271 m^3/s (water level decrease of 0.074 m) (Figure 3). Discharge then increased slightly for the next four days to 312 m^3/s (water level increase of 0.108 m) on 8 September due to local rainfall. This was followed by a decrease to 133 m^3/s (water level decrease of 0.585 m) on 7 October, at the start of the field survey (Environment Canada preliminary unpublished data 1995).

The physical characteristics of water velocity, water depth and substrate composition were kept as similar as field conditions allowed between sample locations within a site, as well as between sites (Appendix B). There was some variation in mean water velocity (difference of 18 cm/s) but very little in mean water depth (difference of 5 cm) between sites (Figure 4). Mean water velocity at the substrate surface between sites ranged from 38 to 56 cm/s and mean water depth ranged from 34 to 39 cm. Water velocity differences between sites resulted from hydraulic and minor habitat differences between reaches of the river.

Substrates at all sites consisted mainly of cobbles and pebbles, with a few gravels (Figure 5). Cobbles were the dominant substrate at Sites 2, 5, 6 and 7 and pebbles were dominant at Sites 1, 3 and 4. Cobbles comprised between 52.6 and 61.9% of the substrate at sites where they were dominant, while pebbles comprised between 35.1

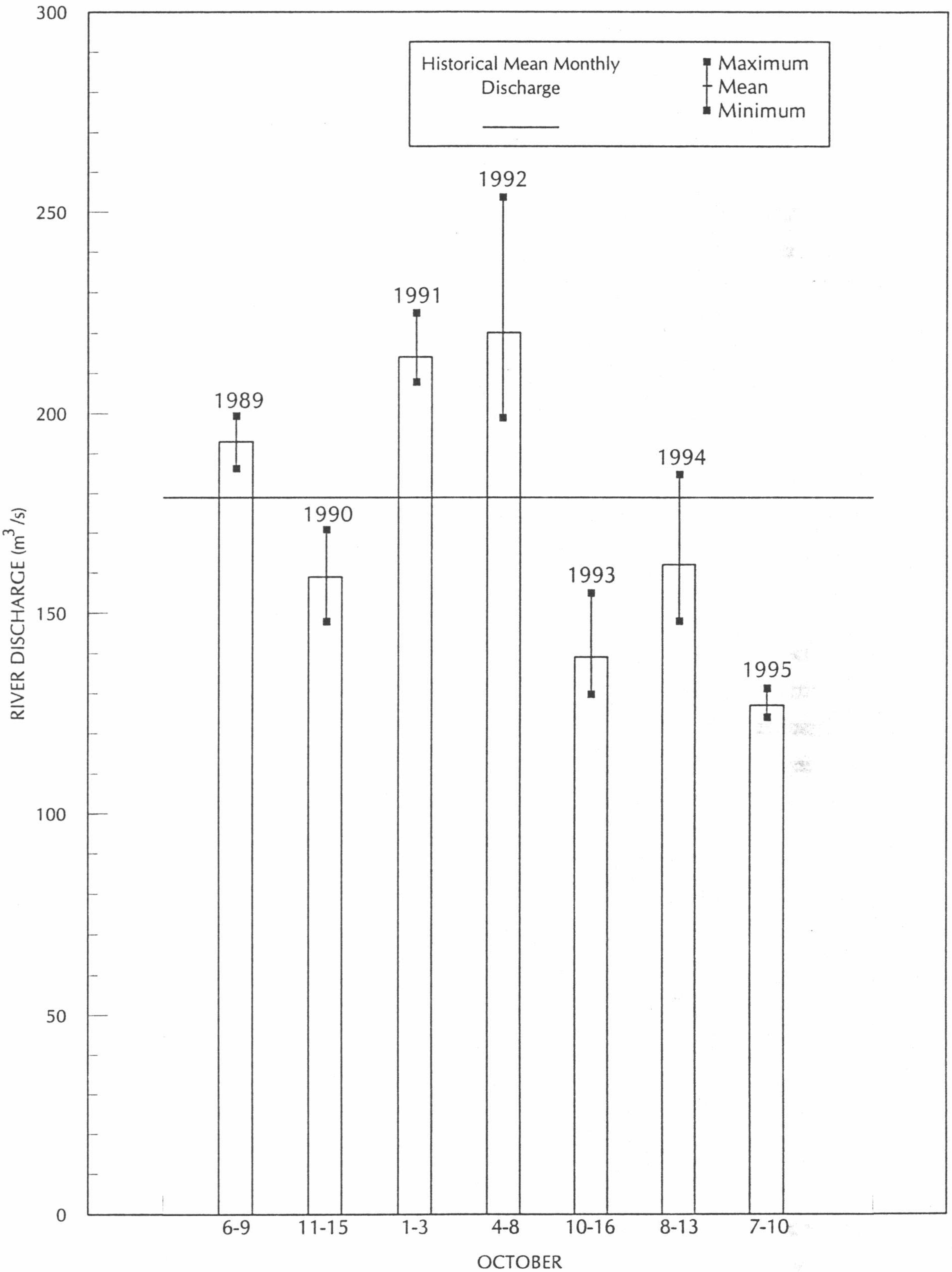

Figure 2. **Mean daily discharge during fall surveys and historical mean monthly discharge (October) of the Athabasca River at Windfall (Station No. 07AE001).**

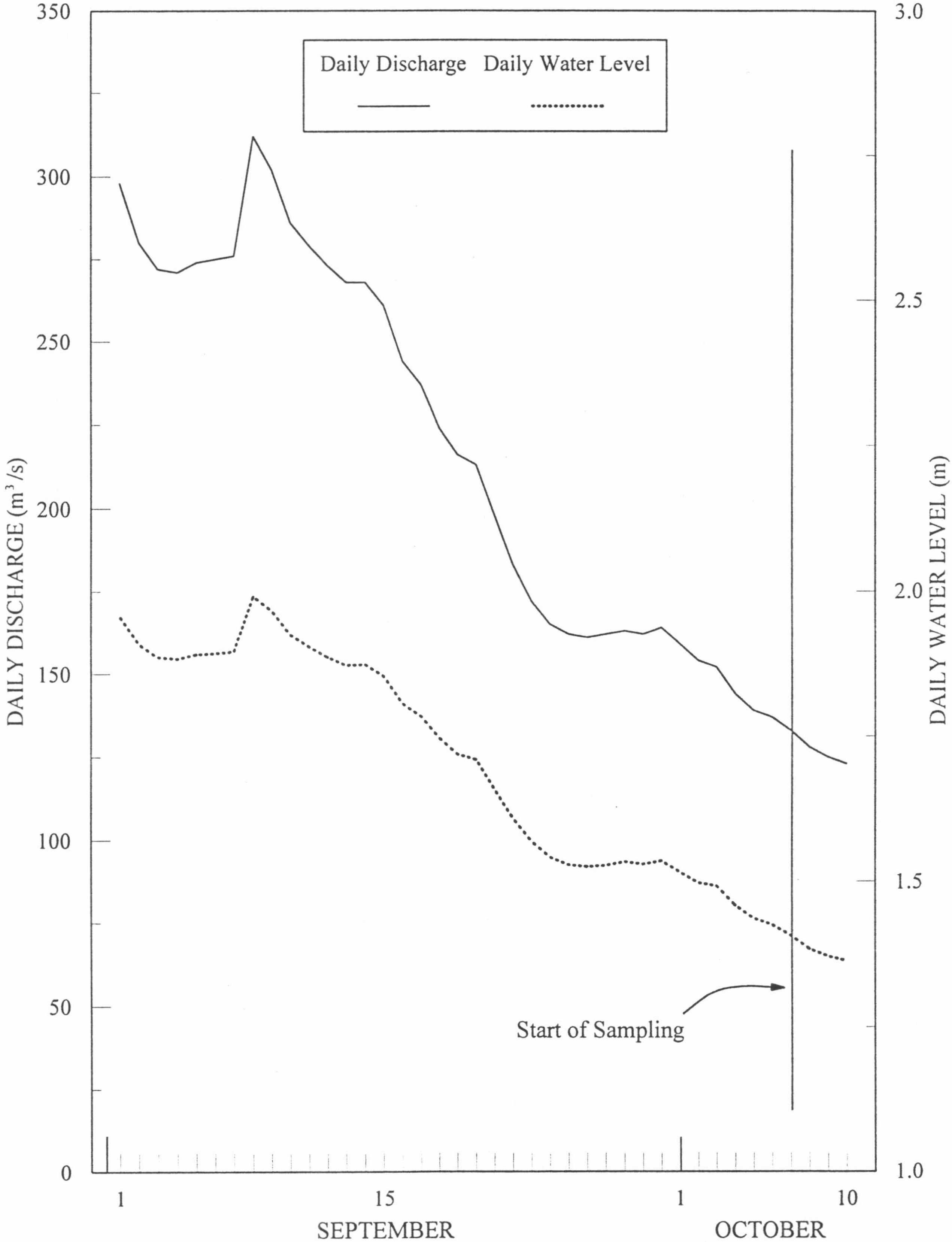

Figure 3. Daily discharge and daily water level prior to and during the fall 1995 benthic survey for the Athabasca River at Windfall (Station No. 07AE001).

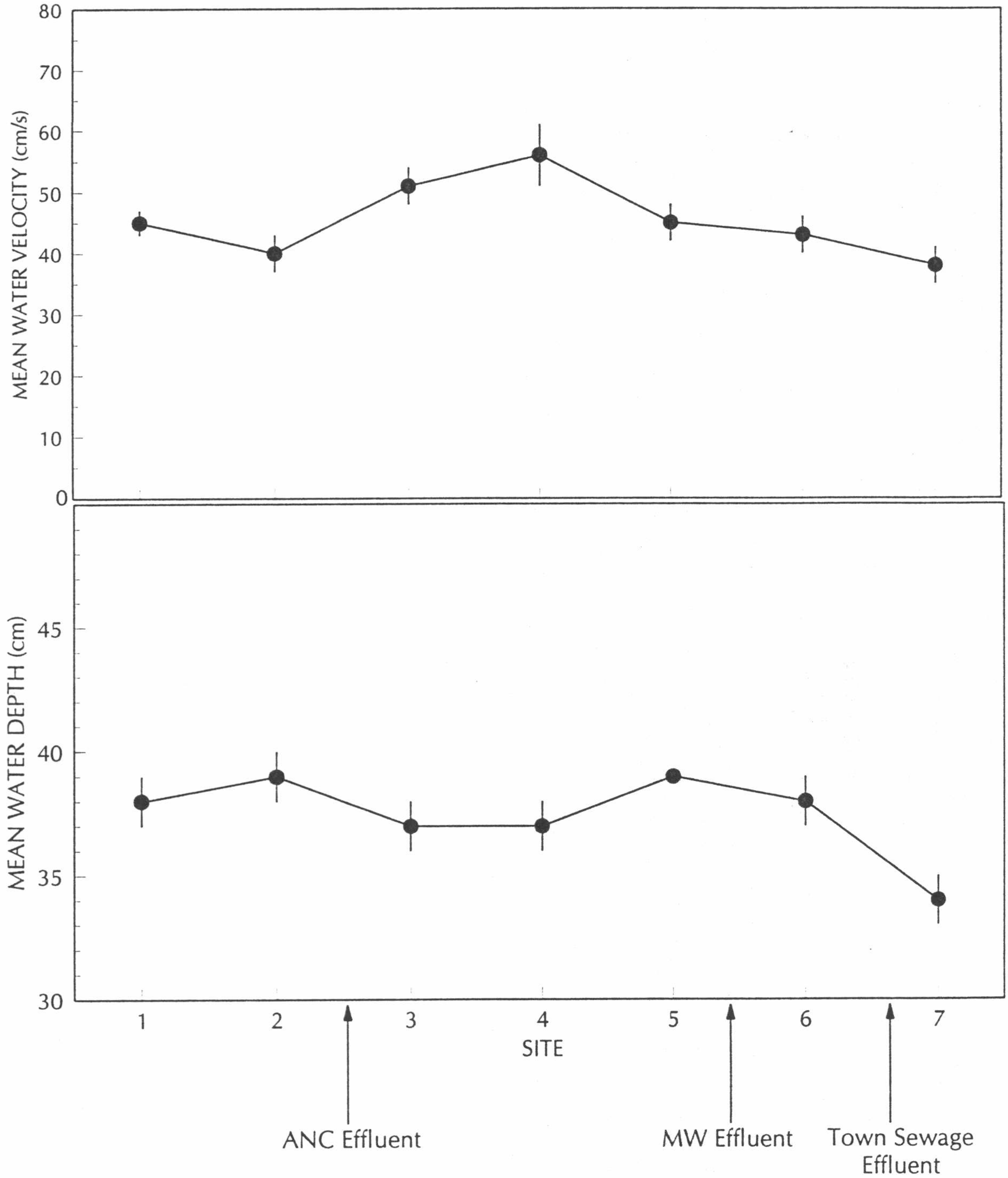

Figure 4. Mean water velocity and water depth with 95% confidence limits for sites on the Athabasca River, October 1995.

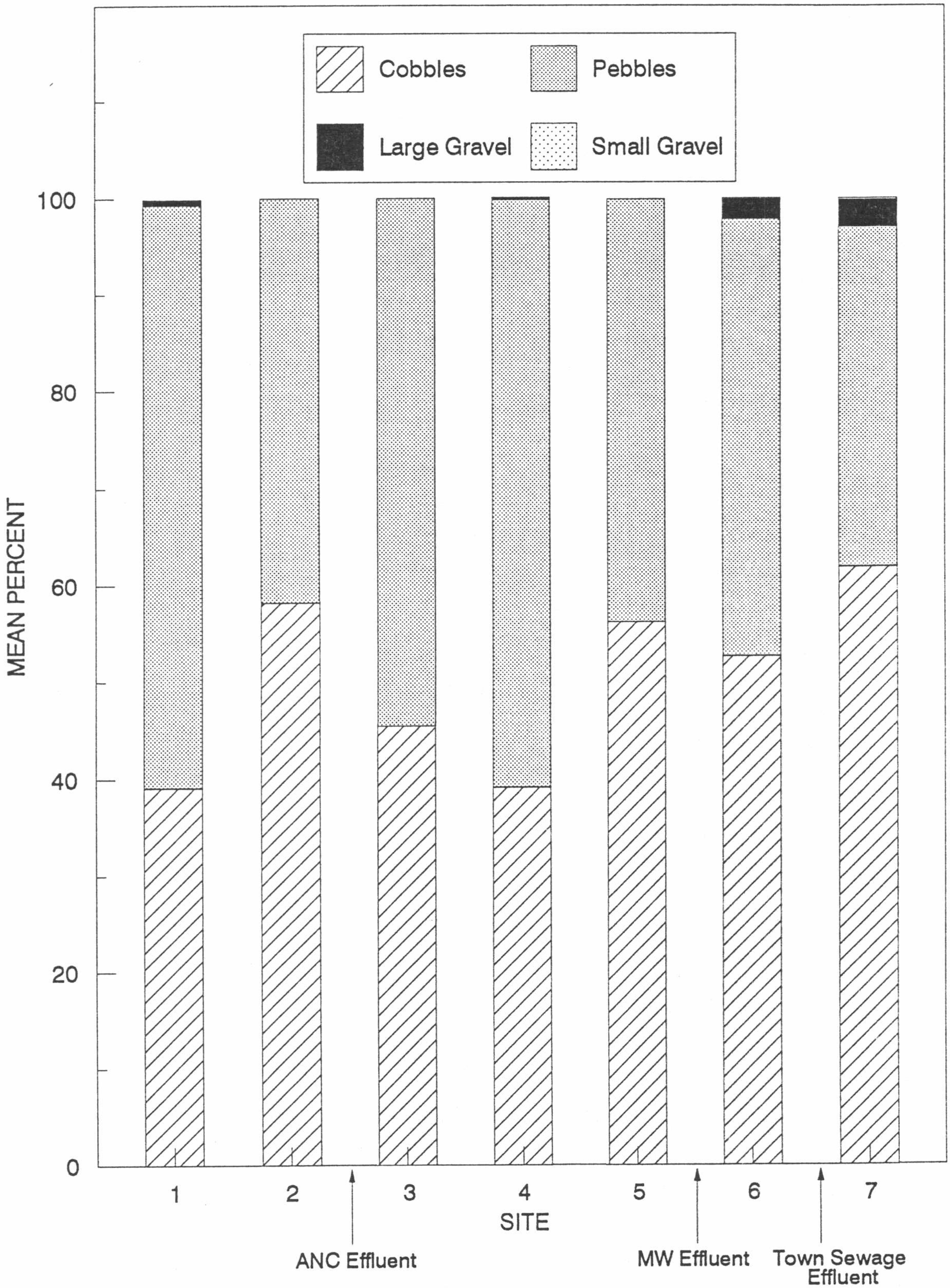

Figure 5. Mean percent of substrate size distribution (by weight) for sites on the Athabasca River, October 1995.

and 45.2%. Pebbles comprised between 54.6 and 60.7% of the substrate at sites where they were dominant, while cobbles comprised between 39.1 and 45.4%. Gravels comprised less than 3% of the substrate at Sites 1, 4, 5, 6 and 7, and sand less than 1% at Site 6.

Generally, these minor differences in physical characteristics of water velocity, water depth and substrate do not cause any detectable differences in benthic community structure between sites. Any habitat differences between sites were, however, considered in the interpretation of the benthic invertebrate results.

3.2 WATER QUALITY

The results of the fall 1995 field and laboratory water quality analyses for all sites on the Athabasca River are presented in Tables 3 and 4. These data were based on single grab samples taken at each site and provide a description of water quality only at the time of sampling. ANC final treated effluent quality data for the fall (August, September and October) of 1995 are shown in Table 5. Mean monthly treated effluent discharge to the river ranged from 14,394 to 16,529 m^3/d during the fall of 1995.

The pH recorded during the survey ranged from 8.2 to 8.5. The pH at both background and downstream sites were within both the Alberta Ambient Surface Water Quality Interim Guidelines (AASWQIG) of 6.5 to 8.5 and the Canadian Water Quality Guideline (CWQG) of 6.5 to 9.0 (Alberta Environmental Protection 1993, CCREM 1987). The mean monthly pH of the ANC treated effluent was 7.8 during the fall. The ANC effluent discharge did not affect pH at any downstream sites.

Conductivity at all sites ranged from 300 to 330 µmhos/cm, with the lowest and highest value occurring at the farthest sites downstream (Sites 6 and 7, respectively). The mean monthly conductivity for the ANC effluent ranged from 1,214 to 1,484 µmhos/cm during the fall. The ANC effluent discharge did not affect conductivity at any downstream sites.

Dissolved oxygen (DO) concentrations at all sites ranged from 11.6 to 12.0 ppm, which represented 102 to 105% saturation (Figure 6). Since the solubility of oxygen in water is temperature dependent and there were some water temperature differences between sites (5.0 to 7.0 °C) during field measurements, an appropriate comparison would be in saturation levels. DO at downstream sites were at or above background

Table 3. Water quality results of samples collected from the Athabasca River, October 1995.

Parameter	Site / Date 1 9/10	2 9/10	3 9/10*	4 8/10*	5 8/10*	6 7/10*	7 8/10	AASWQIG	CWQG
pH (units)**	8.5	8.5	8.5	8.5	8.5	8.5	8.2	6.5 - 8.5	6.5 - 9.0
Conductivity (µmhos/cm)**	320	320	320	320	320	300	330	-	-
Dissolved Oxygen (ppm)**	12.0	11.7	11.8	11.8	11.6	12.0	11.7	5.0	5.0 - 9.5***
DO (percent saturation)**	104	102	104	105	102	102	104	-	-
Temperature (^{o}C)**	6.0	6.0	6.5	7.0	6.5	5.0	7.0	Increase of 3^{o} C	-
Biochemical Oxygen Demand (5 day) (mg/L)	1.8	1.6	1.8	1.0	2.0	1.7	1.6	-	-
True Color (Pt-Co units)	5	5	7.5	7.5	10	7.5	10	Increase of 30 units	-
Total Suspended Solids (mg/L)	<1	< 1	< 1	8	11	1	< 1	Increase of 10 mg/L	Increase of 10 mg/L
Total Phosphorus (mg/L as P)	0.011	0.012	0.012	0.015	0.015	0.014	0.015	0.05	-
Total Kjeldahl Nitrogen (mg/L as N)	0.10	0.10	0.15	0.15	0.15	0.15	0.15	1.0	-

*	Field measurements taken on the date indicated, while water samples for laboratory analyses were taken on 10 October for Sites 3, 4 and 5, and on 9 October for Site 6.
**	Measured in the field.
***	Guideline varies depending on the category of biota and life stage.
Date	Day and Month
AASWQIG	Alberta Ambient Surface Water Quality Interim Guidelines (Alberta Environmental Protection 1993)
CWQG	Canadian Water Quality Guidelines for Freshwater Aquatic Life (CCREM 1987)
DO	Dissolved Oxygen
Pt-Co	Platinum-Cobalt

Table 4. Water quality results for selected parameters of samples collected at Sites 2 and 3 on the Athabasca River, October 1995. All values in mg/L unless otherwise stated.

Parameter	Site / Date Site 2 9/10	 Site 3 10/10	AASWQIG	CWQG
Total Phenols	<0.002	<0.002	0.005	0.001
Total Organic Carbon	4	4	-	-
Metals				
Total Arsenic	<0.0005	<0.0005	0.01	0.05
Total Cadmium	<0.002	<0.002	0.01	0.0018*
Total Chromium	<0.004	<0.004	0.05	0.002
Total Cobalt	<0.005	<0.005	-	-
Total Copper	<0.002	<0.002	0.02	0.006*
Total Iron	0.142	0.193	0.30	0.30
Total Lead	<0.002	<0.002	0.005	0.007*
Total Manganese	0.003	0.005	0.05	-
Total Mercury	<0.0001	<0.0001	0.0001	0.0001
Total Molybdenum	<0.009	<0.009	-	-
Total Nickel	<0.006	<0.006	-	0.15*
Total Selenium	<0.0005	<0.0005	0.01	0.001
Total Silver	<0.003	<0.003	0.05	0.0001
Total Vanadium	<0.005	<0.005	-	-
Resin Acids				
Abietic Acid	ND	ND	-	-
Dehydroabietic Acid	ND	ND	-	-
Isopimaric Acid	ND	ND	-	-
Levopimaric Acid	ND	ND		
Neoabietic Acid	ND	ND	-	-
Palustric Acid	ND	ND	-	-
Pimaric Acid	ND	ND	-	-
Sandaracopimaric Acid	ND	ND	-	-
12-Chlorodehydroabietic Acid	ND	ND	-	-
14-Chlorodehydroabietic Acid	ND	ND	-	-
12,14-Dichlorodehydroabietic Acid	ND	ND	-	-
Fatty Acids				
Arachidic Acid	ND	ND	-	-
Linoleic Acid**	ND	ND	-	-
Linolenic Acid	ND	ND	-	-
Myristic Acid	ND	ND	-	-
Oleic Acid**	ND	ND	-	-
Palmitic Acid	ND	ND	-	-
Stearic Acid	ND	ND	-	-
9,10-Dichlorostearic Acid	ND	ND	-	-
Total Resin and Fatty Acids	0	0	0.1	-

(continued)

Table 4. (concluded)

Parameter	Site / Date		AASWQIG	CWQG
	Site 2 9/10	Site 3 10/10		
Surrogate Recovery				
O-Methylpodocarpic Acid (%)	95 ± 10	95 ± 10	-	-
Tricosanoic Acid (%)	103 ± 6.2	103 ± 6.2	-	-

* At hardness > 180 mg/L ($CaCO_3$)
** Linoleic and oleic acid results were method blank and glassware proof corrected, but they are also constituents of the detergent used in cleaning laboratory glassware.
Date Day and Month
ND Not Detected. Detection limit was 0.001 mg/L for all target compounds.
AASWQG Alberta Ambient Surface Water Quality Interim Guidelines (Alberta Environmental Protection 1993)
CWQG Canadian Water Quality Guidelines for Freshwater Aquatic Life (CCREM 1987)

Table 5. Average monthly concentrations of selected parameters for ANC final treated effluent, fall (August - October) 1995.

Parameter*	August	September	October
Discharge (m^3/d)	15,247	14,394	16,529
pH (units)	7.8	7.8	7.8
Conductivity (µmhos/cm)	1,214	1,282	1,484
Temperature (°C)	28.9	28.0	27.5
Biochemical Oxygen Demand (5 day) (mg/L)	11	7	12
True Color (Pt-Co units)	292	254	307
Total Suspended Solids (mg/L)	25	20	27
Total Phosphorus (as P) (mg/L)	6.7	6.9	2.86
Total Kjeldahl Nitrogen (mg/L)	2.5	2.4	5.7
Total Phenols (mg/L)	0.020	0.019	0.015
Resin Acids (mg/L)			
Abietic Acid	ND	ND	ND
Dehydroabietic Acid	0.006	ND	ND
Isopimaric Acid	ND	ND	ND
Levopimaric Acid	0.007	ND	ND
Neoabietic Acid	ND	ND	ND
Palustric Acid	ND	ND	ND
Pimaric Acid	ND	ND	ND
Sandaracopimaric Acid	ND	ND	ND
Fatty Acids (mg/L)			
Arachidic Acid	ND	ND	ND
Linoleic Acid**	ND	ND	ND
Linolenic Acid	ND	ND	ND
Myristic Acid	ND	ND	ND
Oleic Acid**	0.009	ND	0.006
Palmitic Acid	0.023	ND	0.013
Stearic Acid	ND	ND	0.008
Total Resin and Fatty Acids	0.045	0	0.027

Source: Alberta Newsprint Company (unpublished data)

* All monthly averages were based on daily values, except for total phosphorus and total Kjeldahl nitrogen which were weekly values, and total phenols and total resin and fatty acids which were monthly values.

** Linoleic and oleic acid results were method blank and glassware proof corrected, but they are also constituents of the detergent used in cleaning laboratory glassware.

ND Not Detected. Detection limit was 0.001 mg/L.

Pt-Co Platinum-Cobalt

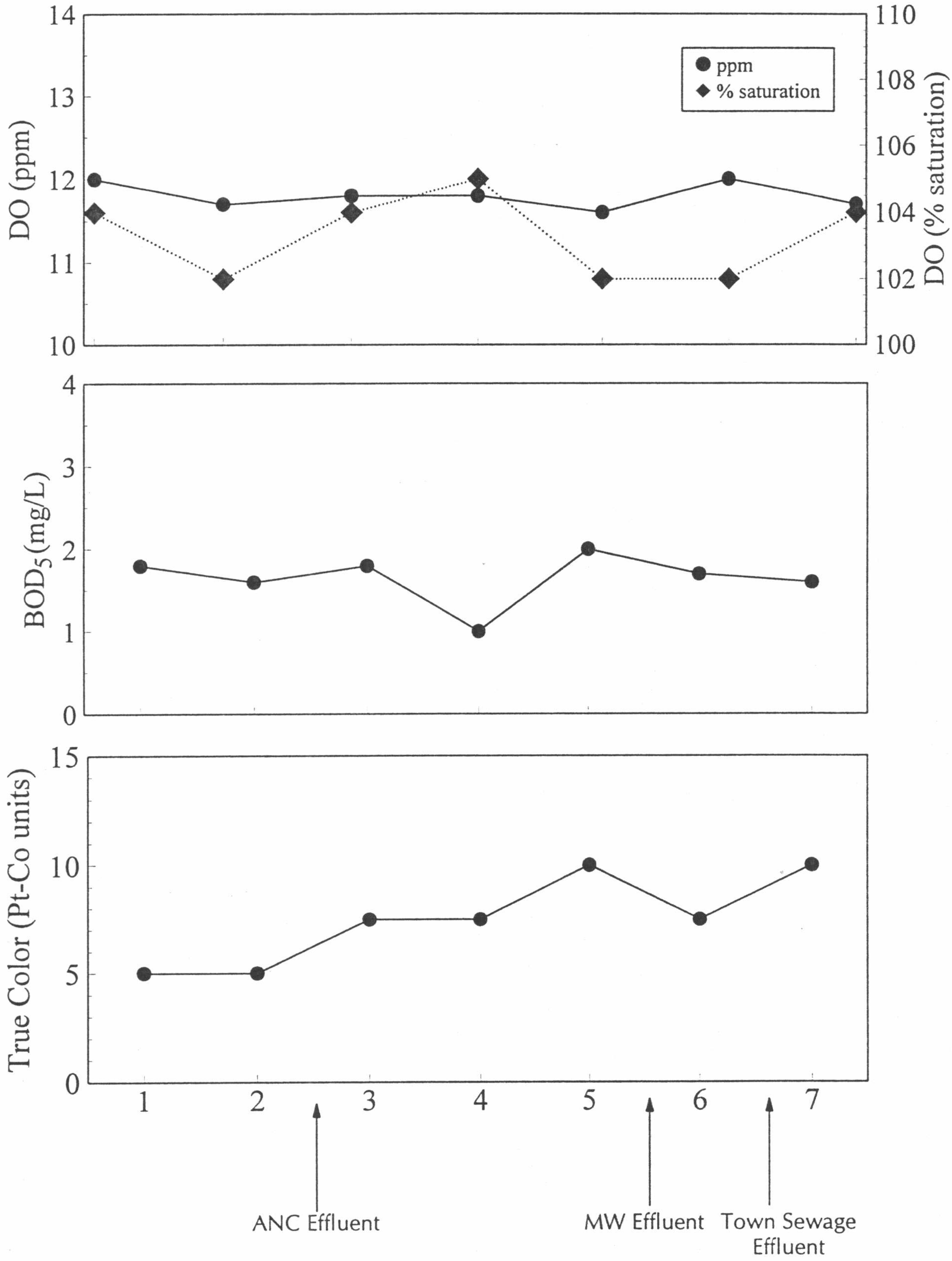

Figure 6. **Dissolved oxygen (DO) (ppm and % saturation), biological oxygen demand (BOD-5 day) and true color for sites on the Athabasca River, October 1995.**

levels indicating no effect from the ANC effluent. ANC is not required to monitor DO in its treated effluent.

Biochemical oxygen demand (BOD), a measure of the amount of oxygen required to oxidize organic matter in water, exhibited little variation between sites. BOD_5 in river samples ranged between 1.0 and 2.0 mg/L, with values at downstream sites similar to background sites (Figure 6). The mean monthly BOD_5 concentration in the ANC treated effluent ranged from 7 to 12 mg/L during the fall. Effluent discharge from ANC had no effect on BOD_5 concentrations in the river.

True color ranged between 5 and 10 Pt-Co units between sites, with slightly higher values at downstream sites (7.5 to 10 Pt-Co units) than at background sites (5 Pt-Co units) (Figure 6). The mean monthly true color value recorded for the ANC treated effluent ranged from 254 to 307 Pt-Co units during the fall. Effluent discharge from ANC appeared to have a slight effect on color values in the river. The Millar Western and Whitecourt sewage treatment plant effluents also likely had an effect on river color values.

Total suspended solids (TSS) ranged from <1 to 11 mg/L, with downstream Sites 4 and 5 having slightly elevated values compared to the background sites (Figure 7). Mean monthly TSS in the ANC treated effluent ranged from 20 to 27 mg/L during the fall. Effluent discharge from ANC appeared to have a slight effect on TSS values in the river. TSS concentrations were within both the AASWQIG and CWQG of an increase of 10 mg/L above background levels at all sites, except Site 5 which had an increase of 11 mg/L above the background level.

Phosphorus is generally regarded as the nutrient that limits productivity in freshwater ecosystems (Wetzel 1975). Total phosphorus (as phosphorus) at sites on the river ranged from 0.011 to 0.015 mg/L, with slightly higher values at downstream sites (0.012 to 0.015 mg/L) than at background sites (0.011 to 0.012 mg/L) (Figure 7). All concentrations were below the AASWQIG of 0.05 mg/L total phosphorus. Mean total phosphorus in the ANC treated effluent ranged from 2.86 to 6.9 mg/L. The slight increase in total phosphorus concentrations at downstream sites was likely due to inputs from the ANC, Millar Western and Whitecourt sewage treatment plant effluent discharges and may also have been due contributions from the McLeod River. The McLeod River is influenced by agricultural and municipal activity and/or the leaching of soils.

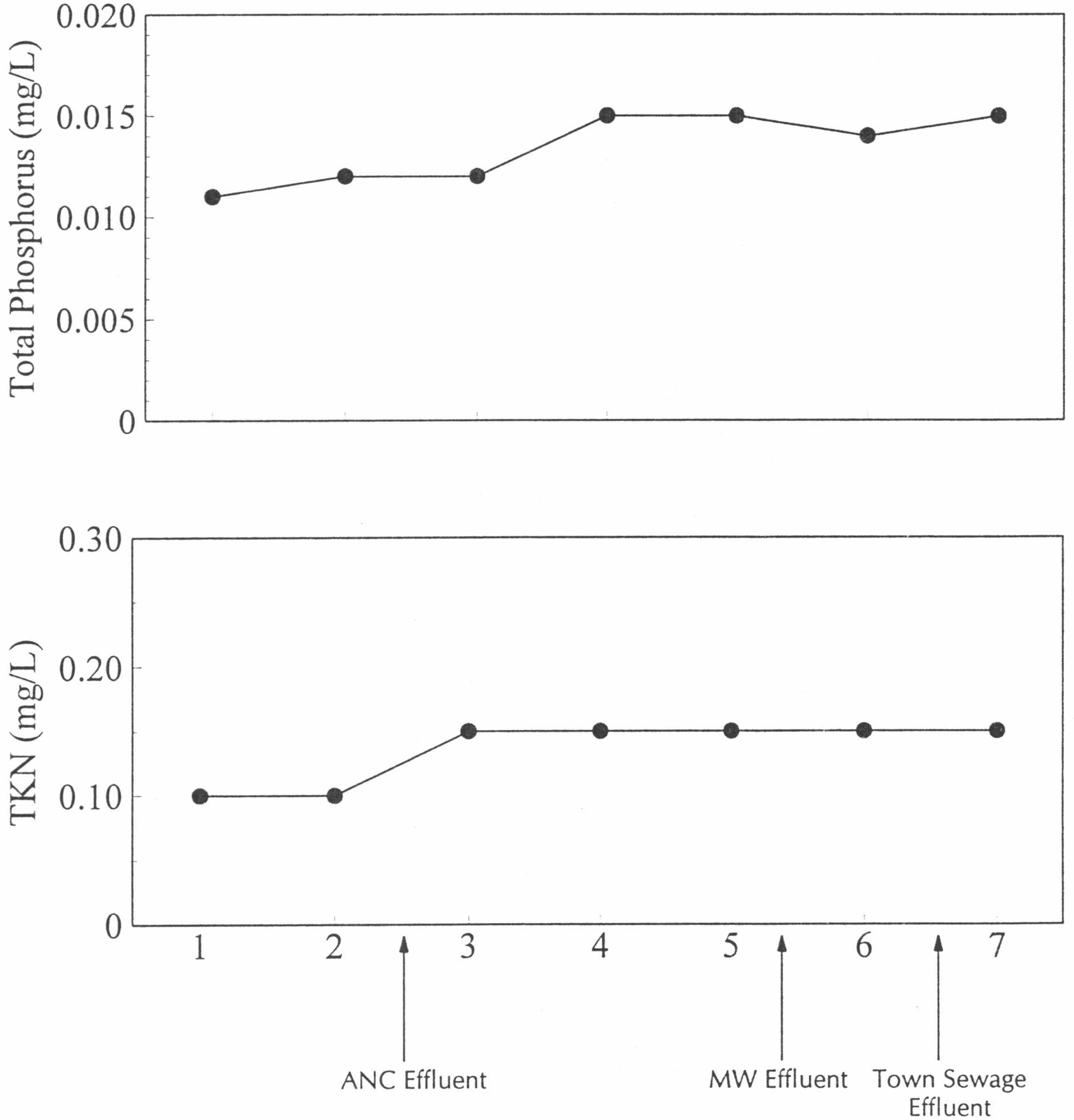

Figure 7. **Total phosphorus and total Kjeldahl nitrogen (TKN) for sites on the Athabasca River, October 1995.**

Total Kjeldahl nitrogen (TKN) (as nitrogen) at sites on the river ranged between 0.10 and 0.15 mg/L, with slightly higher values at downstream sites (0.15 mg/L) than at background sites (0.10 mg/L) (Figure 7). All concentrations were below the AASWQIG of 1.0 mg/L of TKN. Mean monthly TKN in the ANC treated effluent ranged from 2.4 to 5.7 mg/L. The slight increase in TKN concentrations at downstream sites was likely due to inputs from the ANC, Millar Western and Whitecourt sewage treatment plant effluent discharges and the McLeod River.

Total phenols were <0.002 mg/L at both background Site 2 and downstream Site 3. Total phenols in the ANC treated effluent ranged from 0.015 to 0.02 mg/L. The ANC effluent discharge did not affect total phenol concentrations in the river. Phenolic compounds can occur naturally in the aquatic environment as decomposition products of aquatic plants and decaying vegetation (CCREM 1987). Total phenols during the survey at both sites were below the AASWQIG of 0.005 mg/L and likely the CWQG of 0.001 mg/L.

Total organic carbon was 4 mg/L at both background Site 2 and downstream Site 3. No total organic carbon data is available for the ANC effluent.

Metals such as iron, manganese and copper exhibit a strong affinity to adsorb to suspended particulate matter. Metals are not generally considered to be a major component of pulp mill effluent. The concentrations recorded at both Sites 2 and 3 were below detection limits, except for iron and manganese during the fall survey. Iron and manganese concentrations at Site 3 (0.193 and 0.005 mg/L, respectively) were slightly above the concentrations recorded at Site 2 (0.142 and 0.003 mg/L, respectively). Metal concentrations were below both the AASWQIG and CWQG.

Neither resin or fatty acids were detected at Sites 2 and 3 during the fall survey. Dehydroabietic, abietic, pimaric, sandaracopimaric and neoabietic acids, commonly found in softwood pulp mill effluents (Taylor et al. 1988), were not detected in the river during the survey. Most resin and fatty acids concentrations in the ANC treated effluent during the fall were below the detection limit of 0.001 mg/L. Of the resins acids, dehydroabietic acid (0.006 mg/L) and levopimaric acid (0.007 mg/L) were found in the ANC treated effluent in August 1995. Of the fatty acids, oleic acid (0.009 mg/L) and palmitic acid (0.023 mg/L) were found in the ANC treated effluent in August 1995, and stearic acid (0.008 mg/L), oleic acid (0.006 mg/L) and palmitic acid (0.013 mg/L) in October 1995. Total resin and fatty acids concentrations were below the AASWQIG of 0.1 mg/L.

3.3 PERIPHYTIC ALGAE

Mean periphytic chlorophyll *a* on the substrates at sites ranged between <1.3 and 299.2 mg/m^2 during the fall survey (Figure 8) (Appendix C). The lowest values occurred at the background sites ranging between <1.3 and 28.8 mg/m^2 and at the first downstream site (Site 3) which had a value of 22.5 mg/m^2. The highest value of 299.2 mg/m^2 occurred at downstream Site 4 and all other downstream sites ranged between 62.9 and 106.3 mg/m^2. Chlorophyll *a* increased at downstream Site 4 when compared to background sites and then decreased at all other downstream sites (Sites 5, 6 and 7), but values remained above background levels. Larger variability between samples occurred at downstream Sites 4 and 5 (confidence limits of 351.4 and 137.3 mg/m^2, respectively) than at all other sites (confidence limits at sites ranged between 0 and 51.7 mg/m^2).

ANOVA indicated that there was a significant difference in mean chlorophyll *a* between sites ($p < 0.05$) during the fall survey (Appendix C). The orthogonal contrasts showed that mean chlorophyll *a* was significantly higher at all downstream sites than at background sites and it was also significantly higher at near-field sites than at far-field sites ($p < 0.05$).

3.4 BENTHIC INVERTEBRATES

3.4.1 Sorting and Taxonomy

The sorting of all benthic samples consisted of a combination of a whole sort and subsampling. The total subsample amount sorted from the 1 L volume of subsample varied between 100 and 500 mL (fractions of between X10 and X2, respectively) depending on the numbers of organisms present in the sample (Appendix D).

As part of the QA/QC program, the re-sorting of sample residues was conducted on four of the samples to determine the level of sorting efficiency. The sorting efficiency of the four samples ranged between 95.4 and 97.3%, with an overall average of 96.2% (Appendix D). This level of sorting efficiency meets the EEM requirements of $\geq$ 95% recovery of all organisms.

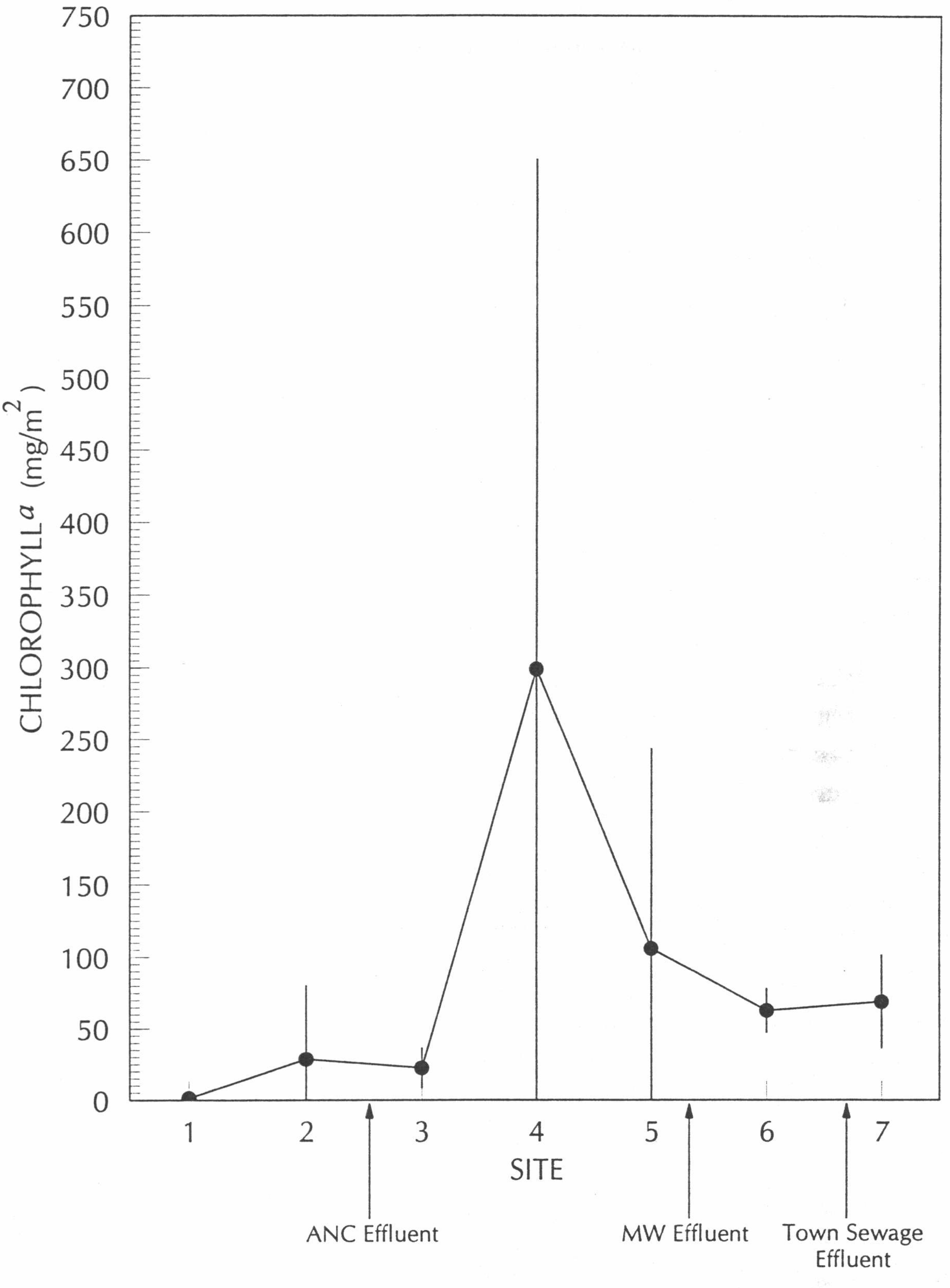

Figure 8. Mean chlorophyll *a* with 95% confidence limits for sites on the Athabasca River, October 1995.

The reference collection of identified benthic invertebrates produced from ANC's previous surveys was updated with additional species from the fall 1995 samples (Appendix D). As part of the EEM study, the benthic invertebrates in this reference collection were independently identified and confirmed by Dr. Gordon Pritchard of the University of Calgary, Calgary, Alberta (Luoma et al. 1996).

The raw benthic data showing taxa identified and the number of organisms per sample (in 0.0892 m^2) for all sites are presented in Appendix E These numbers were weighted for subsampled taxa by the appropriate factor. Summary tables of the basic computations for each sample are presented in Appendix F.

3.4.2 Basic Computations and Statistical Analyses

A total of 143 taxa of benthic invertebrates has been identified (most to the generic level) from the 1989 to 1995 samples collected from the Athabasca River (Table 6). Of these, 78 taxa were identified from the October 1995 samples The fauna consisted of mayfly nymphs (Ephemeroptera), caddisfly larvae (Trichoptera), stonefly nymphs (Plecoptera), fly larvae (Diptera - Athericidae, Ceratopogonidae, Empididae, Simuliidae and Tipulidae), midge larvae (Diptera - Chironomidae), beetles (Coleoptera - Elmidae), water boatmen (Hemiptera - Corixidae), water mites (Hydracarina), seed shrimps (Podocopa - Candonidae), aquatic earthworms (Oligochaeta), roundworms (Nematoda) and flatworms (Turbellaria). Of the taxa identified from the 1995 samples, two were new taxa not collected previously. The new taxa consisted of a Plecoptera (*Rhyacophila* sp.) and a Diptera of the Simuliidae family (*Ectemnia* sp.).

The variables of total standing crop of organisms, standing crop of EPT and standing crop of Chironomidae were log-transformed for statistical analyses. The total number of taxa and number of EPT taxa were not transformed. The ANOVA indicated that there were significant differences between sites for all five variables ($p < 0.05$) (Appendix F).

The mean total number of taxa at sites ranged between 32 and 41 taxa, with slightly higher values at Sites 4 and 7 (38 and 41 taxa, respectively) than at all other sites (32 to 35 taxa) (Figure 9). The mean number of EPT taxa ranged between 12 and 19 taxa, also with slightly higher values at Sites 4 and 7 (17 and 19 taxa, respectively) than at all other sites (12 to 16) (Figure 9). *A priori* testing, using orthogonal contrasts,

Table 6. **Benthic invertebrate species list with codes and functional feeding groups, 1989 - 1995. Abbreviations for functional feeding groups as in Table 2.**

Species Code	Taxa	Functional Feeding Group	Season*
	ARTHROPODA		
	INSECTA		
	Ephemeroptera (mayflies)		
	Ametropodidae		
001	*Ametropus neavei*	D	SF
	Baetidae		
002	*Baetis* spp.	DH	SFW
003	*Acentrella insignificans*[a]	DH	F
	Ephemerellidae		
096	*Drunella coloradensis*	H	S
004	*Drunella doddsi*	H	SF
114	*Drunella grandis ingens*	H	SF
005	*Ephemerella inermis*	DH	SFW
	Ephemeridae		
006	*Ephemera* sp.	D	SF
	Heptageniidae		
007	*Epeorus* sp.	DH	SF
008	*Heptagenia* sp.	DH	SFW
009	*Rhithrogena* sp.	DH	SFW
010	*Stenonema* sp.	DH	F
011	Heptageniidae (early instar)**	DH	S
	Leptophlebiidae		
129	*Leptophlebia* sp.	D	S
012	*Paraleptophlebia* sp.	DH	SFW
	Metretopodidae		
013	*Metretopus borealis*	C	S
	Siphlonuridae		
014	*Ameletus* sp.	DH	SFW
130	*Parameletus* sp.	DH	S
	Tricorythidae		
015	*Tricorythodes* sp.	D	SF
	Trichoptera (caddisflies)		
	Brachycentridae		
016	*Brachycentrus* sp.	O	SFW
	Glossosomatidae		
115	*Glossosoma* sp.	H	FW

(continued)

Table 6. (continued)

Species Code	Taxa	Functional Feeding Group	Season*
	Hydropsychidae		
017	*Arctopsyche* sp.	O	SFW
018	*Cheumatopsyche* sp.	O	SF
019	*Hydropsyche* spp.	O	SFW
	Hydroptilidae		
020	*Hydroptila* sp.	H	SFW
021	*Stactobiella* sp.	DH	SF
	Lepidostomatidae		
022	*Lepidostoma* sp.	D	FW
	Leptoceridae		
023	*Oecetis* sp.	HC	SFW
	Limnephilidae		
116	*Apatania* sp	DH	SFW
097	Limnephilidae (early instar)**	DH	F
	Polycentropodidae		
117	*Neureclipsis* sp.	O	F
	Psychomyiidae		
024	*Psychomyia* sp.	DH	SF
	Rhyacophilidae		
142	*Rhyacophila* sp.	C	F
	Plecoptera (stoneflies)		
025	Capniidae[b]	D	SFW
	Chloroperlidae		
	Chloroperlinae		
026	*Haploperla brevis*	HC	SFW
098	*Triznaka* sp.	C	S
099	Chloroperlinae (early instar)**	C	SF
	Nemouridae		
100	*Nemoura sp.*	D	SF
111	*Podmosta* sp.	D	S
027	*Zapada* sp.	D	SF
	Perlidae		
028	*Claassenia sabulosa*	C	SFW
101	*Hesperoperla pacifica*	C	F
139	Perlidae (early instar)**	C	W
	Perlodidae		
029	*Cultus* sp.	C	SFW
030	*Isogenoides* sp.	C	SFW
031	*Isoperla* sp.	C	SFW
132	*Skwala* sp.	C	F
032	Perlodidae (early instar)**	C	SF
	Pteronarcyidae		
033	*Pteronarcella badia*	DH	SF
034	*Pteronarcys dorsata*	DH	SF

(continued)

Table 6. (continued)

Species Code	Taxa	Functional Feeding Group	Season*
	Taeniopterygidae		
035	*Taenionema* sp.	H	SFW
137	*Taeniopteryx* sp.	D	F
	Diptera (flies, midges)		
	Athericidae		
036	*Atherix* sp.	C	SFW
	Blephariceridae		
118	*Bibiocephala grandis*	H	F
	Ceratopogonidae		
037	*Bezzia/Palpomyia gp.*[b]	C	SF
	Empididae		
038	*Chelifera* sp.	CD	SFW
039	*Hemerodromia* sp.	CD	SFW
119	*Wiedemannia* sp.	C	F
	Simuliidae		
143	*Ectemnia* sp.	O	F
040	*Simulium* sp.	O	SW
	Tanyderidae		
120	*Protanyderus* sp.	DH	F
	Tipulidae		
133	*Antocha* sp.	D	F
123	*Dicranota* sp.	C	F
041	*Hexatoma* sp.	C	SF
042	*Limnophila* sp.	C	SF
043	Eriopterini Tribe	D	SF
	Chironomidae		
	Chironominae		
	Chironomini Tribe		
124	*Chironomus* sp.	DH	F
044	*Cryptochironomus* sp.	C	SF
134	*Demicryptochironomus* sp.	D	F
045	*Microtendipes* sp.	D	SFW
046	*Paracladopelma/Cyphomella* spp.[c]	D	SFW
047	*Paralauterborniella nigrohalteralis*	D	SFW
112	*Paratendipes* sp.	D	S
125	*Phaenopsectra* sp.	DH	FW
048	*Polypedilum* spp.	DH	SFW
049	*Robackia demeijerei*	D	SFW
050	*Saetheria* sp.	D	S
126	*Stenochironomus* sp.	D	F
138	*Stictochironomus* sp.	DH	F
051	Chironomini (early instar)**	D	SF

(continued)

Table 6. (continued)

Species Code	Taxa	Functional Feeding Group	Season*
	Tanytarsini Tribe		
052	*Cladotanytarsus* sp.	D	SFW
053	*Constempellina* sp.	D	SF
054	*Micropsectra* sp.	D	SFW
140	*Paratanytarsus* sp.	D	W
055	*Rheotanytarsus* spp.	D	SFW
056	*Stempellinella* sp.	DH	SF
057	*Sublettea* sp.	D	SFW
058	*Tanytarsus* spp.	D	SFW
059	Tanytarsini (early instar)**	D	S
	Diamesinae		
	Diamesini Tribe		
102	*Diamesa* sp.	D	SFW
060	*Pagastia* sp.	D	F
061	*Potthastia gaedii* gp.	DH	SFW
127	*Potthastia longimana* gp.	DH	FW
135	*Pseudodiamesa* sp.	D	F
	Orthocladiinae		
103	*Brillia* sp.	D	SF
062	*Cardiocladius* sp.	C	FW
104	*Corynoneura* sp.	D	SFW
063	*Cricotopus/Orthocladius* spp.	DH	SFW
064	*Eukiefferiella* spp.	DH	SFW
105	*Heleniella* sp.	D	F
106	*Heterotrissocladius* sp.	D	SF
107	*Krenosmittia* sp.	D	SF
065	*Nanocladius* sp.	D	SFW
108	*Orthocladius (Symposiocladius) lignicola*	D	F
066	*Paracladius* sp.	D	F
067	*Parakiefferiella* spp.	D	SFW
068	*Parametriocnemus* sp.	D	SFW
109	*Psectrocladius* sp.	DH	SF
069	*Rheocricotopus* sp.	DH	SFW
070	*Synorthocladius* sp.	D	SFW
071	*Thienemanniella* sp.	D	SFW
072	*Tvetenia* spp.	D	SFW
073	Orthocladiinae (early instar)**	D	SF
	Prodiamesinae		
074	*Monodiamesa* sp.	D	SFW
	Tanypodinae		
	Macropelopiini Tribe		
113	*Procladius* sp.	C	S

(continued)

Table 6. (continued)

Species Code	Taxa	Functional Feeding Group	Season*
	Pentaneurini Tribe		
075	*Larsia* sp.	C	SF
131	*Monopelopia* sp.	C	S
076	*Nilotanypus* sp.	C	S
077	*Thienemannimyia* gp.	C	SFW
078	Tanypodinae (early instar)**	C	F
	Coleoptera (beetles)		
	Dytiscidae		
079	*Oreodytes* sp.	C	F
141	*Deronectes* sp.	C	W
	Elmidae		
080	*Optioservus* sp.	DH	SF
121	Collembola (springtails)	DH	SF
	Hemiptera		
	Corixidae (water boatmen)		
081	*Callicorixa audeni*	C	SF
122	*Hesperocorixa atopodonta*	C	F
082	*Sigara* spp.[f]	DH	F
	Odonata (dragonflies)		
	Gomphidae		
084	*Ophiogomphus* sp.	C	SF
	Megaloptera (alderflies)		
	Sialidae		
110	*Sialis* sp.	C	S
	ARACHNIDA		
085	Hydracarina (water mites)	C	SFW
	CRUSTACEA		
	Podocopa (seed shrimps)		
	Candonidae[d]		
086	*Candona* sp.	O	SFW

(continued)

Table 6. (continued)

Species Code	Taxa	Functional Feeding Group	Season*
	ANNELIDA		
	OLIGOCHAETA (aquatic earthworms)		
	Haplotaxida		
087	Enchytraeidae	D	SFW
088	Naididae	D	SFW
089	Tubificidae	D	SFW
	Lumbriculida		
090	Lumbriculidae	D	S
	HIRUDINEA (leeches)		
	Rhynchobdellida		
	Glossiphoniidae		
091	*Helobdella stagnalis*	C	SF
092	**NEMATODA** (roundworms)	D	SFW
	MOLLUSCA		
	GASTROPODA (snails)		
	Basommatophora		
	Ancylidae		
136	*Ferrissia* sp.	D	F
	Lymnaeidae		
093	*Stagnicola catascopium*[e]	O	SF
	Planorbidae		
128	*Gyraulus* sp.	DH	F
	PELECYPODA (clams)		
	Heterodonta		
	Sphaeriidae		
094	*Pisidium* sp.	O	S

(continued)

Table 6. (concluded)

Species Code	Taxa	Functional Feeding Group	Season*
	PLATYHELMINTHES		
	TURBELLARIA (flatworms)		
	Tricladida (planarians)		
	Planariidae		
095	*Polycelis coronata*	CD	F

* S - spring, F - fall, W - winter

** The organisms indicated as early instars were too small to identify to the genus level.

a *Pseudocloeon* sp. has recently been placed into the *Acentrella* sp., along with the *Baetis* (*Laponica*) group (McCafferty and Waltz 1990).

b Definitive separation within the Capniidae family and the *Bezzia/Palpomyia* gp. is difficult with the keys presently available.

c *Cyphomella* sp. was previously (1989) identified as *Paracladopelma* sp. Definitive separation between these two genera is difficult with the present keys.

d *Candona* sp. has recently been moved from the Cypridae to the Candonidae family.

e *Stagnicola catascopium* was previously (1989-1991) identified as *Lymnaea* sp.

f The two species, *Sigara decoratella* and *Sigara solensis*, were combined as *Sigara* spp., since not all specimens could be identified to the species level.

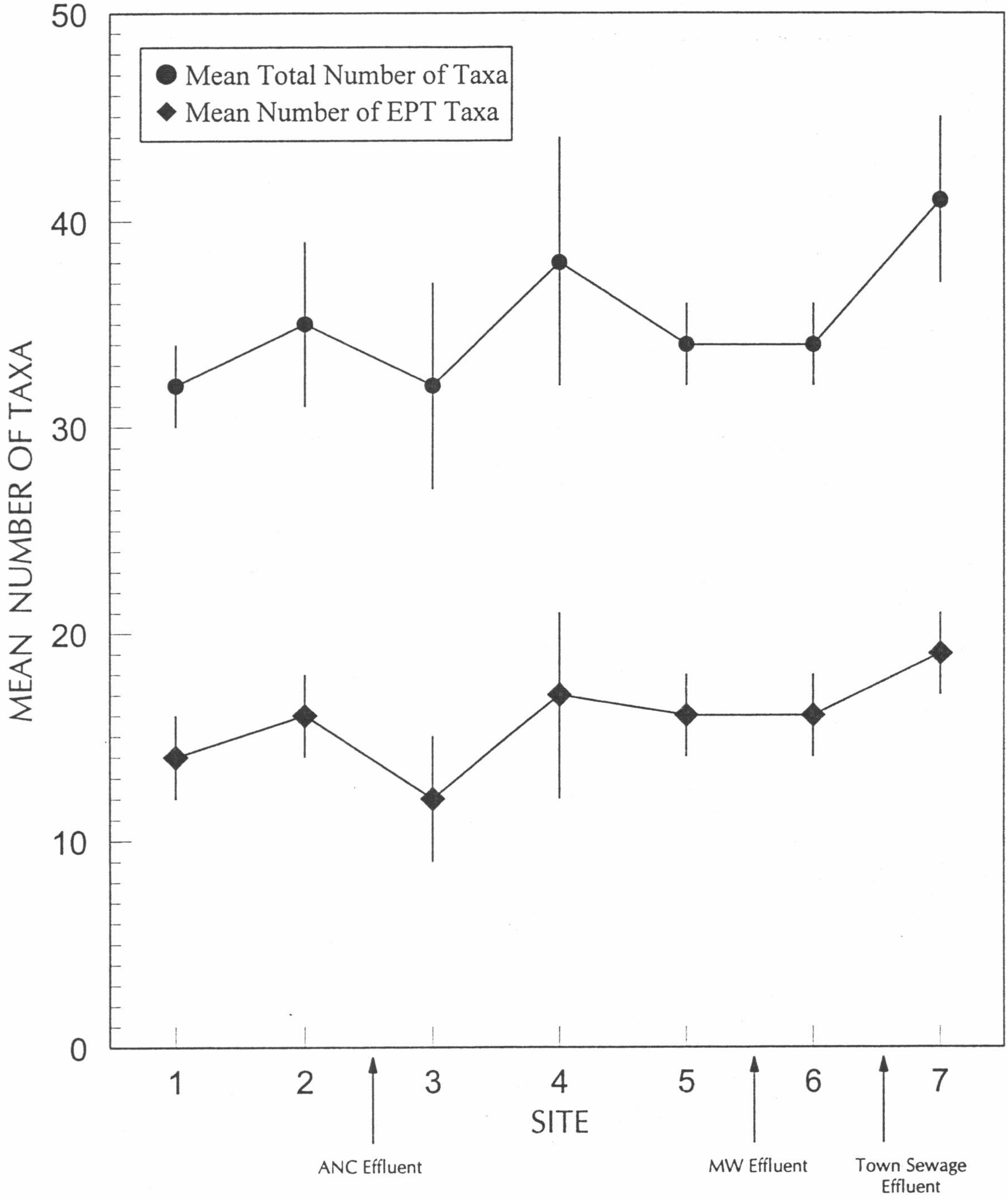

Figure 9. **Mean total number of taxa and mean number of EPT taxa with 95% confidence limits for sites on the Athabasca River, October 1995.**

showed that both the total number of taxa and the number of EPT taxa were not significantly different between downstream sites and background sites ($p > 0.05$). However, the total number of taxa and number of EPT taxa were significantly higher at far-field-sites than near-field sites ($p < 0.05$).

The mean total standing crop at sites ranged between 9,922 and 45,334 organisms/m^2 (Figure 10). The mean total standing crop at background sites varied between 9,922 organisms/m^2 at Site 1 and 33,457 organisms/m^2 at Site 2. At downstream Sites 3, 4, 5 and 7, the mean total standing crop was slightly higher (37,686 to 45,334 organisms/m^2) than at both background sites, but at Site 6 (31,202 organisms/m^2) it was similar to background Site 2. The orthogonal contrasts showed that the total standing crop was significantly higher at downstream sites than at background sites ($p < 0.05$) and it was also significantly higher at near-field sites than at far-field sites ($p < 0.05$).

The mean species diversity at sites ranged between 2.01 and 2.74 (Figure 11). The mean species diversity was the lowest at Site 3 (2.01) and the highest at Site 7 (2.74) than at all other sites (2.11 to 2.36). A low species diversity indicates that the majority of organisms present belong to only a few taxa and that other fauna are low in numbers, thus causing an uneven distribution.

The mean species diversity at all downstream sites (mean 2.27) was similar to background sites (mean 2.28). The mean species diversity at near-field sites (mean 2.16) was slightly lower than at far-field sites (mean 2.43).

Chironomidae (midges) was the dominant major taxonomic group at all sites, followed by Ephemeroptera (mayflies) (Figure 12). The other taxa (fly larvae, beetles, water boatmen, water mites, seed shrimps, roundworms and flatworms), Plecoptera (stoneflies), Trichoptera (caddisflies) and Oligochaeta (aquatic worms) were also present but in smaller numbers. The mean standing crops of all the major taxonomic groups were higher at background Site 2 than at background Site 1. The mean standing crops of the major taxonomic groups were generally higher at downstream sites, mainly Sites 4, 5 and 7, than at background sites.

The mean standing crop of EPT at sites ranged between 2,886 and 12,890 organisms/m^2 (Figure 13). The mean standing crop of EPT was higher at all downstream sites (7,464 to 12,890 organisms/m^2) than at background sites (2,886 to

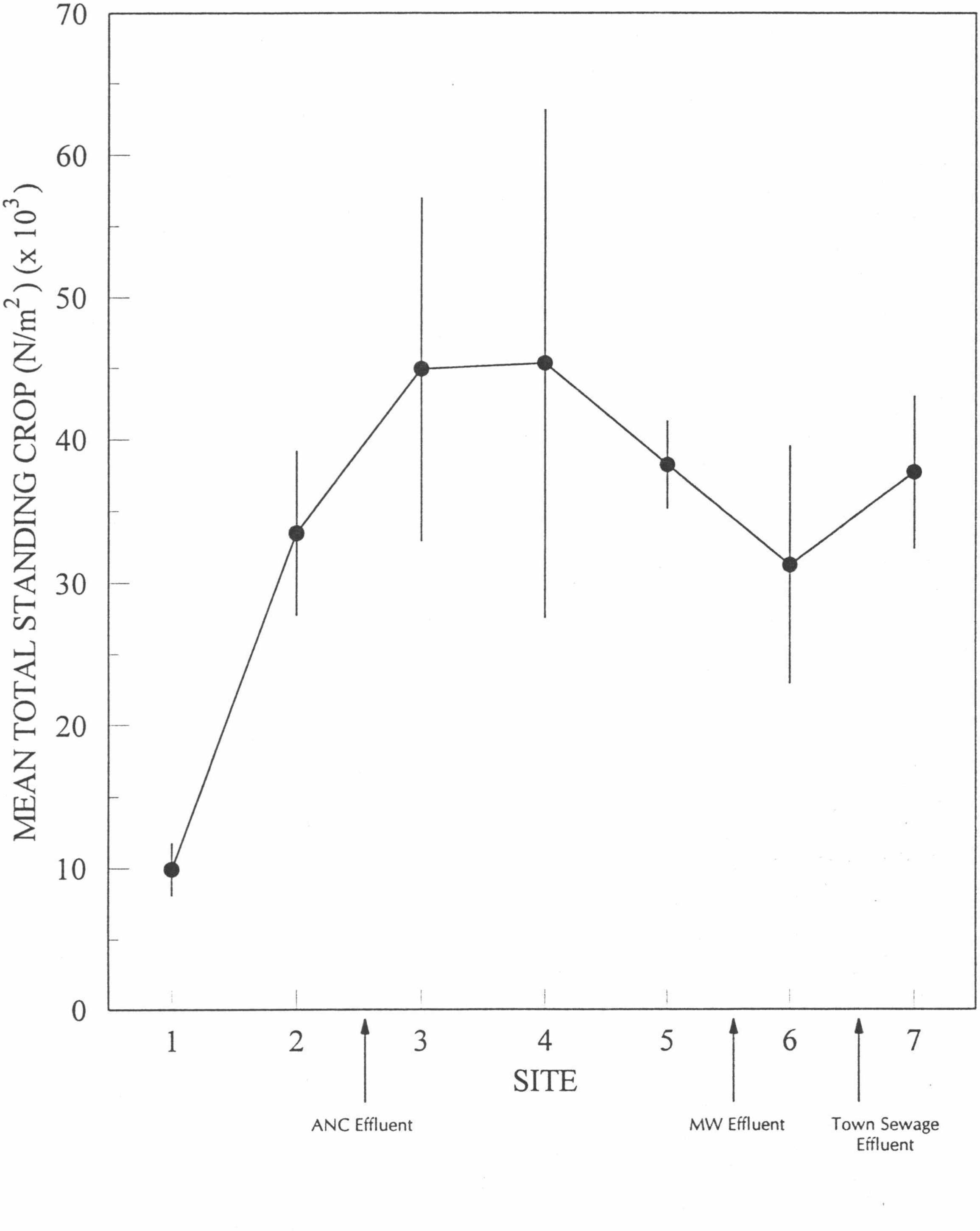

Figure 10. Mean total standing crop (number/m^2) with 95% confidence limits for sites on the Athabasca River, October 1995.

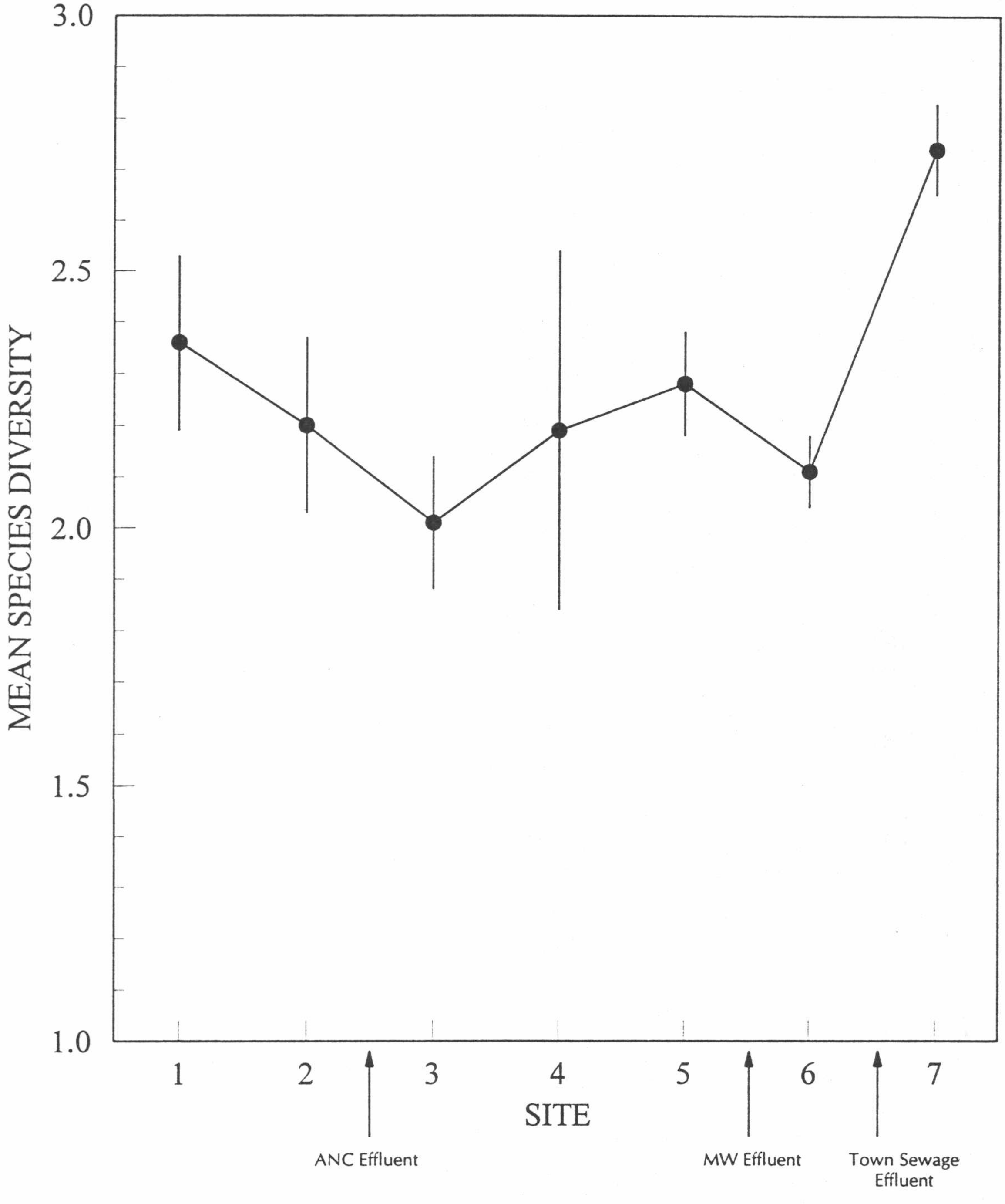

Figure 11. Mean Shannon-Weaver species diversity with 95% confidence limits for sites on the Athabasca River, October 1995.

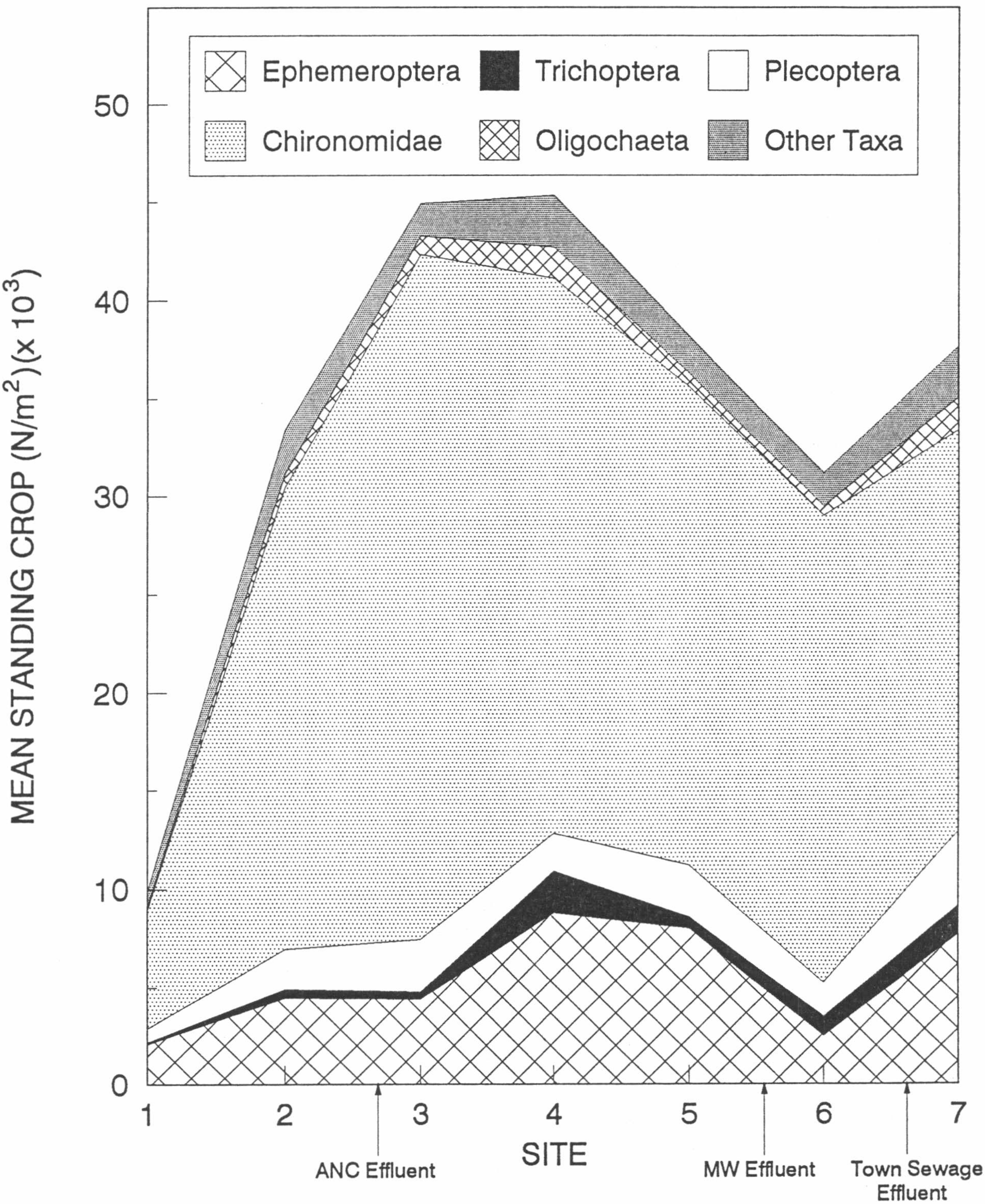

Figure 12. Mean cumulative standing crop (number/m^2) of the major taxonomic groups for sites on the Athabasca River, October 1995.

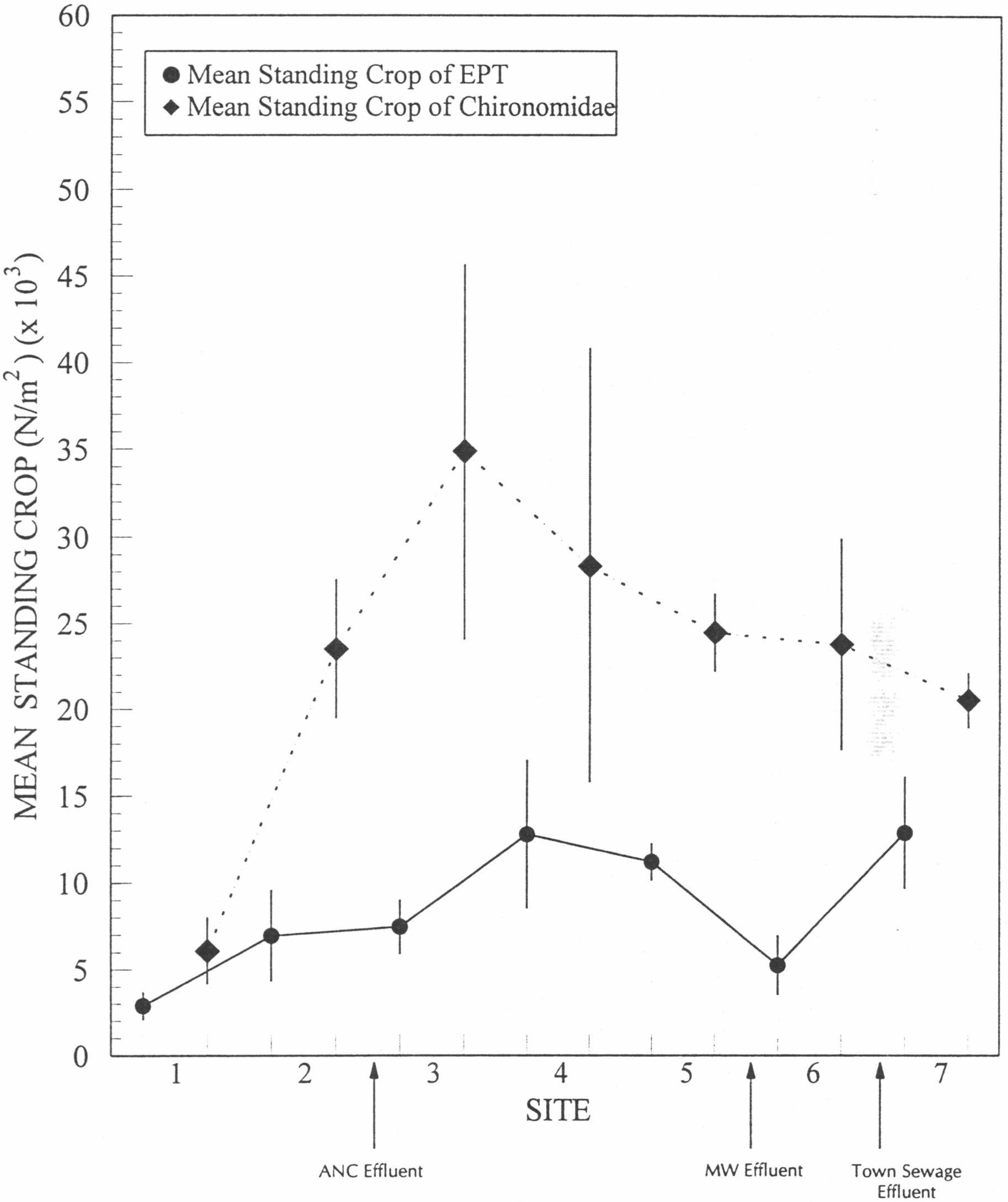

Figure 13. Mean standing crop (number/m^2) of EPT and Chironomidae with 95% confidence limits for sites on the Athabasca River, October 1995.

6,960 organisms/m^2), except at Site 6 (5,249 organisms/m^2) where it was similar. The orthogonal contrasts showed that the standing crop of EPT was significantly higher at downstream sites than at background sites and was also significantly higher at near-field sites than at far-field sites ($p < 0.05$).

The mean standing crop of Chironomidae at sites ranged between 6,079 and 34,857 organisms/m^2 (Figure 13). The mean standing crop of Chironomidae was higher at Sites 3, 4 and 5 (24,442 to 34,857 organisms/m^2) than at background sites (6,079 to 23,502 organisms/m^2), while at Sites 6 and 7 (20,511 to 23,758 organisms/m^2) it was similar to background Site 2. The orthogonal contrasts showed that the standing crop of Chironomidae was significantly higher at downstream sites than at background sites and was also significantly higher at near-field sites than at far-field sites ($p < 0.05$).

3.4.3 Community Analysis

The RA analysis identifies groups of sites with similar benthic invertebrate community structures and provides information on the ecological similarities between sampling sites. The result of the RA analysis is shown as a species dominance distribution matrix for each sample site (Appendix G). This result was plotted as a two-axis (X and Y) ordination for site scores on a scale of 0 to 100 (ordination units) on each axis.

The site ordination indicated four sample clusters (Figure 14). Cluster I consisted of samples from Site 1, Cluster II of samples from Sites 2, 3, 5 and 6, Cluster III of samples from Site 4 and Cluster IV of samples from Site 7. A cluster of samples represents those which have similar benthic community assemblages. The degree of faunal homogeneity between samples within a cluster is represented by the closeness of the samples within the cluster.

The dominant benthic community assemblage characteristic of each cluster, in order of numerical dominance, was a follows:

Cluster I: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., *Baetis* sp., *Ephemerella inermis*, Hydracarina

Cluster II: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., *Baetis* sp., *Micropsectra* sp., *Ephemerella inermis*

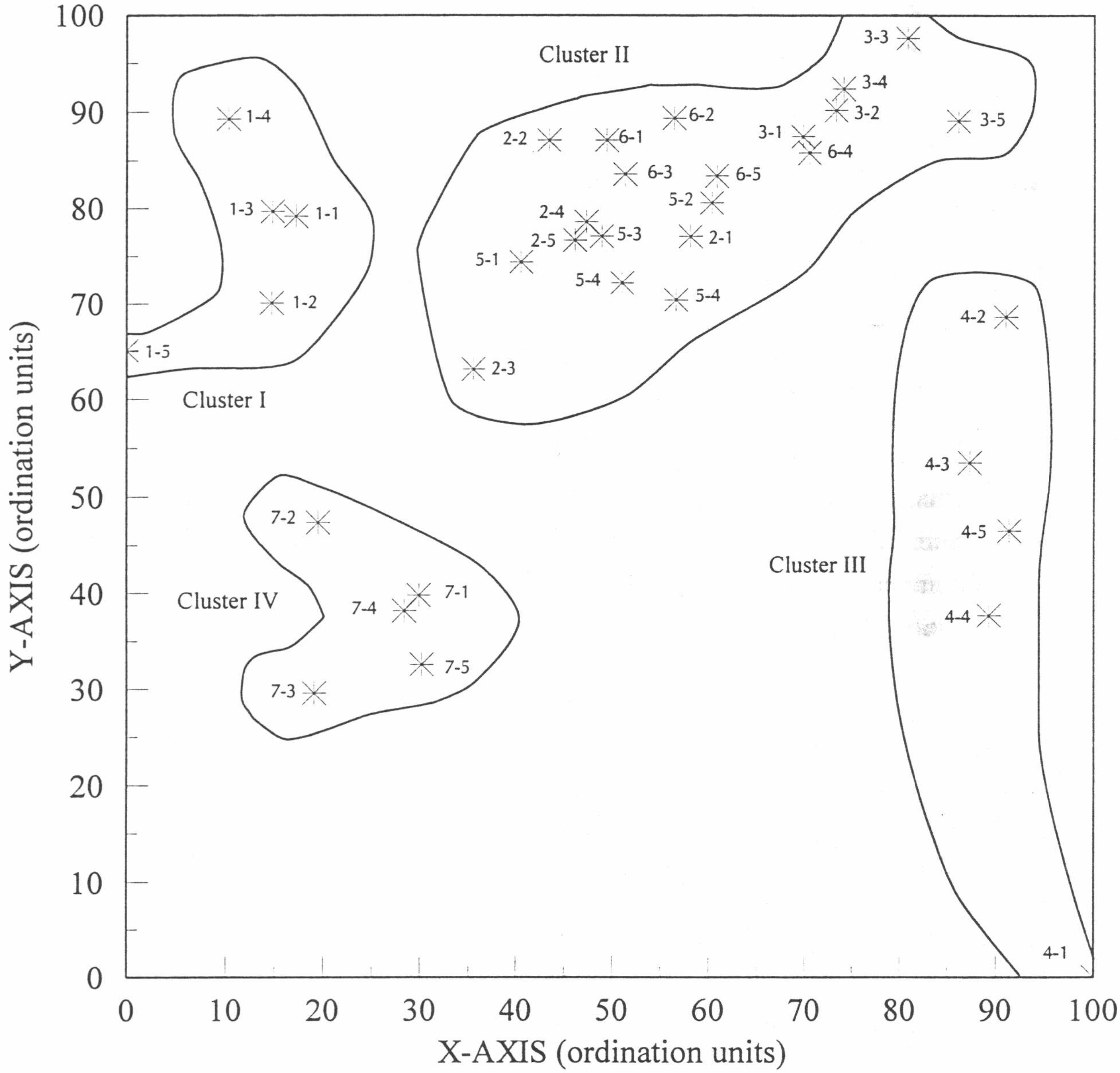

Figure 14. Reciprocal averaging ordination of site scores for sites on the Athabasca River, October 1995.

Cluster III: *Cricotopus/Orthocladius* spp., *Baetis* sp., *Micropsectra* sp., *Ephemerella inermis*

Cluster IV: *Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., *Micropsectra* sp., *Ephemerella inermis*, *Baetis* sp., Hydracarina

The mean standing crops (number/m^2) of the dominant taxa identified by RA for each site are shown in Figure 15 All sites were dominated by the chironomid, *Cricotopus/Orthocladius* spp. (an Orthocladiinae). A gradient appeared to exist between sites during the fall survey as indicated by the numbers of Cri*cotopus/Orthocladius* spp. (Appendix G). This chironomid increased in numbers in samples across the X-axis from left to right (i.e., increased in numbers from samples in Cluster I (Site 1) and Cluster IV (Site 7) to Cluster II (Sites 2, 3, 5 and 6) to Cluster III (Site 4)).

The separation of Cluster I from Cluster II indicated that there were some differences in the benthic community structure of background Site 1 (Cluster I) from background Site 2 (Cluster II). Downstream Sites 3, 5 and 6 had a similar benthic community structure to background Site 2 (Cluster II). Site 1 was dominated by two chironomids (*Cricotopus/Orthocladius* spp. and a Chironominae, *Rheotanytarsus* sp. of the Tanytarsini Tribe), two mayflies (*Baetis* sp. and *Ephemerella inermis*) and water mites (Hydracarina). Sites 2, 3, 5 and 6 were dominated by the same dominant taxa as Site 1, except that the dominance of water mites was replaced with the dominance of another chironomid (a Chironominae, *Micropsectra* sp. of the Tanytarsini Tribe).

The benthic community structure of downstream Site 4 (Cluster III) and downstream Site 7 (Cluster IV) differed from all other sites. Site 4 was dominated by four of the five taxa dominant at Sites 2, 3, 5 and 6 (Cluster II). The dominant taxa at Site 4 were two chironomids (*Cricotopus/Orthocladius* spp. and *Micropsectra* sp.) and two mayflies (*Baetis* sp. and *Ephemerella inermis*). Site 7 was dominated by three chironomids (*Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp. and *Micropsectra* sp.), two mayflies (*Ephemerella inermis* and *Baetis* sp.) and water mites (Hydracarina). Site 7 was dominated by the same five taxa (*Cricotopus/Orthocladius* spp., *Rheotanytarsus* sp., *Ephemerella inermis*, *Baetis* sp. and Hydracarina) which were dominant at Site 1 (Cluster I), as well as an additional chironomid (*Micropsectra* sp.). Site 7 also had the same five taxa (*Cricotopus/Orthocladius* spp.,

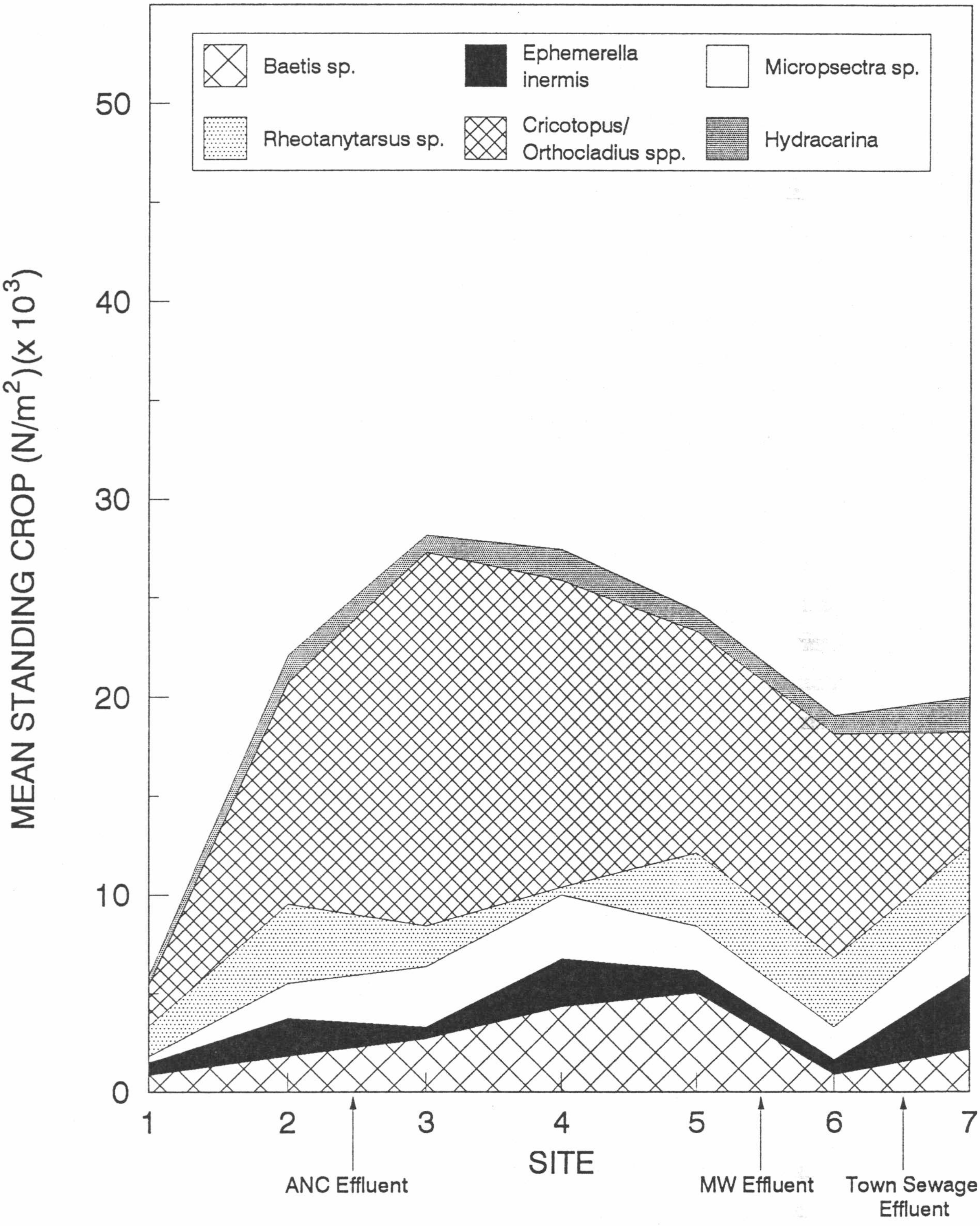

Figure 15. Mean cumulative standing crop (number/m^2) of the dominant taxa identified by RA for sites on the Athabasca River, October 1995.

Rheotanytarsus sp., *Micropsectra* sp., *Ephemerella inermis* and *Baetis* sp.) as Sites 2, 3, 5 and 6 (Cluster II), as well as an additional taxa (Hydracarina).

3.4.4 Trophic Analysis

A trophic (feeding group) analysis of the benthic data was conducted to determine if there were any differences in benthic community trophic structure between sites. The availability of food is a factor which controls the occurrence and abundance of benthic invertebrates species (Hynes 1972). The percent of each functional group of the total number of organisms for each sample and means for each site are presented in Appendix H.

The trophic analysis showed that all sites were dominated by detritivore/herbivores and detritivores (Figure 16). The detritivore/herbivores formed 40.7 to 62.7% and the detritivores formed 23.1 to 41.3% of the total benthic fauna. A dominance of detritivore/herbivores and detritivores is a common natural trait of streams in North America (Egglishaw 1964, Minshall 1967, Hynes 1972, Fisher and Likens 1972, Cummins et al. 1973). These trophic groups were followed by carnivores, herbivores and omnivores. The carnivores formed 6.4 to 11.1%, the herbivores formed 2.0 to 5.5% and the omnivores formed 0.8 to 4.1% of the total benthic fauna. All other groups formed less than 1% of the total benthic fauna.

The dominant detritivore/herbivores were *Cricotopus*/*Orthocladius* spp., *Ephemerella inermis* and *Baetis* sp. and the dominant detritivores were *Rheotanytarsus* sp. *Micropsectra* sp. The dominant carnivore was Hydracarina.

The mean percentages of the dominant feeding groups for each cluster identified by RA was as follows:

Cluster	**DH**	**D**	**C**
I (Site 1)	50.3	34.5	11.1
II (Sites 2, 3, 5 and 6)	57.1	31.2	6.8
III (Site 4)	62.7	23.1	6.7
IV (Site 7)	40.7	41.3	9.2

The trophic analysis indicated that there were some differences in feeding group structure between the groups of sites identified by the RA analysis. The increase in the mean percentage of detritivore/herbivores from Cluster IV to I to II to III was

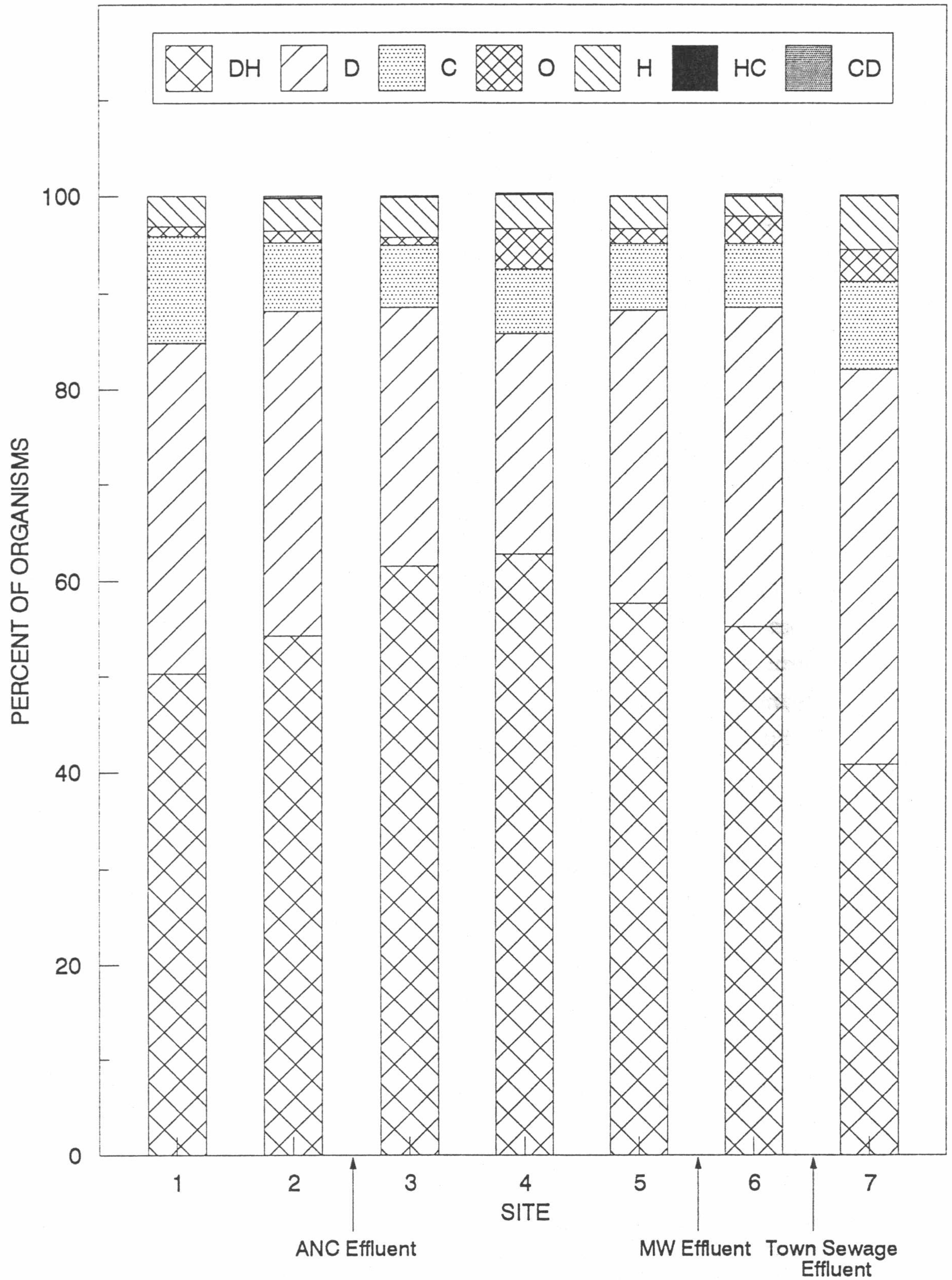

Figure 16. Percent composition of benthic invertebrate functional feeding groups for sites on the Athabasca River, October 1995.

mainly the result of an increase in the numbers of *Cricotopus/Orthocladius* spp. The decrease in the mean percentage of detritivores from Cluster IV to I to II to III was mainly the result of a decrease in the numbers of *Rheotanytarsus* sp. The mean percentage of carnivores was higher in Clusters I and IV than in Cluster II and III as a result of higher numbers of Hydracarina.

3.4.5 Organic Enrichment

Phosphorus is the nutrient that limits productivity in most freshwater ecosystems (Wetzel 1975). Increasing concentrations of phosphorus in streams often result in organic enrichment which increases biomass of algae, aquatic macrophytes and associated biota. Phosphorus inputs into the aquatic ecosystem can occur through either natural (background) or anthropogenic sources. Natural sources of phosphorus into streams include runoff or leaching of soils and weathering of rocks from undisturbed woodlands or non-agricultural grasslands, as well as from decomposing organic matter. Anthropogenic non-point sources include drainage from agricultural land and leaching of agricultural soils with high phosphorus content (Hynes 1972). Anthropogenic point sources include industrial effluents such as pulp mills and sewage treatment plant effluents which can also elevate the phosphorus concentrations in receiving streams. Phosphorus is added to pulp mill effluents to enhance biological degradation of the pulping wastes. Benthic invertebrate enrichment has been reported downstream of pulp mills and sewage treatment plants as a result of organic loading from the effluents (Hynes 1972, Bothwell and Stockner 1980, Rabeni et al. 1985, Noton et al. 1989).

Organic enrichment usually results in a decrease in the number of taxa and an increase in the number of organisms (Lenat et al. 1980). Organic enrichment increases the food energy available in a system and in general, it is accompanied by an increased oxygen demand. This is a result of increased oxygen use by organisms (mainly bacteria) utilizing the additional food energy resources. The community structure may change such that organisms tolerant of low oxygen levels dominate the community and taxa intolerant of reduced oxygen conditions become eliminated over time. The additional food energy resources are available for use by tolerant taxa, such as Chironomidae (chironomids) and Oligochaeta (aquatic worms). They may be directly or indirectly used as a food resource and there may also be a reduction in predation and competition for the remaining species. In cases where organic enrichment does not result in a change in oxygen demand (such as for mild or moderate enrichment, or when oxygenation is maintained by a series of riffles in a lotic system), enrichment will tend to result in an increase in both the number of organisms and the number of taxa (Pearson and Rosenberg 1978, Rabeni et al. 1985, Noton et al. 1989).

The highest chlorophyll *a* value was found at Site 4, which also had the highest standing crop of benthic invertebrates during the fall survey. A similar pattern of increases and decreases between chlorophyll *a* values and the standing crop of benthic invertebrates was found at most sites (Figures 8 and 10). The relationship between the amount of chlorophyll *a* and the standing crop of organisms (i.e. the higher the chlorophyll *a* value, the higher the standing crop) occurred at most sites, except at Sites 2 and 3.

The significantly higher standing crops of benthic invertebrates at downstream sites compared to background sites and at near-field sites (particularly Sites 3 and 4) compared to far-field sites was likely the result of organic loading from the ANC effluent. Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera, Trichoptera and Plecoptera), increased significantly in standing crop at downstream sites, particularly in the near-field, as a response to the organic enrichment. There was no decrease in the number of taxa at downstream sites (i.e., no significant difference between downstream sites and background sites), and in fact, there was an increase in the total number of taxa at some sites (i.e., significantly higher total numbers of taxa and numbers of EPT taxa at far-field sites than at near-field sites), indicating that only mild enrichment was occurring in the Athabasca River as a result of the organic loading from the ANC effluent.

A number of taxa have been found to respond to organic enrichment by increasing in numbers as a response to an increase in food availability, if oxygen is not limiting (Hynes 1960, Roback 1974, Godfrey 1978). Most of the dominant taxa identified by RA have been found to respond to organic enrichment from either natural or anthropogenic sources.

A gradient of organic enrichment appeared to exist between sites during the fall survey as indicated by the numbers of the chironomid, *Cricotopus/Orthocladius* spp. Orthocladiinae, such as *Cricotopus/Orthocladius* spp., have been found to respond to mild organic enrichment where oxygen levels are not seriously depressed (Hynes 1960). Chironominae of the Tanytarsini Tribe (such as *Rheotanytarsus* sp. and

Micropsectra sp.), like Orthocladiinae, have been found to respond to mild organic enrichment (Hynes 1960). Most Ephemeroptera are grazers, feeding principally on algae and detrital materials (Merritt and Cummins 1984) and thus species, such as *Baetis* sp. and *Ephemerella inermis*, are suited to mild organic enrichment (Hynes 1960, Roback 1974). Hydracarina, which can be very numerous in both standing and running water, are active predators on small crustaceans or aquatic insect eggs and larvae (Clifford 1991).

Changes in the numbers of detritivore/herbivores, detritivores and carnivores caused shifts in the feeding group structure between sites. This occurred as a result of the change in the nature of the food supply caused by mild organic enrichment at downstream sites in the Athabasca River.

During the fall 1995 survey, as in previous surveys (Luoma and Shelast 1991, 1992, 1993, 1994, 1995), the dominant benthic community structure of the background sites, especially Site 2, indicated the presence of some mild organic enrichment. The ANC effluent appeared to contribute additional organic enrichment to the river mainly at Sites 3 and 4 (as indicated by the standing crop), and there was a shift in the benthic community structure at Site 4. This shift did not appear to have occurred at Sites 3 and 5, where the benthic community structure was similar to background sites. The slight increase in standing crop of organisms and the shift in the benthic community structure at Site 7 compared to background sites indicated that the Millar Western and Whitecourt sewage treatment effluents appeared to also contribute some mild organic enrichment to the river.

3.5 COMPARISON OF PRE-OPERATIONAL AND OPERATIONAL SURVEYS

To assess the overall effects of pulp mill effluent on the benthic invertebrates of the Athabasca River, a comparison was made between the fall pre-operational and operational surveys. Pre-operational conditions existed in the fall of 1989, while start-up conditions existed in the fall of 1990. Operational conditions existed during the fall of 1991 to 1995.

The benthic community structure can differ between years as a result of numerous factors, such as hydraulic and other physical habitat conditions in the river. However, a comparison between pre-operational and operational data can be of importance in determining impact trends in the benthic community structure. The data for the six variables of total number of taxa, number of EPT taxa, total number (or standing crop) of organisms, number (or standing crop) of EPT, number (or standing crop) of Chironomidae and species diversity are represented in graphs which compare the background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) between the seven years (Figures 17 to 22).

The graphs showed that following a general trend of increases in most cases for the five variables (excluding species diversity) from 1989 to 1993, there were decreases between 1993 and 1994 at most of the sites or in a few cases the values were similar between 1993 and 1994 (Figures 17 to 21). The number of EPT taxa, the total number of organisms and the number of Chironomidae increased only at Sites 1 and 4 between 1993 and 1994 (Figures 18, 19 and 21). At most sites, the values increased slightly between 1994 and 1995. The total number of taxa and number of EPT taxa decreased slightly only at Site 6, while the number of EPT decreased at Sites 1 and 3 between 1994 and 1995 (Figures 17 and 18). The total number of organisms and the number of Chironomidae decreased at Sites 1 and 4, while the number of EPT decreased only at Site 1 between 1994 and 1995 (Figures 19 to 21).

The mean species diversity has fluctuated over the years (Figure 22). There was an increase in mean species diversity between 1994 and 1995 at all sites, except at Sites 5 and 6 where it decreased slightly.

The generally higher numbers of taxa and numbers of organisms at both background and downstream sites during the fall of 1993 than other years, was likely the result of the lower summer and fall flows during 1993. The lower flows likely allowed an increased algal growth at both background and downstream sites during 1993 (Figure 23) and thus increased numbers of taxa and numbers of organisms. This observation emphasizes the significance of physical factors related to river flow (light penetration, scouring and river temperature) throughout the year when determining the extent of the productivity of the river, whether at background sites or downstream sites.

A statistical test of whether the ANC discharge has affected benthic communities was conducted by comparing spatial differences or patterns before and after the mill became operational (i.e. combine temporal contrasts with spatial contrasts). A repeated measures design was used to analyze the five variables of total number of taxa, number of EPT taxa, total number of organisms, number of EPT and number of Chironomidae (Table 7) (Appendix I). The total number of taxa, the number of EPT

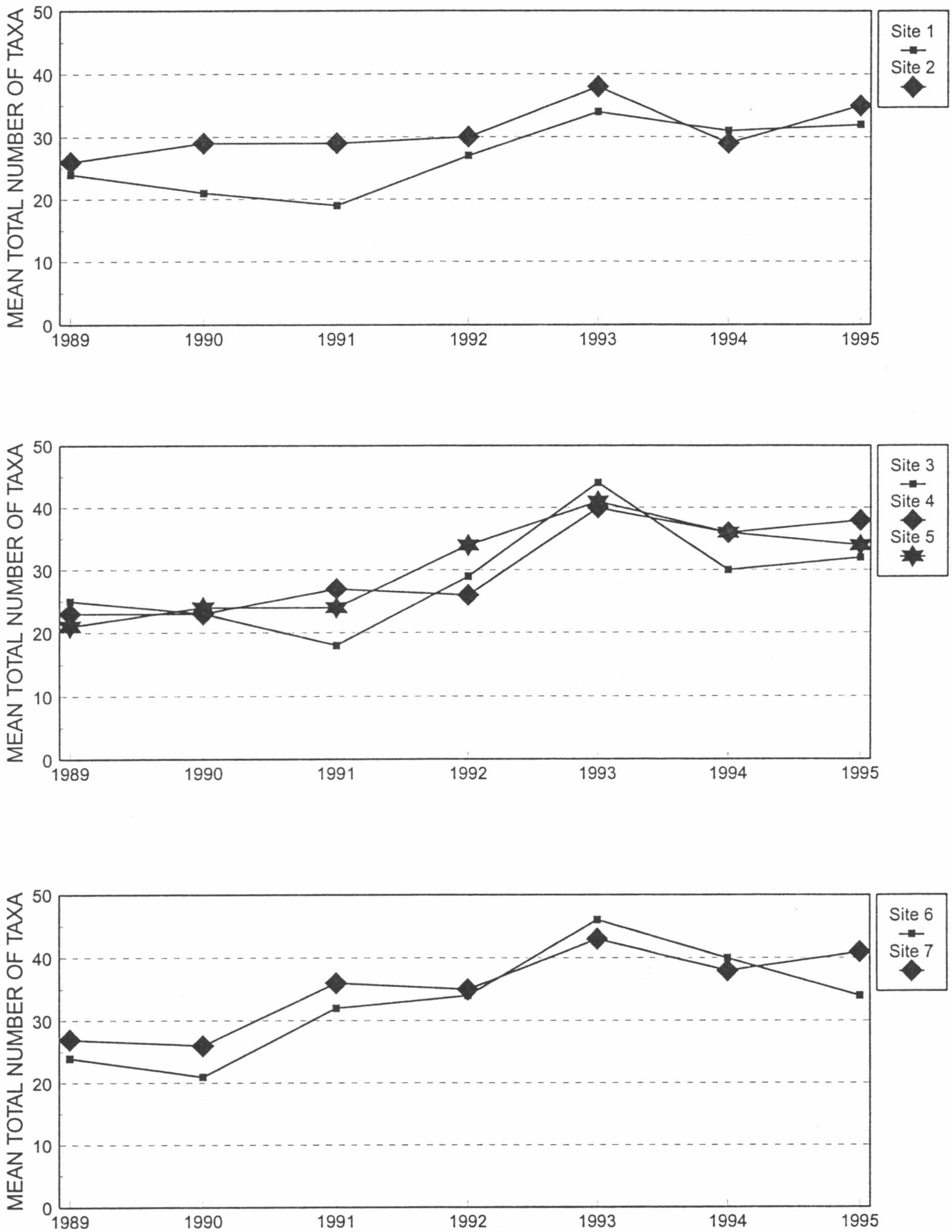

Figure 17. Comparison of mean total number of taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1995.

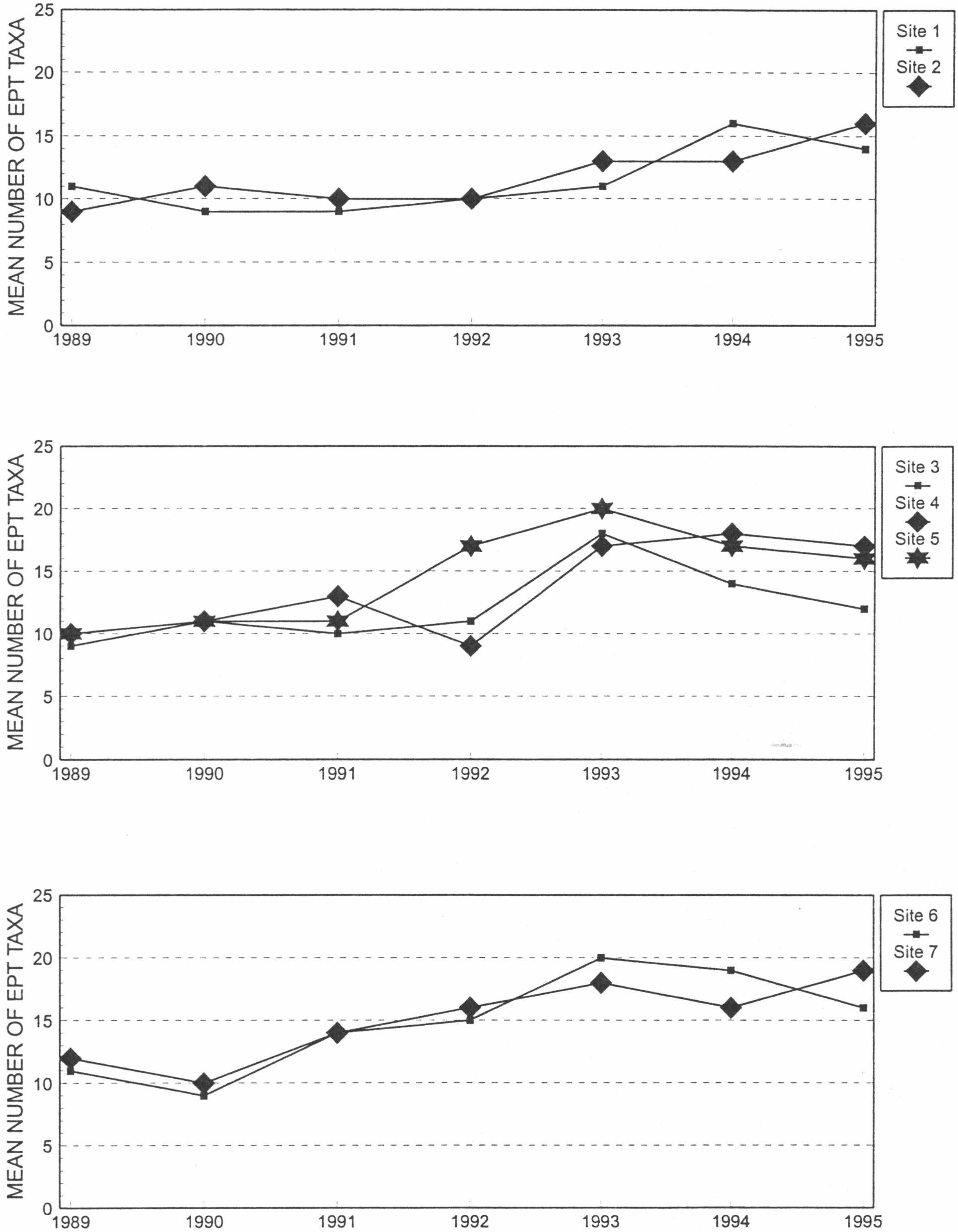

Figure 18. Comparison of mean number of EPT taxa for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1995.

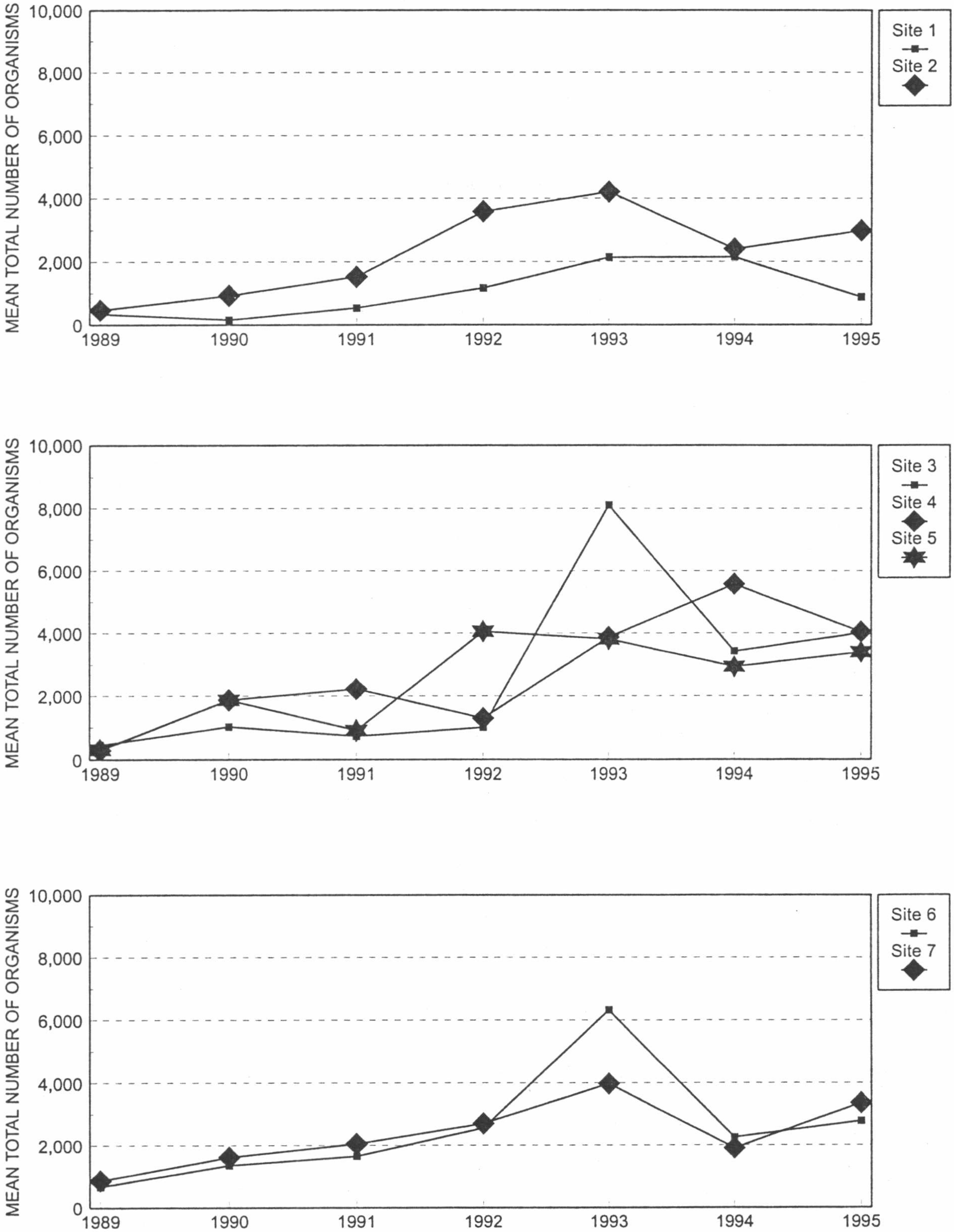

Figure 19. Comparison of mean total number of organisms for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1995.

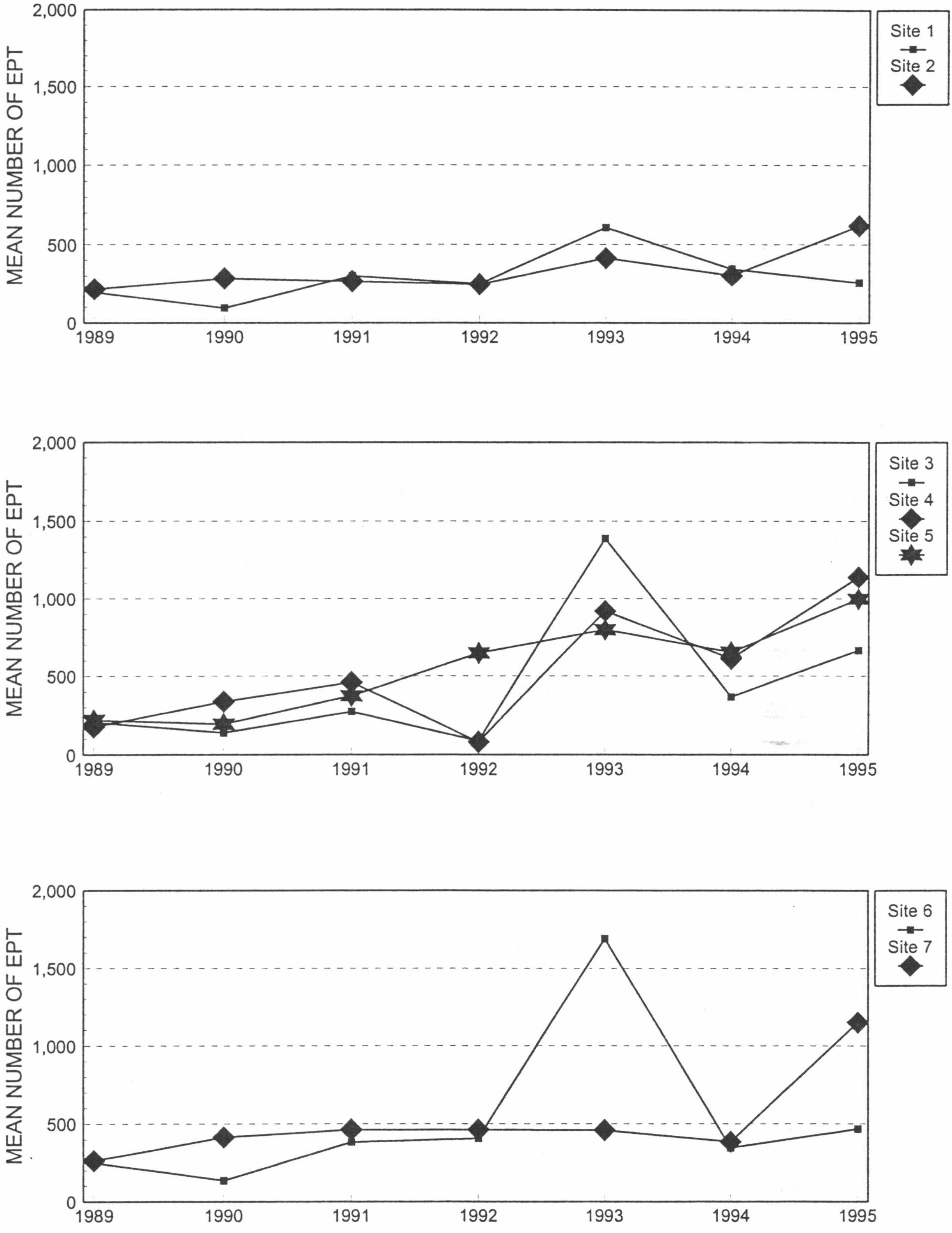

Figure 20. Comparison of mean number of EPT for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1995.

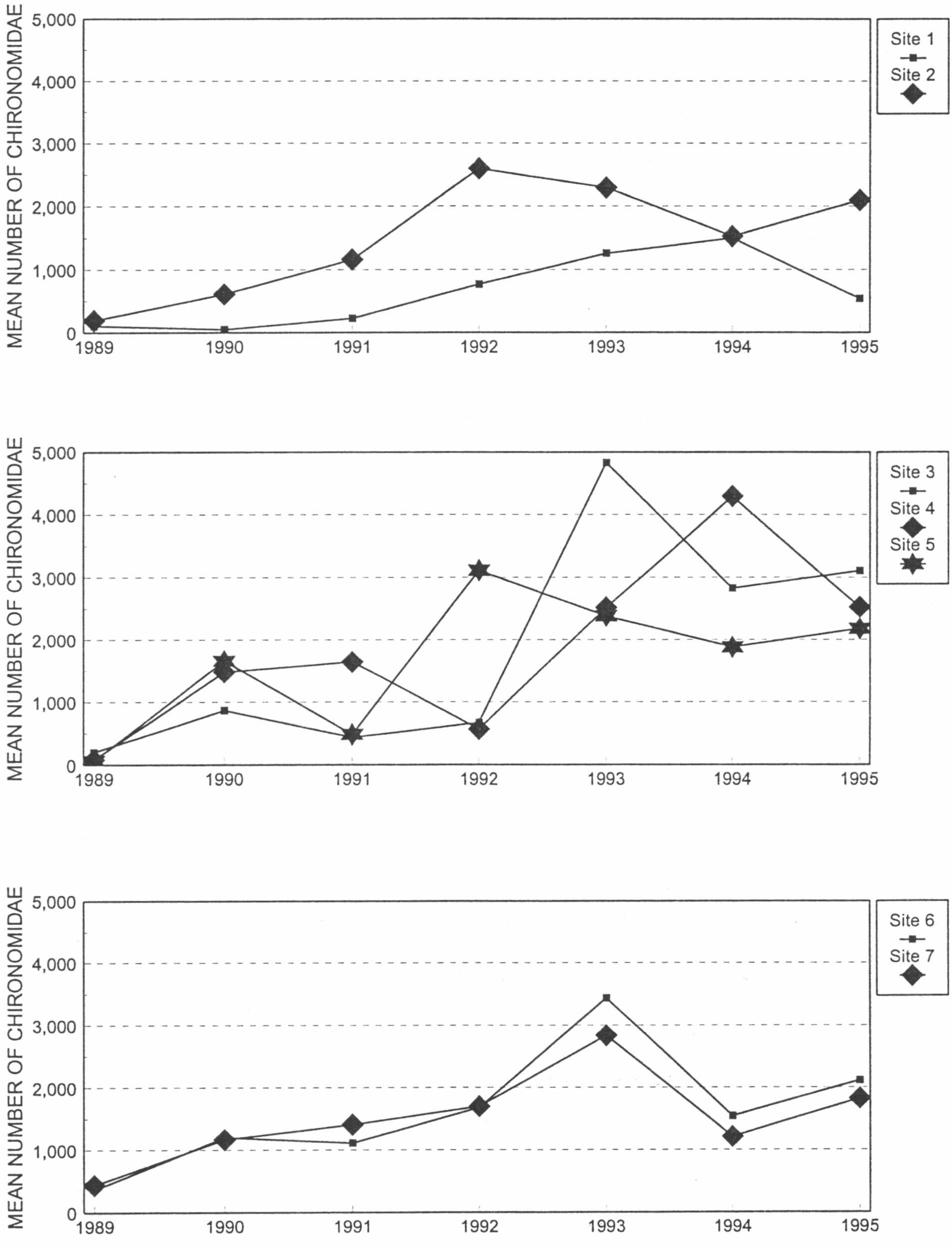

Figure 21. Comparison of mean number of Chironomidae for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1995.

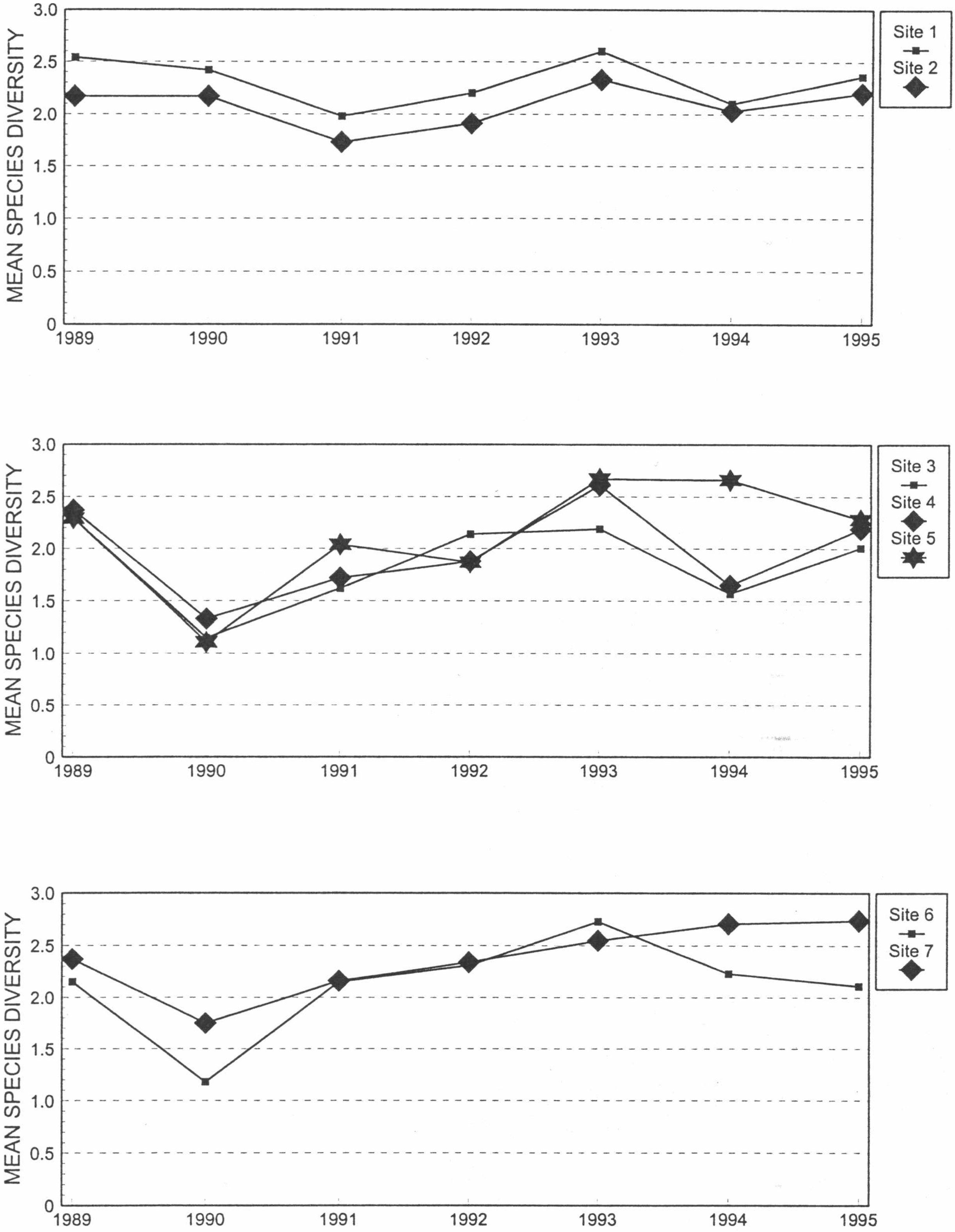

Figure 22. Comparison of mean species diversity for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1989 to 1995.

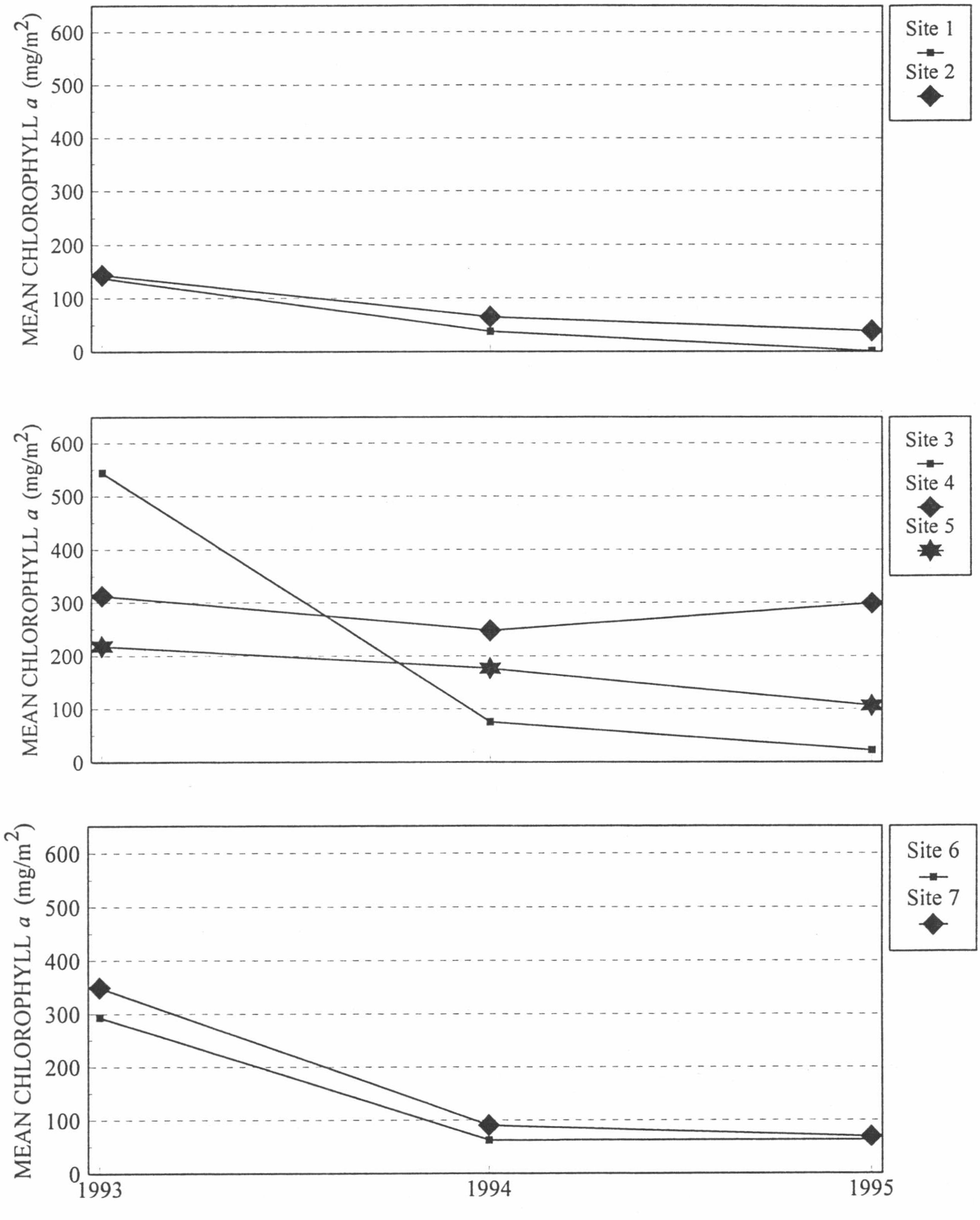

Figure 23. Comparison of mean chlorophyll *a* for background sites (Sites 1 and 2), near-field sites (Sites 3, 4 and 5) and far-field sites (Sites 6 and 7) from fall 1993 to 1995.

Table 7. Results of repeated measures analyses of benthic invertebrate variables for fall samples from pre-operational (1989) and operational (1990 to 1995) years. Values are probabilities (p).

Contrast		Variable				
Temporal	Spatial	Total Number of Taxa	Number of EPT Taxa	Total Number of Organisms	Number of EPT	Number of Chironomidae
1989, vs 1990 - 1995	BG vs DS	0.159	0.220	0.386	0.148	0.513
	NF vs FF	0.806	0.779	0.084	0.428	0.050*
1994 vs 1995	BG vs DS	0.233	0.771	0.240	0.354	0.350
	NF vs FF	0.489	0.591	0.395	0.742	0.407
Year X Area Interaction		0.224	0.140	0.114	0.756	0.054

BG Background
DS Downstream
NF Near-Field
FF Far-Field
* The significance of tests was determined at $p < 0.05$ (i.e., means are not the same). The probability of 0.050 was considered borderline significant.

taxa, the total number of organisms, the number of EPT and the number of Chironomidae were log transformed for these statistical analyses.

There were no significant differences ($p > 0.05$) between downstream sites and background sites between the one pre-operational and six operational years, for any of the five variables. There were also no significant differences ($p > 0.05$) between near-field sites and far-field sites between the one pre-operational and six operational years, for four of the five variables. The number of Chironomidae was, however, borderline significantly higher at near-field sites than at far-field sites during the operational years than the pre-operational year ($p = 0.05$).

When comparing the operational years of 1994 and 1995, there were no significant differences between downstream sites and background sites for any of the five variables ($p > 0.05$). There were also no significant differences between near-field sites and far-field sites between 1994 and 1995 for any of the five variables ($p > 0.05$).

These analyses indicated that there was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the one pre-operational and six operational years and when far-field effects were compared between the pre-operational and operational years, except possibly an increased number of Chironomidae at near-field sites during operational years. A comparison between the operational years of 1994 and 1995 indicated that there were no differences in the benthic community between the two years when the impact over all downstream sites and when far-field effects were compared between the two years.

4.0 SUMMARY AND CONCLUSIONS

Many factors can regulate the occurrence and distribution of benthic invertebrates, including river flow conditions and physical habitat factors. Athabasca River flows during the survey were stable and lower than historically recorded flows. Although benthic sampling sites were chosen to be as similar as possible with regard to physical habitat factors, some minor differences were present. There were some variations in water velocity and substrate composition, but very little in water depth between sites. Water velocity differences between sites resulted from hydraulic and minor habitat differences between reaches of the river. Generally, these minor differences in physical characteristics do not cause any detectable differences in benthic community structure between sites.

The water quality data indicated that the ANC treated effluent discharge did not affect pH, conductivity, dissolved oxygen or biochemical oxygen demand at downstream sites. True color, total suspended solids, total phosphorus and total Kjeldahl nitrogen concentrations were slightly higher at downstream sites than at background sites, likely as a result of effluent inputs. Metal concentrations, which are not generally a major component of pulp mill effluent, were below detection limits, except for iron and manganese which were slightly above background values, but below the provincial (AASWQIG) and federal (CWQG) guidelines. Neither resin or fatty acids were detected in the river. Total resin and fatty acid concentrations in the ANC treated effluent were well below the AASWQIG of 0.1 mg/L.

The ANC effluent discharge appeared to significantly increase periphytic chlorophyll *a* in the river, particularly at near-field sites.

The dominant benthic community structure of the background sites, especially Site 2, indicated the presence of some mild organic enrichment. The ANC effluent appeared to contribute additional organic enrichment to the river mainly at Sites 3 and 4 (as indicated by significant increases in standing crops compared to background sites), and there was a shift in the benthic community structure at Site 4. The slight increase in standing crop and the shift in the benthic community structure at Site 7 indicated that the Millar Western and Whitecourt sewage treatment effluents appeared to also contribute some mild organic enrichment to the river.

Tolerant taxa, mainly Chironomidae, as well as intolerant taxa (Ephemeroptera, Trichoptera and Plecoptera), increased significantly in standing crop, particularly in the near-field, as a response to the organic enrichment. There was no decrease in the number of taxa at downstream sites, and in fact, there was an increase in the number of taxa at some downstream sites, indicating that only mild enrichment was occurring in the river as a result of organic loading from the ANC effluent. Mild organic enrichment, due to nutrient addition (phosphorus) from the ANC effluent, has apparently over the years caused an increase in the abundance of tolerant taxa, such as Chironomidae, but oxygen depletion has not been sufficient to cause a decrease in the more sensitive EPT taxa, which have also increased.

The trophic analysis indicated that there were some differences in feeding group structure between sites. Changes in the numbers of detritivore/herbivores, detritivores and carnivores caused shifts in the feeding group structure between sites. This occurred as a result of the change in the nature of the food supply caused by mild organic enrichment at downstream sites in the Athabasca River.

There was no evidence of major effects on the benthic community of the river from the ANC discharge, when the impact over all downstream sites was compared between the one pre-operational and six operational years and when far-field effects were compared between the pre-operational and operational years, except an increased number of Chironomidae at near-field sites during operational years. A comparison between the operational years of 1994 and 1995 indicated that there were no differences in the benthic community between the two years when the impact over all downstream sites and when far-field effects were compared between the two years.

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6.0 SENTAR QUALITY MANAGEMENT

This report, entitled "A Benthic Invertebrate Monitoring Study on the Athabasca River, Whitecourt, Alberta, 1995", was produced by the following individual:

Maire E. Luoma
Name

Signature

This report was reviewed by the following individual:

Bob M. Shelast
Name

Signature

Approval to transmit to client:

Bob M. Shelast
Acting Office Manager
Senior Aquatic Biologist

Signature

APPENDICES

APPENDIX A

QA/QC

STATEMENT OF SENTAR'S QUALITY ASSURANCE AND QUALITY CONTROL

The basis of SENTAR's Quality Assurance and Quality Control (QA/QC) program is the adherence to a Quality Management Plan. SENTAR's QA/QC program is practiced for all types of studies. The QA program consists of externally imposed technical and management practices which ensure that the generation of quality and defensible data commensurate with the intended use of the data. The QC program consists of internal techniques which are used to measure and assess data quality and remedial actions to be taken when the data quality objectives are not realized. The assurance of adequate data is provided through Data Quality Objectives, which encompass all components of uncertainty in data generation.

Objective

The objective of SENTAR's QA/QC program is to ensure that data generated for our clients is of known and defensible quality.

Organization

Project Manager:

- Communicates committment to and delegates responsibility for quality assurance.
- Allocates funds and resources for effective quality assurance.
- Establishes Standard Operating Procedures (SOPs).

Quality Assurance Officer:

- Responsible for approval of all procedures.
- Authority for corrective action.
- Plans and evaluates QA/QC program.
- Reports any plans or problems of QA/QC to management.

Field Supervisor:

- Supervises compliance to QA/QC program.
- Helps establish SOPs.
- Follows approved field, sample and data analyses procedures and reporting of data as outlined in SOPs.

Field/Office Technicians:

- Have appropriate education and experience for the job.
- Follow approved field, sample and data analyses procedures and reporting of data as outlined in SOPs.

Standard Operating Procedures

SOPs are developed to meet Data Quality Objectives. SENTAR's SOPs outline detailed protocols for sample collection, field procedures, laboratory procedures and reporting of data. Any changes to SOPs during a project are documented and justified.

All SOPs include meticulous record-keeping, proper collection of samples, adequate replication, preservation, shipping and storage of samples, instrument calibration and maintenance and the use of chain-of-custody forms to ensure sample continuity.

Analytical Laboratories

The operations of any analytical laboratories used by SENTAR include the following Quality Control requirements as appropriate to the specific analysis: method blanks, laboratory duplicates, matrix spikes, analysis of reference materials, calibration control, surrogate spikes and internal standards.

alpha

ALPHA LABORATORY SERVICES LTD.
Analytical and Consulting Services

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Edmonton, Alberta T5S 1M7
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TECHNICAL REPORT

To: **Sentar Consultants Ltd.**
Stanley Technology Centre
200 - 1122 4 Street SW
Calgary AB T2R 1M1

File: **8164**
Date: **October 30, 1995**
Client PO:
Attention: **Maire Luoma**

Project: **ANC Athabasca River Waters** **Your Job #09-834-00**

Parameter	Unit	Sample ID: **Site 1** Date Sampled: **Oct. 9/95**	**Site 2** **Oct. 9/95**	Date Analyzed	Analyst Initials
Colour	TCU	5	5	Oct. 12/95	G.M.
Total Suspended Solids	mg/L	<1	<1	Oct. 12/95	T.H.
Biochemical Oxygen Demand	mg/L	1.8	1.6	Oct. 10/95	T.H.
Total Kjeldahl Nitrogen	mg/L N	0.10	0.10	Oct. 19/95	G.M.
Total Phosphorus	mg/L P	0.011	0.012	Oct. 24/95	G.M.
Phenols	mg/L	--	<0.002	Oct. 12/95	E.W.
Total Organic Carbon	mg/L	--	4	Oct. 20/95	B.L.
Total Arsenic	mg/L	--	<0.0005	Oct. 14/95	B.L.
Total Cadmium	mg/L	--	<0.002	Oct. 20/95	B.L.
Total Chromium	mg/L	--	<0.004	Oct. 20/95	B.L.
Total Cobalt	mg/L	--	<0.005	Oct. 20/95	B.L.
Total Copper	mg/L	--	<0.002	Oct. 20/95	B.L.
Total Iron	mg/L	--	0.142	Oct. 20/95	B.L.
Total Lead	mg/L	--	<0.002	Oct. 23/95	B.L.
Total Manganese	mg/L	--	0.003	Oct. 20/95	B.L.
Total Mercury	mg/L	--	<0.0001	Oct. 28/95	B.L.
Total Molybdenum	mg/L	--	<0.009	Oct. 20/95	B.L.
Total Nickel	mg/L	--	<0.006	Oct. 20/95	B.L.
Total Selenium	mg/L	--	<0.0005	Oct. 12/95	B.L.
Total Silver	mg/L	--	<0.003	Oct. 20/95	B.L.
Total Vanadium	mg/L	--	<0.005	Oct. 20/95	B.L.

alpha

ALPHA LABORATORY SERVICES LTD.

Analytical and Consulting Services

17212 - 106 A Avenue
Edmonton, Alberta T5S 1M7
Phone: (403) 489-9100 Fax: (403) 489-9700

TECHNICAL REPORT

To: **Sentar Consultants Ltd.** File: **8164**

Project: **ANC Athabasca River Waters** **Your Job #09-834-00**

Parameter	Unit	Sample ID: **Site 3** Date Sampled: **Oct. 10/95**	**Site 4** **Oct. 10/95**	Date Analyzed	Analyst Initials
Colour	TCU	7.5	7.5	Oct. 12/95	G.M.
Total Suspended Solids	mg/L	<1	8	Oct. 12/95	T.H.
Biochemical Oxygen Demand	mg/L	1.8	1.0	Oct. 10/95	T.H.
Total Kjeldahl Nitrogen	mg/L N	0.15	0.15	Oct. 19/95	G.M.
Total Phosphorus	mg/L P	0.012	0.015	Oct. 24/95	G.M.
Phenols	mg/L	<0.002	--	Oct. 12/95	E.W.
Total Organic Carbon	mg/L	4	--	Oct. 20/95	B.L.
Total Arsenic	mg/L	<0.0005	--	Oct. 14/95	B.L.
Total Cadmium	mg/L	<0.002	--	Oct. 20/95	B.L.
Total Chromium	mg/L	<0.004	--	Oct. 20/95	B.L.
Total Cobalt	mg/L	<0.005	--	Oct. 20/95	B.L.
Total Copper	mg/L	<0.002	--	Oct. 20/95	B.L.
Total Iron	mg/L	0.193	--	Oct. 20/95	B.L.
Total Lead	mg/L	<0.002	--	Oct. 23/95	B.L.
Total Manganese	mg/L	0.005	--	Oct. 20/95	B.L.
Total Mercury	mg/L	<0.0001	--	Oct. 28/95	B.L.
Total Molybdenum	mg/L	<0.009	--	Oct. 20/95	B.L.
Total Nickel	mg/L	<0.006	--	Oct. 20/95	B.L.
Total Selenium	mg/L	<0.0005	--	Oct. 12/95	B.L.
Total Silver	mg/L	<0.003	--	Oct. 20/95	B.L.
Total Vanadium	mg/L	<0.005	--	Oct. 20/95	B.L.

ALPHA LABORATORY SERVICES LTD.
Analytical and Consulting Services
17212 - 106 A Avenue
Edmonton, Alberta T5S 1M7
Phone: (403) 489-9100 Fax: (403) 489-9700

TECHNICAL REPORT

To: **Sentar Consultants Ltd.** File: **8164**

Project: **ANC Athabasca River Waters Your Job #09-834-00**

	Sample ID:	**Site 5**	**Site 6**		
	Date Sampled:	**Oct. 10/95**	**Oct. 9/95**		
Parameter	Unit			Date Analyzed	Analyst Initials
Colour	TCU	10	7.5	Oct. 12/95	G.M.
Total Suspended Solids	mg/L	11	1	Oct. 12/95	T.H.
Biochemical Oxygen Demand	mg/L	2.0	1.7	Oct. 10/95	T.H.
Total Kjeldahl Nitrogen	mg/L N	0.15	0.15	Oct. 19/95	G.M.
Total Phosphorus	mg/L P	0.015	0.014	Oct. 24/95	G.M.

	Sample ID:	**Site 7**		
	Date Sampled:	**Oct. 10/95**		
Parameter	Unit		Date Analyzed	Analyst Initials
Colour	TCU	10	Oct. 12/95	G.M.
Total Suspended Solids	mg/L	<1	Oct. 12/95	T.H.
Biochemical Oxygen Demand	mg/L	1.6	Oct. 10/95	T.H.
Total Kjeldahl Nitrogen	mg/L N	0.15	Oct. 19/95	G.M.
Total Phosphorus	mg/L P	0.015	Oct. 24/95	G.M.

ALPHA LABORATORY SERVICES LTD.
Analytical and Consulting Services
17212 - 106 A Avenue
Edmonton, Alberta T5S 1M7
Phone: (403) 489-9100 Fax: (403) 489-9700

TECHNICAL REPORT

To: **Sentar Consultants Ltd.** File: **8164**

Project: **ANC Athabasca River Waters Your Job #09-834-00**

Report Verified by:

Bill Durnford
Supervisor, Quality Assurance/Quality Control

Report Authorized by:

Bob Lickacz, B.Sc., P.Biol
President

Note: All samples will be disposed of 30 days after analysis. Please advise the laboratory if you require additional sample storage time.

ALPHA LABORATORY

SERVICES LTD.

QA REPORT FOR: Sentar

ATTENTION: Ms. M. Luoma

SAMPLE INFORMATION:
Project: 09-834-00
Date :

REFERENCE:
Client P.O.:
Alpha Job #: 8164

REPORT:
Date: 30-Oct-95
Verified By:

DESCRIPTION	DATE	QC CHECK				DUPLICATE CHECK			SPIKE CHECK			
PARAMETER – METHOD	ANALYSED	RESULT	MEAN	95% CONFIDENCE LIMITS		a	b	Diff. 95% C.L.	%RECOV.	MEAN	95% CONFIDENCE LIMITS	
Color - Vision	12-Oct	20.00	20.00	20.00	20.00	10.00	10.00	0.00	Spike Check Not Applicable			
Total Suspended Solids - Gravi	12-Oct	94.90	97.63	94.79	100.47	240.00	283.00	33.97	Spike Check Not Applicable			
B.O.D. - BOD5	10-Oct	9.20	7.59	5.70	9.48	182.00	168.00	20.79	Spike Check Not Applicable			
TKN - Ion Specific Electrode	19-Oct	0.22	0.22	0.20	0.24	0.10	0.10	0.02	86.20	89.96	76.55	103.37
Total Phosphate - Stannous Chl	24-Oct	0.108	0.102	0.090	0.115	0.010	0.010	0.006	103.000	108.672	79.549	137.795
Phenol - Chloroform Extraction	12-Oct	25.100	25.220	23.537	26.903	Duplicate Check Not Applicable			93.250	98.267	87.990	108.543
TOC - Auto sampler	20-Oct	4.70	4.91	4.33	5.50	1.30	0.80	5.01	Spike Check Not Applicable			
Arsenic - Hydride	14-Oct	4.526	4.826	4.385	5.267	0.001	0.001	0.000	99.250	98.739	79.632	117.847
Cadmium - ICP Low Level	20-Oct	0.049	0.050	0.046	0.054	0.002	0.002	0.000	99.133	96.227	83.873	108.581
Chromium - ICP Low Level	20-Oct	0.050	0.049	0.046	0.053	0.004	0.004	0.002	93.800	95.838	86.974	104.703
Cobalt - ICP Low Level	20-Oct	0.050	0.051	0.043	0.059	0.005	0.005	0.001	97.693	96.648	83.128	110.168
Copper - ICP Low Level	20-Oct	0.049	0.048	0.044	0.051	0.011	0.011	0.002	93.840	94.821	81.045	108.596
Iron - ICP Low Level	20-Oct	0.254	0.254	0.234	0.273	0.319	0.315	0.008	100.880	103.923	90.615	117.231
Lead - Graphite A.A.	23-Oct	0.026	0.025	0.021	0.029	0.002	0.002	0.000	80.000	90.202	49.004	131.399
Manganese - ICP Low Level	20-Oct	0.241	0.254	0.238	0.270	0.129	0.130	0.003	95.000	97.602	88.285	106.920
Molybdenum - ICP Low Level	20-Oct	0.050	0.047	0.041	0.053	0.009	0.009	0.002	98.680	92.512	70.447	114.578
Nickel - ICP Low Level	20-Oct	0.054	0.050	0.043	0.058	0.006	0.006	0.003	94.587	100.455	85.070	115.840
Selenium - Hydride	12-Oct	4.838	5.027	4.744	5.309	0.002	0.002	0.000	84.475	100.610	81.291	119.929
Silver - ICP Low Level	20-Oct	0.046	0.049	0.042	0.055	0.003	0.003	0.001	83.893	85.535	65.264	105.806
Vanadium - ICP Low Level	20-Oct	0.048	0.049	0.043	0.055	0.005	0.005	0.000	95.787	98.241	82.102	114.380
Zinc - ICP Low Level	28-Oct	0.049	0.049	0.044	0.054	0.028	0.029	0.006	96.680	99.641	82.892	116.389

ETL Enviro·Test
A DIVISION OF ETL CHEMSPEC ANALYTICAL LIMITED

9936 - 67 Avenue, Edmonton, Alberta T6E 0P5 Telephone: (403) 434-9509 Fax: (403) 437-2311
Bay 2, 1313 - 44 Avenue N.E., Calgary, Alberta T2E 6L5 Telephone: (403) 291-9897 Fax: (403) 291-0298
107 - 111 Research Drive, Saskatoon, Saskatchewan S7N 3R2 Telephone: (306) 668-8370 Fax: (306) 668-8383
Bay 3, 10919 - 96 Avenue, Grande Prairie T8V 3J4 Telephone: (403) 539-5196 Fax: (403) 539-6295
Unit F - 1420 Clarence Avenue, Winnipeg, Manitoba R3T 1T6 Telephone: (204) 452-8104 Fax: (204) 477-8719

Recycled Paper

CHEMICAL ANALYSIS REPORT

SENTAR CONSULTANTS
SUITE 200, 1122-4 STREET S.W.
CALGARY, ALBERTA
T2R 1M1

DATE: October 19, 1995

ATTN: MAIRE LUOMA

Lab Work Order #: E510237

Sampled By: CLIENT

Project Reference: ANC 09-834-00

Date Received: 10/11/95

Project P.O.#: NOT SUBMITTED

Comments:

RECEIVED SENTAR

APPROVED BY:

Milan Ralitsch,PhD
Project Manager

Maire

RESIN AND FATTY ACIDS ANALYSIS REPORT
ENVIROTEST LABORATORIES
PULP AND PAPER DIVISION

PROJECT	: SENTAR CONSULTANTS	INSTRUMENT	: HEWLETT PACKARD 5971D GC/MSD
MATRIX	: WATER	ANALYSIS DATE	: 17-Oct-95
LAB SAMPLE#	: E5-10-237-01A	ANALYST	: Greg McCoy, Residue Analyst
CLIENT I.D.	: SITE 2		
SAMPLE SIZE	: 800 mL	DETECTION LIMIT:	0.001 mg/L (ppm)

	COMPOUND	CONCENTRATION mg/L (ppm)
FATTY ACIDS	ARACHIDIC ACID	ND
	LINOLEIC ACID	ND
	LINOLENIC ACID	ND
	MYRISTIC ACID	ND
	OLEIC ACID	ND
	PALMITIC ACID	ND
	STEARIC ACID	ND
	9,10-DICHLOROSTEARIC ACID	ND
	TOTAL FATTY ACIDS :	ND
RESIN ACIDS	ABIETIC ACID	ND
	DEHYDROABIETIC ACID	ND
	ISOPIMARIC ACID	ND
	LEVOPIMARIC ACID	ND
	NEOABIETIC ACID	ND
	PALUSTRIC ACID	ND
	PIMARIC ACID	ND
	SANDARACOPIMARIC ACID	ND
	12,14-DICHLORODEHYDROABIETIC ACID	ND
	12-CHLORODEHYDROABIETIC ACID [#2]	ND
	14-CHLORODEHYDROABIETIC ACID [#1]	ND
	TOTAL RESIN ACIDS :	ND
	TOTAL RESIN AND FATTY ACIDS :	ND

NOTES:

1.) ND = Not Detected, less than detection limit listed.
2.) NDR = Not Detected due to incorrect ion ratios.
3.) The detection limit applies to all compounds listed.

QA/QC:

1.) To ensure resin acid extraction efficiency, the sample was fortified with a surrogate compound prior to extraction. Based on in-house data, the average % recovery for:

O-Methylpodocarpic Acid is: 95% ± 10%

2.) To ensure resin acid derivatization efficiency, the final extracts were fortified with tricosanoic acid prior to methylation with diazomethane. Based on in-house recovery data, the average % recovery for:

Tricosanoic Acid is: 103% ± 6.2%

RESIN AND FATTY ACIDS ANALYSIS REPORT
ENVIROTEST LABORATORIES
PULP AND PAPER DIVISION

PROJECT : SENTAR CONSULTANTS
MATRIX : WATER
LAB SAMPLE# : E5-10-237-02A
CLIENT I.D. : SITE 3
SAMPLE SIZE : 800 mL

INSTRUMENT : HEWLETT PACKARD 5971D GC/MSD
ANALYSIS DATE : 17-Oct-95
ANALYST : Greg McCoy, Residue Analyst

DETECTION LIMIT: 0.001 mg/L (ppm)

	COMPOUND	CONCENTRATION mg/L (ppm)
FATTY ACIDS	ARACHIDIC ACID	ND
	LINOLEIC ACID	ND
	LINOLENIC ACID	ND
	MYRISTIC ACID	ND
	OLEIC ACID	ND
	PALMITIC ACID	ND
	STEARIC ACID	ND
	9,10-DICHLOROSTEARIC ACID	ND
	TOTAL FATTY ACIDS :	ND
RESIN ACIDS	ABIETIC ACID	ND
	DEHYDROABIETIC ACID	ND
	ISOPIMARIC ACID	ND
	LEVOPIMARIC ACID	ND
	NEOABIETIC ACID	ND
	PALUSTRIC ACID	ND
	PIMARIC ACID	ND
	SANDARACOPIMARIC ACID	ND
	12,14-DICHLORODEHYDROABIETIC ACID	ND
	12-CHLORODEHYDROABIETIC ACID [#2]	ND
	14-CHLORODEHYDROABIETIC ACID [#1]	ND
	TOTAL RESIN ACIDS :	ND
	TOTAL RESIN AND FATTY ACIDS :	ND

NOTES:

1.) ND = Not Detected, less than detection limit listed.
2.) NDR = Not Detected due to incorrect ion ratios.
3.) The detection limit applies to all compounds listed.

QA/QC:

1.) To ensure resin acid extraction efficiency, the sample was fortified with a surrogate compound prior to extraction. Based on in-house data, the average % recovery for:

O-Methylpodocarpic Acid is: 95% ± 10%

2.) To ensure resin acid derivatization efficiency, the final extracts were fortified with tricosanoic acid prior to methylation with diazomethane. Based on in-house recovery data,the average % recovery for:

Tricosanoic Acid is: 103% ± 6.2%

Appendix A Test Methodologies

Resin Acids in Water

Resin and Fatty Acids Method Reference: Alberta Environment AE 129.0

THIS IS THE LAST PAGE OF THE METHODOLOGY APPENDIX.

CHEMEX Labs Alberta Inc.

Calgary : 2021 - 41st Avenue N.E., T2E 6P2. Telephone (403) 291-3077, FAX (403) 291-9468
Edmonton : 9331 - 48th Street, T6B 2R4, Telephone (403) 465-9877, FAX (403) 466-3332

SENTAR CONSULTANTS LTD.
MAIRE LUOMA

DATE : November 1, 1995
CHEMEX PROJECT NO.: SENT010-0501-95-03783
CLIENT REFERENCE : ANC
CLIENT JOB NO. : PROJ.#09-834-00

Analytical Data Reviewed By : ______________

QA/QC Reviewed By : J Jardine

The above signatures indicate that the individuals identified have reviewed the enclosed documents.

NOTE : Soil samples and water samples (for stable parameters) will be retained for a period of 60 days after completion of analysis.
Retention beyond this period can be arranged for a fee.

CHEMEX Labs Alberta Inc. is accredited by both the Canadian Association for Environmental Analytical Laboratories and the Standards Council of Canada for specific parameters registered with the Association and the Council.

CHEMEX Labs Alberta Inc.

Calgary : 2021 - 41st Avenue N.E., T2E 6P2. Telephone (403) 291-3077, FAX (403) 291-9468
Edmonton : 9331 - 48th Street, T6B 2R4, Telephone (403) 465-9877, FAX (403) 466-3332

SENTAR CONSULTANTS LTD.
ATTENTION : MAIRE LUOMA

ANC
PROJ.#09-834-00

Chemex Worksheet Number : 95-03783
Chemex Project Number : SENT010-0501
Report Date : November 1. 1995

SAMPLE DESCRIPTION	SET NUMBER	MATRIX	DATE SAMPLED		Chlorophyll 'A 06711L mg
SITE 1-1 ALGAE	1	FILTER	09-10-95	<	0.001
SITE 1-2 ALGAE	2	FILTER	09-10-95	<	0.001
SITE 1-3 ALGAE	3	FILTER	09-10-95	<	0.001
SITE 2-1 ALGAE	4	FILTER	09-10-95		0.011
SITE 2-2 ALGAE	5	FILTER	09-10-95		0.042
SITE 2-3 ALGAE	6	FILTER	09-10-95		0.016
SITE 3-1 ALGAE	7	FILTER	10-10-95		0.019
SITE 3-2 ALGAE	8	FILTER	10-10-95		0.022
SITE 3-3 ALGAE	9	FILTER	10-10-95		0.013
SITE 4-1 ALGAE	10	FILTER	08-10-95		0.370
SITE 4-2 ALGAE	11	FILTER	08-10-95		0.173
SITE 4-3 ALGAE	12	FILTER	08-10-95		0.175
SITE 5-1 ALGAE	13	FILTER	08-10-95		0.051
SITE 5-2 ALGAE	14	FILTER	08-10-95		0.069
SITE 5-3 ALGAE	15	FILTER	08-10-95		0.135
SITE 6-1 ALGAE	16	FILTER	07-10-95		0.055
SITE 6-2 ALGAE	17	FILTER	07-10-95		0.045
SITE 6-3 ALGAE	18	FILTER	07-10-95		0.051
SITE 7-1 ALGAE	19	FILTER	08-10-95		0.044
SITE 7-2 ALGAE	20	FILTER	08-10-95		0.065
SITE 7-3 ALGAE	21	FILTER	08-10-95		0.057

CHEMEX Labs Alberta Inc.

Calgary : 2021 - 41st Avenue N.E., T2E 6P2. Telephone (403) 291-3077, FAX (403) 291-9468
Edmonton : 9331 - 48th Street, T6B 2R4, Telephone (403) 465-9877, FAX (403) 466-3332

SENTAR CONSULTANTS LTD.
ATTENTION : MAIRE LUOMA

ANC
PROJ.#09-834-00

Chemex Worksheet Number : 95-03783
Chemex Project Number : SENT010-0501
Report Date : November 1, 1995

BATCH SPECIFIC QA/QC FOR: Chlorophyll 'A(06711L)

Sample Description	SET NUMBER	DATE ANALYZED (DD-MM-YY)	QA/QC BATCH NUMBER	DUP Rr	SPIKES % RECOV	SPIKES CONTROL LIMITS LOWER	SPIKES CONTROL LIMITS UPPER	CHECK % RECOV	CHECK CONTROL LIMITS LOWER	CHECK CONTROL LIMITS UPPER
SITE 1-1 ALGAE	1	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 1-2 ALGAE	2	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 1-3 ALGAE	3	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 2-1 ALGAE	4	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 2-2 ALGAE	5	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 2-3 ALGAE	6	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 3-1 ALGAE	7	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 3-2 ALGAE	8	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 3-3 ALGAE	9	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 4-1 ALGAE	10	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 4-2 ALGAE	11	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 4-3 ALGAE	12	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 5-1 ALGAE	13	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 5-2 ALGAE	14	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 5-3 ALGAE	15	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 6-1 ALGAE	16	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 6-2 ALGAE	17	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 6-3 ALGAE	18	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 7-1 ALGAE	19	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 7-2 ALGAE	20	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		
SITE 7-3 ALGAE	21	24-10-95	1	N.A.	NOT APPLICABLE			NOT APPLICABLE		

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 269-9300

Date Shipped: Oct. 10/95

Carrier: In Person

Weigh Bill No.: —

SHIP TO: Alpha Laboratory Services
Edmonton, Alberta

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC

Project No.: 09-834-00

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma		Oct. 10/95	3:30pm
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 1	Water Sample 1	9/10/95; 3:30pm	See previously	
Site 1	Water Sample 2	9/10/95; 3:30pm	faxed parameters	
Site 2	Water Sample 1	9/10/95; 5:55pm		
Site 2	Water Sample 2	" "		
Site 2	Water Sample 3	" "		
Site 2	Water Sample 4	" "		
Site 2	Water Sample 5	" "		

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ______

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) [signature]

Phone: 269-9300

Date Shipped: Oct. 10/95

Project Name: ANC

Project No.: 09-834-00

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 3	Water Sample 1	10/10/95; 11:30am		
Site 3	Water Sample 2	" "		
Site 3	Water Sample 3	" "		
Site 3	Water Sample 4	" "		
Site 3	Water Sample 5	" "		
Site 4	Water Sample 1	10/10/95; 11:50am		
Site 4	Water Sample 2	" "		
Site 5	Water Sample 1	10/10/95; 12:00pm		
Site 5	Water Sample 2	" "		
Site 6	Water Sample 1	9/10/95; 10:30am		
Site 6	Water Sample 2	" "		
Site 7	Water Sample 1	10/10/95; 1:20pm		
Site 7	Water Sample 2	" "		

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): E.W. ________ ________

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 269-9300

Date Shipped: Oct. 10/95

Carrier: In Person

Weigh Bill No.: —

SHIP TO: Enviro-Test Laboratories
9936 - 67th Avenue
Edmonton, AB T6E 0P5

ATTENTION: Dieb Birkholz

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

** Please quote SENTAR project number on results **

Project Name: ANC

Project No.: 09-834-00

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma		Oct. 10/95	3:00 pm
Relinquished by: (Signature)	**Received at lab by: (Signature)**	**Date**	**Time**
	W Rodger	OCT 11/95	11:50
Discarded at lab by: (Signature)	**Discard approved by: (Signature)**	**Date**	**Time**

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 2	Water Sample	09/10/95; 5:55pm	Rosin/Fatty Acids	E510237-01
Site 3	Water Sample	10/10/95; 11:30am		02

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 269-9300

Date Shipped: Oct. 16/95

Carrier: In Person

Weigh Bill No.: —

SHIP TO: Chemex Labs Alberta Inc.
2021 - 41 Avenue N.E.
Calgary, Alberta

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

* *Please quote SENTAR project number on results* *

Project Name: ANC

Project No.: 09-834-00

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma	[signature]	Oct. 16, 1995	1:50 pm
Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 1-1	Algae	9/10/95; 3:00pm		
Site 1-2	Algae	" "		
Site 1-3	Algae	" "		
Site 2-1	Algae	9/10/95; 5:45pm	chlorophyll a	
Site 2-2	Algae	" "		
Site 2-3	Algae	" "		
Site 3-1	Algae	10/10/95; 10:45am		
Site 3-2	Algae	" "		

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Total Samples = 21

Expected lab turn-around time: Rush (surcharge): _____ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Marie Luoma

Phone: 269-9300

Date Shipped: Oct. 16, 1995

Project Name: ANC

Project No.: 09-834-00

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 3-3	Algae	10/10/95; 10:45am	Chlorophyll a	
Site 4-1	Algae	8/10/95; 7:00pm		
Site 4-2	Algae	" "		
Site 4-3	Algae	" "		
Site 5-1	Algae	8/10/95; 8:30pm		
Site 5-2	Algae	" "		
Site 5-3	Algae	" "		
Site 6-1	Algae	7/10/95; 5:00pm		
Site 6-2	Algae	" "		
Site 6-3	Algae	" "		
Site 7-1	Algae	8/10/95; 1:15pm		
Site 7-2	Algae	" "		
Site 7-3	Algae	" "		

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ______ Standard: ✓

Relinquished/Received (Initials): ML / RC ______

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Maire Luoma

Phone: 269-9300

Date Shipped: Oct. 30, 1995

Carrier: In person

Weigh Bill No.: -

SHIP TO: Jack Zloty
8527 - 33 Avenue N.W.
Calgary, Alberta
T3B 1M2

SEND RESULTS TO: SENTAR Consultants Ltd.
#200, 1122 - 4th Street SW
Calgary, AB T2R 1M1

ATTENTION: Maire Luoma

* *Please quote SENTAR project number on results* *

Project Name: ANC

Project No.: 09-834-00

Relinquished by: (Signature)	Received by: (Signature)	Date	Time
Maire Luoma	[signature]	Oct. 30/95	4:35

Relinquished by: (Signature)	Received at lab by: (Signature)	Date	Time
			4

Discarded at lab by: (Signature)	Discard approved by: (Signature)	Date	Time

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 1-1	Benthos	9/10/95; 2:00pm	Sort and Identify Organisms	
Site 1-2	Benthos	" "		
Site 1-3	Benthos	" "		
Site 1-4	Benthos	" "		
Site 1-5	Benthos	" "		
Site 2-1	Benthos	9/10/95; 4:00pm		
Site 2-2	Benthos	" "		
Site 2-3	Benthos	" "		

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments: Total Samples = 35

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Marie Luoma
Phone: 269-9300

Date Shipped: Oct. 30, 1995
Project Name: ANC
Project No.: 09-834-00

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 2-4	Benthos	9/10/95; 4:00pm	Sort and identify Organisms	
Site 2-5	Benthos	" "		
Site 3-1	Benthos	9/10/95; 6:30pm		
Site 3-2	Benthos	" "		
Site 3-3	Benthos	" "		
Site 3-4	Benthos	" "		
Site 3-5	Benthos	" "		
Site 4-1	Benthos	8/10/95; 3:30pm		
Site 4-2	Benthos	" "		
Site 4-3	Benthos	" "		
Site 4-4	Benthos	" "		
Site 4-5	Benthos	" "		
Site 5-1	Benthos	7/10/95; 6:00pm		
Site 5-2	Benthos	" "		
Site 5-3	Benthos	" "		
Site 5-4	Benthos	" "		
Site 5-5	Benthos	" "		
Site 6-1	Benthos	7/10/95; 2:00pm		
Site 6-2	Benthos	" "		
Site 6-3	Benthos	" "		
Site 6-4	Benthos	" "		
Site 6-5	Benthos	" "		
Site 7-1	Benthos	8/10/95; 11:00am		

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): [signature] ________ ________

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

SENTAR
CHAIN-OF-CUSTODY RECORD

Sampler: (Signature) Marie Luoma

Phone: 269-9300

Date Shipped: Oct. 30, 1995

Project Name: ANC

Project No.: 09-834-00

ANALYSIS REQUEST

Sample ID No.	Sample Description	Date/Time Sampled	Analysis Requested	Sample Condition Upon Receipt
Site 7-2	Benthos	8/10/95; 11:00am	Sort and Identify Organisims	
Site 7-3	Benthos	" "		
Site 7-4	Benthos	" "		
Site 7-5	Benthos	" "		

NOTE: DO NOT DISCARD SAMPLES UNTIL DISCARD APPROVED BY SENTAR.

Special Instructions/Comments:

Expected lab turn-around time: Rush (surcharge): ________ Standard: ✓

Relinquished/Received (Initials): [signature] ________ ________

*** PLEASE RETURN WHITE COPY TO SENTAR WITH FINAL RESULTS ***

APPENDIX B

PHYSICAL CHARACTERISTICS OF SAMPLE LOCATIONS, OCTOBER 1995

Appendix B-1. Water velocity and depth for each sample location (average of three measurements) with means and 95% confidence limits (CL) per site, October 1995.

Site-Sample	Water Velocity (cm/s)	Water Depth (cm)
1-1	47	39
1-2	45	39
1-3	46	38
1-4	41	38
1-5	44	37
Mean ± 95% CL	45 ± 2	38 ± 1
2-1	37	40
2-2	37	40
2-3	44	39
2-4	41	40
2-5	39	38
Mean ± 95% CL	40 ± 3	39 ± 1
3-1	53	36
3-2	53	37
3-3	52	36
3-4	45	38
3-5	50	36
Mean ± 95% CL	51 ± 3	37 ± 1
4-1	55	38
4-2	49	38
4-3	58	36
4-4	64	36
4-5	52	35
Mean ± 95% CL	56 ± 5	37 ± 1
5-1	45	39
5-2	40	38
5-3	50	39
5-4	46	39
5-5	44	39
Mean ± 95% CL	45 ± 3	39 ± 0
6-1	41	40
6-2	45	38
6-3	48	37
6-4	41	38
6-5	39	39
Mean ± 95% CL	43 ± 3	38 ± 1
7-1	36	33
7-2	39	33
7-3	33	35
7-4	41	34
7-5	40	35
Mean ± 95% CL	38 ± 3	34 ± 1

Appendix B-2. **Substrate size distribution (percentage by weight) for each sample location with means and 95% confidence limits (CL) per site, October 1995.**

Site-Sample	Cobble (64-256 mm)	Pebble (16-64 mm)	Large Gravel (4-16 mm)	Small Gravel (2-4 mm)	Coarse Sand (0.5-2 mm)
1-1	28.7	70.8	0.5	-	-
1-2	28.1	71.9	0	-	-
1-3	36.2	63.8	0	-	-
1-4	63.0	36.7	0.4	-	-
1-5	39.6	58.0	2.4	-	-
Mean ± 95% CL	39.1 ± 12.5	60.2 ± 12.6	0.6 ± 0.9	-	-
2-1	77.6	22.4	-	-	-
2-2	53.5	46.5	-	-	-
2-3	51.3	48.7	-	-	-
2-4	44.2	55.8	-	-	-
2-5	64.6	35.4	-	-	-
Mean ± 95% CL	58.2 ± 11.5	41.8 ± 11.5	-	-	-
3-1	42.3	57.7	-	-	-
3-2	43.7	56.3	-	-	-
3-3	48.6	51.4	-	-	-
3-4	42.6	57.4	-	-	-
3-5	49.7	50.3	-	-	-
Mean ± 95% CL	45.4 ± 3.1	54.6 ± 3.1	-	-	-
4-1	22.7	77.0	0.3	-	-
4-2	53.0	47.0	0	-	-
4-3	35.0	64.7	0.3	-	-
4-4	35.8	63.8	0.4	-	-
4-5	48.8	51.0	0.2	-	-
Mean ± 95% CL	39.1 ± 10.6	60.7 ± 10.5	0.3 ± 0.1	-	-
5-1	54.0	45.9	<0.01	-	-
5-2	66.9	33.1	0	-	-
5-3	50.8	49.0	0.2	-	-
5-4	56.4	43.6	0	-	-
5-5	53.1	46.9	0	-	-
Mean ± 95% CL	56.2 ± 5.5	43.7 ± 5.5	<0.01 ± 0.1	-	-
6-1	63.3	33.1	3.3	0.3	<0.01
6-2	50.3	46.7	2.6	0.3	<0.01
6-3	59.1	37.6	3.3	0	<0.01
6-4	47.1	52.2	0.8	0	<0.01
6-5	43.3	56.2	0.4	<0.01	<0.01
Mean ± 95% CL	52.6 ± 7.3	45.2 ± 8.5	2.1 ± 1.2	0.1 ± 0.1	<0.01 ± 0
7-1	66.4	30.0	3.4	0.2	-
7-2	56.0	41.4	2.7	0	-
7-3	57.5	38.5	3.6	0.3	-
7-4	65.5	31.4	2.8	0.2	-
7-5	64.3	34.5	1.2	0	-
Mean ± 95% CL	61.9 ± 4.2	35.1 ± 4.2	2.8 ± 0.8	0.2 ± 0.1	-

APPENDIX C

PERIPHYTIC CHLOROPHYLL A RESULTS, OCTOBER 1995

Appendix C-1. Periphytic algae chlorophyll *a* values per sample with means and 95% confidence limits (CL) per site, October 1995.

Site-Sample	Periphytic Algae Chlorophyll *a* (mg/m^2)
1-1	<1.3
1-2	<1.3
1-3	<1.3
Mean ± 95% CL	<1.3 ± 0
2-1	13.8
2-2	52.5
2-3	20.0
Mean ± 95% CL	28.8 ± 51.7
3-1	23.8
3-2	27.5
3-3	16.3
Mean ± 95% CL	22.5 ± 14.2
4-1	462.5
4-2	216.3
4-3	218.8
Mean ± 95% CL	299.2 ± 351.4
5-1	63.8
5-2	86.3
5-3	168.8
Mean ± 95% CL	106.3 ± 137.3
6-1	68.8
6-2	56.3
6-3	63.8
Mean ± 95% CL	62.9 ± 15.6
7-1	55.0
7-2	81.3
7-3	71.3
Mean ± 95% CL	69.2 ± 32.9

Appendix C-2. ANOVA on Chlorophyll *a* for Sites, October 1995.

Source	DF	SS	MS	F	P
Site	6	183,400.0	30,569.0	9.01	0.0004*
Within	14	47,493.8	3,392.4		
Total	20	230,900.0			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-970.00
SE (Contrast)	281.35
SS (Contrast)	40,300.00
T-Statistic	-3.45
P (T-Statistic)	0.0039*

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	459.58
SE (Contrast)	184.18
SS (Contrast)	21,100.00
T-Statistic	2.50
P (T-Statistic)	0.0257*

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

APPENDIX D

SORTING OF BENTHIC INVERTEBRATE SAMPLES, OCTOBER 1995

Appendix D-1. Sorting of benthic invertebrate samples, October 1995.

Project: ANC - Athabasca River

Project No.: 09-834-00

Sampling Date: October 1995

Site-Sample	Subsample Count in First 50 mL	Subsample Amount Sorted (mL)*	Subsample Fraction
1 - 1	42	500	X2
1 - 2	36	500	X2
1 - 3	34	500	X2
1 - 4	54	500	X2
1 - 5	40	500	X2
Sorter:	Gordon Pritchard		

Site-Sample	Subsample Count in First 50 mL	Subsample Amount Sorted (mL)*	Subsample Fraction
2 - 1	152	125	X8
2 - 2	150	125	X8
2 - 3	154	125	X8
2 - 4	150	125	X8
2 - 5	148	125	X8
Sorter:	Ela Grygorasz		

* Total subsample amount sorted from the 1 L sample.

Appendix D-1. (continued)

Site-Sample	Subsample Count in First 50 mL	Subsample Amount Sorted (mL)*	Subsample Fraction
3 - 1	124	200	X5
3 - 2	238	100	X10
3 - 3	226	100	X10
3 - 4	206	100	X10
3 - 5	160	125	X8
Sorter:	Gordon Pritchard		

Site-Sample	Subsample Count in First 50 mL	Subsample Amount Sorted (mL)*	Subsample Fraction
4 - 1	164	125	X8
4 - 2	160	125	X8
4 - 3	218	100	X10
4 - 4	254	100	X10
4 - 5	204	100	X10
Sorter:	Ela Grygorasz		

Site-Sample	Subsample Count in First 50 mL	Subsample Amount Sorted (mL)*	Subsample Fraction
5 - 1	180	125	X8
5 - 2	184	125	X8
5 - 3	176	125	X8
5 - 4	180	125	X8
5 - 5	160	125	X8
Sorter:	Gordon Pritchard		

* Total subsample amount sorted from the 1 L sample.

Appendix D-1. (concluded)

Site-Sample	Subsample Count in First 50 mL	Subsample Amount Sorted (mL)*	Subsample Fraction
6 - 1	100	200	X5
6 - 2	106	200	X5
6 - 3	150	125	X8
6 - 4	150	125	X8
6 - 5	104	200	X5
Sorter:	Ela Grygorasz		

Site-Sample	Subsample Count in First 50 mL	Subsample Amount Sorted (mL)*	Subsample Fraction
7 - 1	158	125	X8
7 - 2	148	125	X8
7 - 3	162	125	X8
7 - 4	176	125	X8
7 - 5	164	125	X8
Sorter:	Gordon Pritchard		

* Total subsample amount sorted from the 1 L sample.

Appendix D-2. Sorting efficiency of benthic invertebrate samples, October 1995.

Project: ANC - Athabasca River

Project No.: 09-834-00

Sampling Date: October 1995

Re-Sorter: Jack Zloty

Site-Sample	Total Number of Organisms				Percent Recovery		
	Initial Sort		Re-Sort				
	Coarse	Fine	Coarse	Fine	Coarse	Fine	Total
2 - 1	174	344	9	16	95.1	95.6	95.4
3 - 2	182	471	7	11	96.3	97.7	97.3
5 - 3	84	398	5	15	94.4	96.4	96.0
7 - 4	323	428	12	19	96.4	95.7	96.0
Average							96.2

Appendix D-3. Reference collection for benthic invertebrate samples.

Project: ANC

Project No.: 09-834-00

Sampling Date: October 1995

Date Reference Collection Prepared: June 1993

Date Reference Collection Updated: May 1996

Location of Reference Collection: SENTAR Consultants Ltd., Calgary, Alberta

Reference Collection Prepared By: Bob Saunders (1993)

Reference Collection Updated By: Jack Zloty (1996)

Taxonomists: Bob Saunders (1989 - 1993) and Jack Zloty (1992 - 1995)

Reference Collection Identifications Verified By: Dr. Gordon Pritchard, University of Calgary, Calgary, Alberta

APPENDIX E

BENTHIC INVERTEBRATE SPECIES IDENTIFICATIONS AND NUMBERS PER SAMPLE, OCTOBER 1995

Site 1 - October 1995

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Ephemeroptera					
	Baetidae					
002	*Baetis* sp.	81	121	58	41	106
	Ephemerellidae					
005	*Ephemerella inermis*	81	60	62	72	84
	Heptageniidae					
007	*Epeorus* sp.	0	2	0	0	0
008	*Heptagenia* sp.	0	0	1	0	0
009	*Rhithrogena* sp.	31	13	31	28	32
	Siphlonuridae					
014	*Ameletus* sp.	1	2	3	2	4
	Trichoptera					
	Brachycentridae					
016	*Brachycentrus* sp.	0	4	0	5	8
	Hydropsychidae					
017	*Arctopsyche* sp.	0	1	0	0	0
019	*Hydropsyche* sp.	0	11	6	5	3
	Lepidostomatidae					
022	*Lepidostoma* sp.	2	2	0	0	2
	Plecoptera					
025	Capniidae	19	12	21	13	26
	Chloroperlidae					
099	Chloroperlinae (early instar)	5	4	4	2	6
	Perlidae					
028	*Claassenia sabulosa*	0	2	4	3	1
	Perlodidae					
029	*Cultus* sp.	5	2	9	0	4
030	*Isogenoides* sp.	2	1	2	3	7
031	*Isoperla* sp.	2	0	0	0	0
032	Perlodidae (early instar)	4	4	4	6	6
	Pteronarcyidae					
034	*Pteronarys dorsata*	0	0	0	1	0
	Taeniopterygidae					
035	*Taenionema* sp.	22	56	13	5	42
	Diptera					
	Empididae					
119	*Wiedemannia* sp.	0	0	0	0	1
	Tipulidae					
041	*Hexatoma* sp.	0	0	0	5	0

(continued)

Site 1 - October 1995 (concluded)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Chironomidae					
	Chironominae					
	Chironomini Tribe					
044	*Cryptochironomus* sp.	0	2	0	0	0
045	*Microtendipes* sp.	2	0	0	4	2
048	*Polypedilum* spp.	4	6	0	0	2
049	*Robackia demeijerei*	1	2	4	2	0
138	*Stictochironomus* sp.	0	0	0	2	0
	Tanytarsini Tribe					
052	*Cladotanytarsus* sp.	0	2	0	0	0
054	*Micropsectra* sp.	20	32	42	68	40
055	*Rheotanytarsus* sp.	130	204	124	264	196
057	*Sublettea* sp.	4	10	2	2	10
058	*Tanytarsus* sp.	2	0	4	8	0
	Orthocladiinae					
062	*Cardiocladius* sp.	26	15	28	10	8
104	*Corynoneura* sp.	2	0	0	0	0
063	*Cricotopus/Orthocladius* spp.	226	242	224	384	203
064	*Eukiefferiella* sp.	0	1	0	0	0
105	*Heleniella* sp.	0	0	0	1	0
065	*Nanocladius* sp.	4	8	14	22	12
067	*Parakiefferiella* sp.	0	2	0	2	0
109	*Psectrocladius* sp.	0	0	2	0	0
070	*Synorthocladius* sp.	8	0	10	4	4
071	*Thienemanniella* sp.	4	0	2	4	0
072	*Tvetenia* sp.	1	7	8	2	4
	Tanypodinae					
	Pentaneurini Tribe					
077	*Thienemannimyia* gp.	6	0	2	4	8
085	Hydracarina	30	70	44	66	71
	Podocopa					
	Candonidae					
086	*Candona* sp.	0	0	0	0	2
	Haplotaxida					
087	Enchytraeidae	2	4	6	10	6
088	Naididae	8	12	10	2	8
089	Tubificidae	0	0	0	0	1
092	Nematoda	22	10	8	20	9

Site 2 - October 1995

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Ephemeroptera					
	Baetidae					
002	*Baetis* sp.	122	147	269	96	256
	Ephemerellidae					
004	*Drunella doddsi*	0	0	0	1	0
005	*Ephemerella inermis*	225	128	241	170	253
	Heptageniidae					
008	*Heptagenia* sp.	2	1	0	0	2
009	*Rhithrogena* sp.	9	0	12	17	25
	Leptophlebiidae					
012	*Paraleptophlebia* sp.	0	0	0	1	0
	Siphlonuridae					
014	*Ameletus* sp.	0	0	9	0	0
	Trichoptera					
	Brachycentridae					
016	*Brachycentrus* sp.	11	7	15	1	3
	Glossosomatidae					
115	*Glossosoma* sp.	8	2	0	1	4
	Hydropsychidae					
019	*Hydropsyche* sp.	35	34	18	19	20
	Hydroptilidae					
020	*Hydroptila* sp.	3	0	9	1	0
	Lepidostomatidae					
022	*Lepidostoma* sp.	2	0	0	0	0
	Leptoceridae					
023	*Oecetis* sp.	8	0	0	0	1
	Limnephilidae					
116	*Apatania* sp.	0	1	0	1	0
	Rhyacophilidae					
142	*Rhyacophila* sp.	0	0	0	0	1
	Plecoptera					
025	Capniidae	37	17	105	25	32
	Chloroperlidae					
099	Chloroperlinae (early instar)	9	1	3	2	21
	Perlidae					
028	*Claassenia sabulosa*	0	2	1	2	2
	Perlodidae					
029	*Cultus* sp.	5	27	29	19	5
030	*Isogenoides* sp.	0	3	2	11	4
031	*Isoperla* sp.	8	0	0	17	2
032	Perlodidae (early instar)	0	2	21	8	26
	Taeniopterygidae					
035	*Taenionema* sp.	21	77	143	115	109

(continued)

Site 2 - October 1995 (concluded)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Diptera					
	Empididae					
038	*Chelifera* sp.	0	2	9	2	6
039	*Hemerodromia* sp.	0	8	1	0	0
	Simuliidae					
143	*Ectemnia* sp.	0	0	0	0	8
	Tipulidae					
041	*Hexatoma* sp.	1	1	0	0	0
	Chironomidae					
	Chironominae					
	Chironomini Tribe					
046	*Paracladopelma/Cyphomella* spp.	16	0	8	24	8
048	*Polypedilum* spp.	9	0	9	2	35
049	*Robackia demeijerei*	0	8	0	0	0
	Tanytarsini Tribe					
052	*Cladotanytarsus* sp.	0	0	8	0	0
053	*Constempellina* sp.	0	0	0	1	3
054	*Micropsectra* sp.	182	136	242	186	210
055	*Rheotanytarsus* sp.	354	445	439	407	506
057	*Sublettea* sp.	32	88	104	120	49
058	*Tanytarsus* sp.	0	8	16	0	24
	Orthocladiinae					
062	*Cardiocladius* sp.	1	8	9	18	4
063	*Cricotopus/Orthocladius* spp.	1306	1121	896	1191	1553
064	*Eukiefferiella* sp.	1	0	1	4	9
105	*Heleniella* sp.	0	8	0	0	0
065	*Nanocladius* sp.	8	16	0	16	6
067	*Parakiefferiella* sp.	1	0	7	10	4
070	*Synorthocladius* sp.	40	32	40	72	57
071	*Thienemanniella* sp.	0	0	0	0	8
072	*Tvetenia* sp.	74	29	55	53	77
	Tanypodinae					
	Pentaneurini Tribe					
077	*Thienemannimyia* gp.	24	1	4	18	21
085	Hydracarina	152	136	100	121	217
	Haplotaxida					
087	Enchytraeidae	0	16	16	25	25
088	Naididae	81	8	20	48	53
089	Tubificidae	0	0	8	0	0
092	Nematoda	139	34	17	59	23

Site 3 - October 1995

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Ephemeroptera					
	Baetidae					
002	*Baetis* sp.	303	280	212	265	376
	Ephemerellidae					
005	*Ephemerella inermis*	86	92	40	53	52
	Heptageniidae					
007	*Epeorus* sp.	0	10	0	0	0
008	*Heptagenia* sp.	0	0	0	0	1
009	*Rhithrogena* sp.	35	34	34	61	29
	Trichoptera					
	Brachycentridae					
016	*Brachycentrus* sp.	0	0	0	2	0
	Glossosomatidae					
115	*Glossosoma* sp.	0	0	0	0	1
	Hydropsychidae					
019	*Hydropsyche* sp.	36	54	21	9	28
	Hydroptilidae					
020	*Hydroptila* sp.	0	10	0	0	0
	Lepidostomatidae					
022	*Lepidostoma* sp.	1	0	0	1	0
	Leptoceridae					
023	*Oecetis* sp.	0	0	0	0	2
	Limnephilidae					
116	*Apatania* sp.	0	0	0	1	0
	Plecoptera					
025	Capniidae	34	54	63	52	71
	Chloroperlidae					
099	Chloroperlinae (early instar)	0	1	2	0	1
	Nemouridae					
027	*Zapada* sp.	0	0	0	1	0
	Perlidae					
028	*Claassenia sabulosa*	1	0	0	4	1
	Perlodidae					
029	*Cultus* sp.	9	5	0	14	5
030	*Isogenoides* sp.	4	6	1	4	4
031	*Isoperla* sp.	0	0	0	4	1
032	Perlodidae (early instar)	12	40	10	22	4
	Taeniopterygidae					
035	*Taenionema* sp.	176	190	110	131	163

(continued)

Site 3 - October 1995 (concluded)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Diptera					
	Empididae					
038	*Chelifera* sp.	0	0	2	0	12
	Chironomidae					
	Chironominae					
	Chironomini Tribe					
044	*Cryptochironomus* sp.	0	0	1	1	10
046	*Paracladopelma/Cyphomella* spp.	10	0	0	20	0
048	*Polypedilum* spp.	5	30	0	20	25
	Tanytarsini Tribe					
054	*Micropsectra* sp.	137	423	390	382	367
055	*Rheotanytarsus* sp.	156	335	220	326	173
057	*Sublettea* sp.	20	120	110	70	56
058	*Tanytarsus* sp.	5	40	30	0	8
	Orthocladiinae					
062	*Cardiocladius* sp.	85	122	151	151	153
104	*Corynoneura* sp.	10	30	0	10	8
063	*Cricotopus/Orthocladius* spp.	1193	2534	2173	2034	2307
064	*Eukiefferiella* sp.	1	0	0	10	1
105	*Heleniella* sp.	5	0	0	10	0
065	*Nanocladius* sp.	35	40	20	50	16
067	*Parakiefferiella* sp.	15	0	0	0	0
109	*Psectrocladius* sp.	0	10	0	0	0
070	*Synorthocladius* sp.	106	100	170	110	96
071	*Thienemanniella* sp.	10	40	10	20	0
072	*Tvetenia* sp.	13	76	23	61	21
	Tanypodinae					
	Pentaneurini Tribe					
077	*Thienemannimyia* gp.	5	10	10	1	0
085	Hydracarina	30	130	100	50	137
	Haplotaxida					
087	Enchytraeidae	0	20	0	10	0
088	Naididae	0	20	10	50	120
089	Tubificidae	5	2	2	101	72
092	Nematoda	30	33	121	64	40
	Tricladida					
	Planariidae					
095	*Polycelis coronata*	0	1	0	0	0

Site 4 - October 1995

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Ephemeroptera					
	Baetidae					
002	*Baetis* sp.	218	355	788	661	496
	Ephemerellidae					
004	*Drunella doddsi*	1	0	0	0	1
005	*Ephemerella inermis*	156	220	383	229	311
	Heptageniidae					
008	*Heptagenia* sp.	1	0	0	2	0
009	*Rhithrogena* sp.	33	24	10	2	23
	Leptophlebiidae					
012	*Paraleptophlebia* sp.	1	0	0	0	1
	Trichoptera					
	Brachycentridae					
016	*Brachycentrus* sp.	115	16	34	52	172
	Glossosomatidae					
115	*Glossosoma* sp.	18	20	19	13	31
	Hydropsychidae					
017	*Arctopsyche* sp.	3	0	0	0	3
018	*Cheumatopsyche* sp.	1	0	0	0	0
019	*Hydropsyche* sp.	104	20	15	20	118
	Hydroptilidae					
020	*Hydroptila* sp.	33	25	22	33	15
021	*Stactobiella* sp.	0	1	0	0	0
	Lepidostomatidae					
022	*Lepidostoma* sp.	4	4	3	2	1
	Leptoceridae					
023	*Oecetis* sp.	0	0	0	0	2
	Limnephilidae					
116	*Apatania* sp.	24	0	0	0	4
	Plecoptera					
025	Capniidae	45	21	74	45	110
	Chloroperlidae					
099	Chloroperlinae (early instar)	1	0	0	1	13
	Perlidae					
101	*Hesperoperla pacifica*	1	0	0	0	0
	Perlodidae					
029	*Cultus* sp.	3	16	0	15	5
030	*Isogenoides* sp.	2	1	2	1	1
031	*Isoperla* sp.	0	0	2	17	5
032	Perlodidae (early instar)	16	10	2	1	24

(continued)

Site 4 - October 1995 (continued)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Taeniopterygidae					
035	*Taenionema* sp.	70	72	80	77	107
137	*Taeniopteryx* sp.	1	0	0	0	0
	Diptera					
	Athericidae					
036	*Atherix* sp.	0	1	1	0	1
	Empididae					
038	*Chelifera* sp.	1	2	1	3	2
039	*Hemerodromia* sp.	0	8	0	0	0
	Tipulidae					
133	*Antocha* sp.	0	1	0	0	0
123	*Dicranota* sp.	1	0	0	0	0
041	*Hexatoma* sp.	1	0	0	0	0
	Chironomidae					
	Chironominae					
	Chironomini Tribe					
044	*Cryptochironomus* sp.	16	24	40	60	30
046	*Paracladopelma/Cyphomella* spp.	8	0	20	10	0
048	*Polypedilum* spp.	40	4	33	2	14
	Tanytarsini Tribe					
054	*Micropsectra* sp.	141	59	463	753	693
055	*Rheotanytarsus* sp.	37	26	72	43	41
057	*Sublettea* sp.	40	8	20	110	70
058	*Tanytarsus* sp.	0	0	0	0	1
	Orthocladiinae					
062	*Cardiocladius* sp.	1	18	21	22	25
063	*Cricotopus/Orthocladius* spp.	659	1943	2090	1945	2002
064	*Eukiefferiella* sp.	2	0	1	0	1
065	*Nanocladius* sp.	16	8	0	0	0
067	*Parakiefferiella* sp.	24	16	50	60	40
070	*Synorthocladius* sp.	24	49	93	41	24
072	*Tvetenia* sp.	62	74	93	126	116
	Tanypodinae					
	Pentaneurini Tribe					
077	*Thienemannimyia* gp.	2	0	26	34	37
	Coleoptera					
	Elmidae					
080	*Optioservus* sp.	0	1	0	0	0
	Hemiptera					
	Corixidae					
081	*Callicorixa audeni*	0	0	0	1	0

(continued)

Site 4 - October 1995 (concluded)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
085	Hydracarina	34	217	142	232	301
	Haplotaxida					
087	Enchytraeidae	16	24	10	11	3
088	Naididae	19	166	143	153	124
089	Tubificidae	1	11	1	16	3
092	Nematoda	37	38	25	40	99
	Tricladida					
	Planariidae					
095	*Polycelis coronata*	0	0	0	0	1

Site 5 - October 1995

Species Code	Taxa	Number per Sample (0.0892 m^2)				
		1	2	3	4	5
	Ephemeroptera					
	Baetidae					
002	*Baetis* sp.	613	470	475	435	637
	Ephemerellidae					
005	*Ephemerella inermis*	131	152	96	247	114
	Heptageniidae					
008	*Heptagenia* sp.	0	8	0	0	0
009	*Rhithrogena* sp.	34	26	28	42	33
	Leptophlebiidae					
012	*Paraleptophlebia* sp.	0	1	0	0	0
	Siphlonuridae					
014	*Ameletus* sp.	1	1	2	6	11
	Trichoptera					
	Brachycentridae					
016	*Brachycentrus* sp.	5	4	6	2	4
	Glossosomatidae					
115	*Glossosoma* sp.	4	2	0	9	8
	Hydropsychidae					
017	*Arctopsyche* sp.	1	0	0	1	0
018	*Cheumatopsyche* sp.	0	0	0	1	0
019	*Hydropsyche* sp.	44	52	54	46	24
	Hydroptilidae					
020	*Hydroptila* sp.	0	1	1	0	2
	Lepidostomatidae					
022	*Lepidostoma* sp.	0	1	2	1	0
	Limnephilidae					
116	*Apatania* sp.	0	0	2	0	0
	Plecoptera					
025	Capniidae	96	90	64	87	53
	Chloroperlidae					
099	Chloroperlinae (early instar)	16	0	9	9	0
	Perlidae					
028	*Claassenia sabulosa*	1	0	13	12	6
	Perlodidae					
029	*Cultus* sp.	0	1	0	0	10
030	*Isogenoides* sp.	7	6	20	5	13
031	*Isoperla* sp.	0	1	0	16	16
032	Perlodidae (early instar)	16	8	16	16	16
	Taeniopterygidae					
035	*Taenionema* sp.	112	87	136	91	109

(continued)

Site 5 - October 1995 (concluded)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Diptera					
	Empididae					
038	*Chelifera* sp.	0	8	16	0	0
	Tipulidae					
041	*Hexatoma* sp.	0	0	1	1	1
	Chironomidae					
	Chironominae					
	Chironomini Tribe					
044	*Cryptochironomus* sp.	0	16	0	1	0
046	*Paracladopelma/Cyphomella* spp.	0	0	8	0	16
048	*Polypedilum* spp.	0	0	16	25	40
049	*Robackia demeijerei*	8	0	0	0	0
	Tanytarsini Tribe					
054	*Micropsectra* sp.	225	172	248	233	332
055	*Rheotanytarsus* sp.	497	347	445	381	323
057	*Sublettea* sp.	48	25	72	88	64
058	*Tanytarsus* sp.	0	1	0	16	32
	Orthocladiinae					
062	*Cardiocladius* sp.	33	98	81	33	48
104	*Corynoneura* sp.	8	16	16	8	8
063	*Cricotopus/Orthocladius* spp.	1015	1367	1119	1329	1346
064	*Eukiefferiella* sp.	1	2	1	2	0
105	*Heleniella* sp.	0	0	8	0	0
065	*Nanocladius* sp.	8	8	0	0	8
070	*Synorthocladius* sp.	56	48	33	123	57
071	*Thienemanniella* sp.	8	0	16	8	1
072	*Tvetenia* sp.	38	31	59	40	52
	Tanypodinae					
	Pentaneurini Tribe					
077	*Thienemannimyia* gp.	1	18	17	20	33
085	Hydracarina	120	113	89	73	137
	Haplotaxida					
087	Enchytraeidae	8	18	8	24	64
088	Naididae	0	33	32	48	40
089	Tubificidae	16	0	0	0	8
092	Nematoda	48	44	59	61	66

Site 6 - October 1995

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Ephemeroptera					
	Baetidae					
002	*Baetis* sp.	26	95	180	100	76
	Ephemerellidae					
005	*Ephemerella inermis*	76	102	79	132	70
	Heptageniidae					
008	*Heptagenia* sp.	3	0	2	3	5
009	*Rhithrogena* sp.	18	10	58	42	21
	Leptophlebiidae					
012	*Paraleptophlebia* sp.	0	0	1	0	0
	Siphlonuridae					
014	*Ameletus* sp.	0	0	0	0	2
	Trichoptera					
	Brachycentridae					
016	*Brachycentrus* sp.	1	10	3	12	7
	Glossosomatidae					
115	*Glossosoma* sp.	17	8	14	1	10
	Hydropsychidae					
018	*Cheumatopsyche* sp.	0	1	2	3	1
019	*Hydropsyche* sp.	41	45	89	101	72
	Hydroptilidae					
020	*Hydroptila* sp.	1	0	0	0	0
021	*Stactobiella* sp.	1	5	0	0	0
	Leptoceridae					
023	*Oecetis* sp.	0	0	0	8	0
	Polycentropodidae					
117	*Neureclipsis* sp.	0	0	3	1	0
	Plecoptera					
025	Capniidae	54	94	80	76	113
	Chloroperlidae					
099	Chloroperlinae (early instar)	5	7	3	12	22
	Nemouridae					
100	*Nemoura* sp.	0	0	1	0	0
	Perlidae					
028	*Claassenia sabulosa*	0	0	0	1	2
	Perlodidae					
029	*Cultus* sp.	0	6	0	1	10
030	*Isogenoides* sp.	1	3	1	1	2
031	*Isoperla* sp.	11	15	3	20	6
032	Perlodidae (early instar)	0	0	0	0	5
	Taeniopterygidae					
035	*Taenionema* sp.	36	44	79	62	7

(continued)

Site 6 - October 1995 (concluded)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Diptera					
	Empididae					
038	*Chelifera* sp.	0	0	0	8	6
039	*Hemerodromia* sp.	0	5	2	8	0
	Tipulidae					
123	*Dicranota* sp.	1	1	0	0	0
	Chironomidae					
	Chironominae					
	Chironomini Tribe					
044	*Cryptochironomus* sp.	0	0	0	0	5
046	*Paracladopelma/Cyphomella* spp.	0	10	0	0	5
048	*Polypedilum* spp.	20	2	8	16	0
	Tanytarsini Tribe					
054	*Micropsectra* sp.	181	155	220	178	161
055	*Rheotanytarsus* sp.	364	386	553	249	257
057	*Sublettea* sp.	20	45	88	64	20
058	*Tanytarsus* sp.	15	0	9	0	15
	Orthocladiinae					
062	*Cardiocladius* sp.	20	40	34	104	20
063	*Cricotopus/Orthocladius* spp.	964	1210	1562	1665	1140
105	*Heleniella* sp.	0	10	27	0	10
065	*Nanocladius* sp.	5	15	8	32	10
067	*Parakiefferiella* sp.	0	5	0	0	0
070	*Synorthocladius* sp.	10	75	72	56	90
071	*Thienemanniella* sp.	5	5	0	0	5
072	*Tvetenia* sp.	20	40	93	79	74
	Tanypodinae					
	Pentaneurini Tribe					
077	*Thienemannimyia* gp.	10	0	17	8	10
	Hemiptera					
	Corixidae					
081	*Callicorixa audeni*	0	0	0	1	0
085	Hydracarina	75	75	136	96	120
	Haplotaxida					
087	Enchytraeidae	15	10	16	17	5
088	Naididae	15	10	56	33	10
089	Tubificidae	5	5	2	0	0
092	Nematoda	63	54	69	24	36

Site 7 - October 1995

Species Code	Taxa	Number per Sample (0.0892 m^2)				
		1	2	3	4	5
	Ephemeroptera					
	Baetidae					
002	*Baetis* sp.	178	190	327	228	236
	Ephemerellidae					
005	*Ephemerella inermis*	243	125	345	485	506
	Ephemeridae					
006	*Ephemera* sp.	0	0	1	0	0
	Heptageniidae					
007	*Epeorus* sp.	8	0	0	0	0
008	*Heptagenia* sp.	3	0	3	0	3
009	*Rhithrogena* sp.	101	96	65	129	122
	Leptophlebiidae					
012	*Paraleptophlebia* sp.	1	0	8	0	0
	Tricorythidae					
015	*Tricorythodes* sp.	8	8	6	5	8
	Trichoptera					
	Brachycentridae					
016	*Brachycentrus* sp.	1	4	4	1	2
	Glossosomatidae					
115	*Glossosoma* sp.	7	13	23	4	14
	Hydropsychidae					
017	*Arctopsyche* sp.	3	0	0	2	1
018	*Cheumatopsyche* sp.	1	3	2	0	3
019	*Hydropsyche* sp.	59	47	82	195	141
	Hydroptilidae					
020	*Hydroptila* sp.	8	1	2	0	2
021	*Stactobiella* sp.	0	0	1	0	2
	Limnephilidae					
116	*Apatania* sp.	1	0	1	0	0
	Polycentropodidae					
117	*Neureclipsis* sp.	1	8	0	9	0
	Plecoptera					
025	Capniidae	149	111	104	109	81
	Chloroperlidae					
099	Chloroperlinae (early instar)	3	22	1	1	10
	Perlidae					
028	*Claassenia sabulosa*	12	7	8	17	1
	Perlodidae					
029	*Cultus* sp.	0	1	8	1	0
030	*Isogenoides* sp.	1	3	0	1	1
031	*Isoperla* sp.	7	20	3	18	1
032	Perlodidae (early instar)	1	60	0	26	33

(continued)

Site 7 - October 1995 (continued)

Species Code	Taxa	Number per Sample (0.0892 m^2) 1	2	3	4	5
	Pteronarcyidae					
033	*Pteronarcella badia*	0	0	0	1	0
	Taeniopterygidae					
035	*Taenionema* sp.	181	157	137	152	214
	Diptera					
	Ceratopogonidae					
037	*Bezzia/Palpomyia* gp.	0	1	18	2	2
	Empididae					
039	*Hemerodromia* sp.	8	2	0	0	0
	Tipulidae					
133	*Antocha* sp.	0	0	9	0	8
123	*Dicranota* sp.	1	0	0	0	0
	Chironomidae					
	Chironominae					
	Chironomini Tribe					
044	*Cryptochironomus* sp.	8	0	0	0	16
046	*Paracladopelma/Cyphomella* spp.	16	0	8	8	0
048	*Polypedilum* spp.	11	20	14	25	2
138	*Stictochironomus* sp.	8	0	0	0	0
	Tanytarsini Tribe					
052	*Cladotanytarsus* sp.	0	0	1	0	0
054	*Micropsectra* sp.	391	284	379	362	316
055	*Rheotanytarsus* sp.	351	471	346	337	266
057	*Sublettea* sp.	80	104	96	144	168
058	*Tanytarsus* sp.	8	24	56	8	24
	Orthocladiinae					
062	*Cardiocladius* sp.	33	24	18	9	33
063	*Cricotopus/Orthocladius* spp.	600	617	461	903	821
064	*Eukiefferiella* sp.	3	5	5	0	2
105	*Heleniella* sp.	0	0	0	0	8
065	*Nanocladius* sp.	0	8	32	0	0
067	*Parakiefferiella* sp.	24	48	32	16	24
109	*Psectrocladius* sp.	0	8	0	0	0
070	*Synorthocladius* sp.	64	104	56	64	57
071	*Thienemanniella* sp.	8	0	0	0	8
072	*Tvetenia* sp.	119	92	146	71	129
	Tanypodinae					
	Pentaneurini Tribe					
077	*Thienemannimyia* gp.	39	46	21	21	17
085	Hydracarina	77	218	218	216	240

(continued)

Site 7 - October 1995 (concluded)

Species Code	Taxa	Number per Sample ($0.0892\ m^2$) 1	2	3	4	5
	Haplotaxida					
087	Enchytraeidae	17	24	16	48	64
088	Naididae	117	104	16	85	140
089	Tubificidae	1	9	34	40	36
092	Nematoda	26	32	36	20	26

APPENDIX F

BASIC COMPUTATIONS AND STATISTICAL ANALYSES OF BENTHIC INVERTEBRATE DATA, OCTOBER 1995

Appendix F-1. **Total number (N) of taxa, number of EPT taxa, total number of organisms, total standing crop and species diversity of benthic invertebrate samples with means and 95% confidence limits (CL) per site, October 1995.**

Site-Sample	Total Number of Taxa	Number of EPT Taxa	Total Number of Organisms	Total Standing Crop (N/m^2)	Species Diversity*
1-1	31	12	757	8,487	2.39
1-2	33	16	926	10,381	2.34
1-3	30	13	752	8,430	2.48
1-4	34	13	1,072	12,018	2.14
1-5	32	14	918	10,291	2.47
Mean ± 95% CL	32 ± 2	14 ± 2	885 ± 166	9,922 ± 1,865	2.36 ± 0.17
2-1	32	15	2,926	32,803	2.11
2-2	33	14	2,554	28,632	2.05
2-3	35	14	2,886	32,354	2.40
2-4	37	18	2,884	32,332	2.25
2-5	39	17	3,672	41,166	2.19
Mean ± 95% CL	35 ± 4	16 ± 2	2,984 ± 512	33,457 ± 5,744	2.20 ± 0.17
3-1	31	11	2,573	28,845	2.10
3-2	32	12	4,892	54,843	2.03
3-3	26	9	4,036	45,247	1.87
3-4	36	15	4,175	46,805	2.11
3-5	33	15	4,361	48,890	1.93
Mean ± 95% CL	32 ± 5	12 ± 3	4,007 ± 1,074	44,926 ± 12,041	2.01 ± 0.13
4-1	44	22	2,033	22,791	2.62
4-2	35	14	3,503	39,271	1.86
4-3	33	13	4,779	53,576	2.04
4-4	35	16	4,833	54,182	2.14
4-5	41	20	5,071	56,850	2.26
Mean ± 95% CL	38 ± 6	17 ± 5	4,044 ± 1,589	45,334 ± 17,816	2.19 ± 0.35
5-1	31	14	3,219	36,087	2.23
5-2	35	17	3,276	36,726	2.16
5-3	35	15	3,268	36,637	2.35
5-4	36	17	3,540	39,686	2.32
5-5	35	15	3,732	41,839	2.33
Mean ± 95% CL	34 ± 2	16 ± 2	3,407 ± 274	38,195 ± 3,074	2.28 ± 0.10
6-1	32	14	2,099	23,531	2.04
6-2	34	14	2,603	29,182	2.11
6-3	34	16	3,570	40,022	2.16
6-4	34	17	3,214	36,031	2.07
6-5	36	17	2,430	27,242	2.16
Mean ± 95% CL	34 ± 2	16 ± 2	2,783 ± 742	31,202 ± 8,322	2.11 ± 0.07
7-1	45	22	2,987	33,487	2.75
7-2	39	18	3,121	34,989	2.81
7-3	42	20	3,149	35,303	2.80
7-4	36	18	3,763	42,186	2.63
7-5	41	19	3,788	42,466	2.73
Mean ± 95% CL	41 ± 4	19 ± 2	3,362 ± 475	37,686 ± 5,329	2.74 ± 0.09

* Shannon-Weaver Index

Appendix F-2. **Number (N) of organisms for major taxonomic groups for each sample with total number, mean number and mean standing crop (SC) per site, October 1995.**

	Number of Organisms					
Site-Sample	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Oligochaeta	Others
1-1	194	2	59	440	10	52
1-2	198	18	81	533	16	80
1-3	155	6	57	466	16	52
1-4	143	10	33	783	12	91
1-5	226	13	92	489	15	83
Total Number	916	49	322	2,711	69	358
Mean Number	183	10	64	542	14	72
Mean SC (N/m^2)	2,054	110	722	6,079	155	803
2-1	358	67	80	2,048	81	292
2-2	276	44	129	1,900	24	181
2-3	531	42	304	1,838	44	127
2-4	285	23	199	2,122	73	182
2-5	536	28	202	2,574	78	254
Total Number	1,986	204	914	10,482	300	1,036
Mean Number	397	41	183	2,096	60	207
Mean SC (N/m^2)	4,453	457	2,049	23,502	673	2,323
3-1	424	37	236	1,811	5	60
3-2	416	64	296	3,910	42	164
3-3	286	21	186	3,308	12	223
3-4	379	13	232	3,276	161	114
3-5	458	31	250	3,241	192	189
Total Number	1,963	166	1,200	15,546	412	750
Mean Number	393	33	240	3,109	82	150
Mean SC (N/m^2)	4,401	372	2,691	34,857	924	1,682

(continued)

Appendix F-2. (continued)

Site-Sample	Number of Organisms					
	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Oligochaeta	Others
4-1	410	302	139	1,072	36	74
4-2	599	86	120	2,229	201	268
4-3	1,181	93	160	3,022	154	169
4-4	894	120	157	3,206	180	276
4-5	832	346	265	3,094	130	404
Total Number	3,916	947	841	12,623	701	1,191
Mean Number	783	189	168	2,525	140	238
Mean SC (N/m^2)	8,780	2,123	1,886	28,303	1,572	2,670
5-1	779	54	248	1,946	24	168
5-2	658	60	193	2,149	51	165
5-3	601	65	258	2,139	40	165
5-4	730	60	236	2,307	72	135
5-5	795	38	223	2,360	112	204
Total Number	3,563	277	1,158	10,901	299	837
Mean Number	713	55	232	2,180	60	167
Mean SC (N/m^2)	7,989	621	2,496	24,442	670	1,877
6-1	123	61	107	1,634	35	139
6-2	207	69	169	1,998	25	135
6-3	320	111	167	2,691	74	207
6-4	277	126	173	2,451	50	137
6-5	174	90	167	1,822	15	162
Total Number	1,101	457	783	10,596	199	780
Mean Number	220	91	157	2,119	40	156
Mean SC (N/m^2)	2,469	1,025	1,756	23,758	446	1,749

(continued)

Appendix F-2. (concluded)

Site-Sample	Number of Organisms					
	Ephemeroptera	Trichoptera	Plecoptera	Chironomidae	Oligochaeta	Others
7-1	542	81	354	1,763	135	112
7-2	419	76	381	1,855	137	253
7-3	755	115	261	1,671	66	281
7-4	847	211	326	1,968	173	238
7-5	875	165	341	1,891	240	276
Total Number	3,438	648	1,663	9,148	751	1,160
Mean Number	688	130	333	1,830	150	232
Mean SC (N/m^2)	7,709	1,453	3,729	20,511	1,684	2,601

Appendix F-3. ANOVA, October 1995.

ANOVA on the Number of Taxa for Sites, October 1995

Source	DF	SS	MS	F	P
Site	6	300.286	50.048	5.57	0.0007*
Within	28	251.600	8.986		
Total	34	551.886			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-20.400
SE (Contrast)	11.216
SS (Contrast)	29.726
T-Statistic	-1.82
P (T-Statistic)	0.0797**

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	-16.600
SE (Contrast)	7.3426
SS (Contrast)	45.927
T-Statistic	-2.26
P (T-Statistic)	0.0317*

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Appendix F-3. (continued)

ANOVA on the Number of EPT Taxa for Sites, October 1995

Source	DF	SS	MS	F	P
Site	6	153.200	25.533	5.21	0.0010*
Within	28	137.200	4.900		
Total	34	290.400			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-14.000
SE (Contrast)	8.283
SS (Contrast)	14.000
T-Statistic	-1.69
P (T-Statistic)	0.1021**

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	-15.000
SE (Contrast)	5.422
SS (Contrast)	37.500
T-Statistic	-2.77
P (T-Statistic)	0.0099*

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Appendix F-3. (continued)

ANOVA on the Standing Crop of Organisms (Log Transformed) for Sites, October 1995

Source	DF	SS	MS	F	P
Site	6	1.53915	0.25652	30.61	0.0000*
Within	28	0.23466	0.00838		
Total	34	1.77381			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-3.2664
SE (Contrast)	0.3425
SS (Contrast)	0.7621
T-Statistic	-9.54
P (T-Statistic)	0.0000*

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	0.5356
SE (Contrast)	0.2242
SS (Contrast)	0.0478
T-Statistic	2.39
P (T-Statistic)	0.0239*

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Appendix F-3. (continued)

ANOVA on the Standing Crop of EPT (Log Transformed) for Sites, October 1995

Source	DF	SS	MS	F	P
Site	6	1.70140	0.28357	27.56	0.0000*
Within	28	0.28805	0.01029		
Total	34	1.98945			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-3.2470
SE (Contrast)	0.3795
SS (Contrast)	0.7531
T-Statistic	-8.56
P (T-Statistic)	0.0000*

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	0.5909
SE (Contrast)	0.2484
SS (Contrast)	0.0582
T-Statistic	2.38
P (T-Statistic)	0.0245*

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Appendix F-3. (concluded)

ANOVA on the Standing Crop of Chironomidae (Log Transformed) for Sites, October 1995

Source	DF	SS	MS	F	P
Site	6	1.80072	0.30012	26.34	0.0000*
Within	28	0.31907	0.01140		
Total	34	2.11978			

Orthogonal Contrasts

Contrast Number 1 (Background/Downstream)

Contrast Coefficients: 5 5 -2 -2 -2 -2 -2

Contrast	-3.3227
SE (Contrast)	0.3994
SS (Contrast)	0.7886
T-Statistic	-8.32
P (T-Statistic)	0.0000*

Contrast Number 2 (Near-field/Far-field)

Contrast Coefficients: 0 0 2 2 2 -3 -3

Contrast	0.6342
SE (Contrast)	0.2615
SS (Contrast)	0.0670
T-Statistic	2.43
P (T-Statistic)	0.0220*

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

APPENDIX G

RA ANALYSIS RESULTS, OCTOBER 1995

Appendix G. Species dominance distribution matrix for each sample, October 1995. The taxa represented by the species codes are listed in Table 6.

Site	1	1	1	1	1	7	7	7	7	7	2	5	2	2	2	5	6	5	6	6	5	2	5	6	3	6	3	3	3	3	4	4	4	4	4
Species Code / Sample	5	4	2	3	1	3	2	4	1	5	3	1	2	5	4	3	1	4	3	2	5	1	2	5	1	4	2	4	3	5	3	5	2	4	1
086	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
119	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
045	+	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
034	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
006	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
037	-	-	-	-	-	+	+	+	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
138	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
049	-	+	+	+	+	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
015	-	-	-	-	-	+	+	+	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
014	+	+	+	+	+	-	-	-	-	-	+	+	-	-	-	+	-	+	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-
052	-	-	+	-	-	+	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
041	-	+	-	-	-	-	-	-	-	-	-	-	+	-	-	+	-	+	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	+
133	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
033	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
117	-	-	-	-	-	-	+	+	+	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-
028	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	-	+	-	-	+	-	-	+	+	+	-	+	-	+	-	-	-	-	-
109	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
009	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
007	-	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-
099	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-	+	+	-	+	+	-	+	-	+	+
055	3	4	3	2	3	1	2	1	2	1	2	2	3	2	2	2	3	1	2	2	1	2	1	1	1	1	1	1	+	+	+	+	+	+	+
012	-	-	-	-	-	+	-	-	+	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	-	-	-	-	-	-	-	+	-	-	+
030	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+
058	-	+	-	+	+	+	+	+	+	+	+	-	+	+	-	-	+	+	+	-	+	-	+	+	+	-	+	-	+	+	-	+	-	-	-
065	+	+	+	+	+	+	+	-	-	-	-	+	+	+	+	-	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	-	+	-	+
087	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+	+	-	-	+	+	+	+	+
032	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	-	+	-	-	+	-	+	+	+	-	+	+	+	+	+	+	+	+	+
029	+	-	+	+	+	+	+	+	-	-	+	-	+	+	+	-	-	-	-	+	+	+	+	+	+	+	+	+	-	+	-	+	+	+	+
005	1	1	1	1	1	1	+	2	1	2	1	+	+	1	1	+	+	1	+	+	+	1	+	+	+	+	+	+	+	+	1	1	1	+	1
077	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	-	+	+	-	+	+
085	1	1	1	1	+	1	1	1	+	1	+	+	+	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	1	+	+
022	+	-	+	-	+	-	-	-	-	-	-	-	-	-	-	+	-	+	-	-	-	+	+	-	+	-	-	+	-	-	+	+	+	+	+
143	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
142	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
053	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
018	-	-	-	-	-	+	+	-	+	+	-	-	-	-	-	-	-	+	+	+	-	-	-	+	-	+	-	-	-	-	-	-	-	-	+
025	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
035	+	+	1	+	+	+	+	+	1	1	+	+	+	+	+	+	+	+	+	+	+	+	+	+	1	+	+	+	+	+	+	+	+	+	+
064	-	-	+	-	-	+	+	-	+	+	+	+	-	+	+	+	-	+	-	-	-	+	+	-	+	-	-	+	-	+	+	+	-	-	+
071	-	+	-	+	+	-	-	-	+	+	-	+	-	+	-	+	+	+	-	+	+	-	-	+	+	-	+	+	+	-	-	-	-	-	-

(continued)

Appendix G. (concluded)

Species Code	Site																																		
	1	1	1	1	1	7	7	7	7	7	2	5	2	2	2	5	6	5	6	6	5	2	5	6	3	6	3	3	3	3	4	4	4	4	4
	Sample																																		
	5	4	2	3	1	3	2	4	1	5	3	1	2	5	4	3	1	4	3	2	5	1	2	5	1	4	2	4	3	5	3	5	2	4	1
057	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
031	-	-	-	-	+	+	+	+	+	+	-	-	-	+	+	-	+	+	+	+	+	+	+	+	-	+	-	+	-	+	+	+	-	+	-
008	-	-	-	+	-	+	-	-	+	+	-	-	+	+	-	-	+	-	+	-	-	+	+	+	-	+	-	-	-	+	-	-	-	+	+
100	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
021	-	-	-	-	-	+	-	-	-	+	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
092	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
105	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	+	-	-	+	+	-	-	-	+	+	-	-	+	-	-	-	-	-	-	-
019	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
002	2	+	2	1	1	1	1	1	1	1	1	3	1	1	+	2	+	2	+	+	3	+	2	+	2	+	1	1	+	1	2	1	1	2	1
072	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
062	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
017	-	-	+	-	-	-	-	+	+	+	-	+	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
054	+	1	+	1	+	2	1	1	2	1	1	1	+	1	1	1	1	1	1	1	1	1	+	1	+	+	1	1	1	1	1	2	+	2	1
039	-	-	-	-	-	-	+	-	+	-	+	-	+	-	-	-	-	-	+	+	-	-	-	-	-	+	-	-	-	-	-	-	+	-	-
088	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	-	+	+	+	+	+	+	+	+	+	+
070	+	+	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+
089	+	-	-	-	-	+	+	+	+	+	+	+	-	-	-	-	+	-	+	+	+	-	-	-	+	-	+	+	+	+	+	+	+	+	+
048	+	-	+	-	+	+	+	+	+	+	+	-	-	+	+	+	+	+	+	+	+	+	-	-	+	+	+	+	-	+	+	+	+	+	+
067	-	+	+	-	-	+	+	+	+	+	+	-	-	+	+	-	-	-	-	+	-	+	-	-	+	-	-	-	-	-	+	+	+	+	+
063	3	6	4	5	5	2	3	4	3	3	5	5	7	7	7	6	8	6	7	8	6	8	7	8	8	9	9	8	9	9	7	7	9	7	5
046	-	-	-	-	-	+	-	+	+	-	+	-	-	+	+	+	-	-	-	+	+	+	-	+	+	-	-	+	-	-	+	-	-	+	+
104	-	-	-	-	+	-	-	-	-	-	-	+	-	-	-	+	-	+	-	-	+	-	+	-	+	-	+	+	-	+	-	-	-	-	-
115	-	-	-	-	-	+	+	+	+	+	-	+	+	+	+	-	+	+	+	+	+	+	+	+	-	+	-	-	-	+	+	+	+	+	+
038	-	-	-	-	-	-	-	-	-	-	+	-	+	+	+	+	-	-	-	-	-	-	+	+	-	+	-	-	+	+	+	+	+	+	+
123	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
023	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-	-	-	+	-	-	-	+	-	+	-	-	-
027	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-
016	+	+	+	-	-	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	+	-	+	-	+	-	-	+	+	+	+	1
044	-	-	+	-	-	-	-	-	+	+	-	-	-	-	-	-	-	+	-	-	-	-	+	+	-	-	-	+	+	+	+	+	+	+	+
081	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	+	-
095	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	+	-	-	-
020	-	-	-	-	-	+	+	-	+	+	+	-	-	-	+	+	+	-	-	-	+	+	+	-	-	-	+	-	-	-	+	+	+	+	+
004	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-	+
036	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	+	+	-	-
080	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+	-	-
116	-	-	-	-	-	+	-	-	+	-	-	-	+	-	+	+	-	-	-	-	-	-	-	-	-	-	-	+	-	-	-	+	-	-	+
137	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+
101	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	+

+ present

- absent

1 to 9 weighted species abundance score

APPENDIX H

PERCENT COMPOSITION OF BENTHIC INVERTEBRATE FUNCTIONAL FEEDING GROUPS, OCTOBER 1995

Appendix H. **Percent composition of benthic invertebrate functional feeding groups for each sample and means for each site, October 1995.**

Site-Sample	Functional Feeding Group (percent)						
	C	H	D	HC	DH	CD	O
1-1	10.6	2.9	30.5	-	56.0	-	0
1-2	10.8	6.0	33.2	-	48.3	-	1.7
1-3	12.9	1.7	33.9	-	50.7	-	0.8
1-4	9.2	0.5	39.9	-	49.4	-	0.9
1-5	12.2	4.6	34.9	-	46.9	-	1.4
Mean	11.1	3.1	34.5	-	50.3	-	1.0
2-1	6.8	1.1	33.0	0.3	57.2	0	1.6
2-2	7.1	3.1	33.1	0	54.7	0.4	1.6
2-3	5.9	5.3	37.6	0	49.8	0.3	1.1
2-4	7.5	4.1	36.3	0	51.4	0.1	0.7
2-5	8.3	3.1	29.5	<0.1	58.1	0.2	0.8
Mean	7.1	3.3	33.9	0.1	54.2	0.2	1.2
3-1	5.7	6.8	23.0	0	63.1	0	1.4
3-2	6.4	4.1	27.2	0	61.1	<0.1	1.1
3-3	6.8	2.7	29.0	0	60.9	<0.1	0.5
3-4	6.0	3.1	32.0	0	58.5	0	0.3
3-5	7.2	3.8	24.0	<0.1	64.0	0.3	0.6
Mean	6.4	4.1	27.0	<0.1	61.5	0.1	0.8
4-1	3.8	6.0	23.4	0	55.8	<0.1	11.0
4-2	8.2	3.3	14.4	0	72.7	0.3	1.0
4-3	4.9	2.5	22.3	0	69.2	<0.1	1.0
4-4	7.9	2.5	29.2	0	58.8	0.1	1.5
4-5	8.7	3.0	26.1	<0.1	56.2	0.1	5.8
Mean	6.7	3.5	23.1	<0.1	62.7	0.1	4.1
5-1	6.0	3.6	33.1	-	55.8	0	1.6
5-2	8.0	2.7	25.5	-	61.9	0.2	1.7
5-3	7.5	4.2	32.7	-	53.2	0.5	1.8
5-4	5.3	2.8	31.6	-	58.9	0	1.4
5-5	7.5	3.2	30.1	-	58.4	0	0.8
Mean	6.9	3.3	30.6	-	57.6	0.1	1.5
6-1	5.9	2.6	36.8	0	52.8	0	2.0
6-2	5.6	2.0	35.3	0	54.7	0.2	2.2
6-3	5.4	2.6	36.2	0	52.9	0.1	2.7
6-4	7.6	2.0	25.1	0.2	60.9	0.5	3.6
6-5	8.3	0.7	33.4	0	54.1	0.2	3.3
Mean	6.6	2.0	33.4	0.1	55.1	0.2	2.8
7-1	6.1	6.6	46.2	-	38.7	0.3	2.2
7-2	12.9	5.5	45.6	-	34.0	0.1	2.0
7-3	9.4	5.1	43.6	-	39.1	0	2.8
7-4	8.3	4.1	35.0	-	47.1	0	5.5
7-5	9.3	6.1	36.0	-	44.7	0	3.9
Mean	9.2	5.5	41.3	-	40.7	0.1	3.3

APPENDIX I

REPEATED MEASURES ANALYSES FOR PRE-OPERATIONAL AND OPERATIONAL DATA, 1989 - 1995

Appendix I. Repeated measures, October 1995.

Repeated Measures Analysis on the Total Number of Taxa (Log Transformed), Fall 1989 to 1995

Source	DF	SS	MS	F	P
Year	6	1.683	0.280	23.520	0.000*
Year x Area	12	0.203	0.017	1.421	0.224**
Error	24	0.286	0.012		
Temporal 1989 vs 1990 - 1995					
Spatial BG vs DS					
Hypothesis	1	1.191	1.191	2.979	0.159**
Error	4	1.599	0.400		
Spatial NF vs FF					
Hypothesis	1	0.028	0.028	0.069	0.806**
Error	4	1.599	0.400		
Temporal 1994 vs 1995					
Spatial BG vs DS					
Hypothesis	1	0.023	0.023	1.974	0.233**
Error	4	0.047	0.012		
Spatial NF vs FF					
Hypothesis	1	0.007	0.007	0.580	0.489**
Error	4	0.047	0.012		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Repeated Measures Analysis on the Number of EPT Taxa (Log Transformed), Fall 1989 to 1995

Source	DF	SS	MS	F	P
Year	6	1.759	0.293	19.253	0.000*
Year x Area	12	0.304	0.025	1.661	0.140**
Error	24	0.366	0.015		
Temporal 1989 vs 1990 - 1995					
Spatial BG vs DS					
Hypothesis	1	0.739	0.739	2.107	0.220**
Error	4	1.403	0.351		
Spatial NF vs FF					
Hypothesis	1	0.032	0.032	0.090	0.779**
Error	4	1.403	0.351		
Temporal 1994 vs 1995					
Spatial BG vs DS					
Hypothesis	1	0.003	0.003	0.097	0.771**
Error	4	0.135	0.034		
Spatial NF vs FF					
Hypothesis	1	0.011	0.011	0.339	0.591**
Error	4	0.135	0.034		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Appendix I. (continued)

Repeated Measures Analysis on the Total Number of Organisms (Log Transformed), Fall 1989 to 1995

Source	DF	SS	MS	F	P
Year	6	22.483	3.747	23.444	0.000*
Year x Area	12	3.387	0.282	1.766	0.114**
Error	24	3.836	0.160		
Temporal 1989 vs 1990 - 1995					
Spatial BG vs DS					
Hypothesis	1	4.642	4.642	0.945	0.386**
Error	4	19.640	4.910		
Spatial NF vs FF					
Hypothesis	1	25.731	25.731	5.241	0.084**
Error	4	19.640	4.910		
Temporal 1994 vs 1995					
Spatial BG vs DS					
Hypothesis	1	0.390	0.390	1.901	0.240**
Error	4	0.820	0.205		
Spatial NF vs FF					
Hypothesis	1	0.186	0.186	0.906	0.395**
Error	4	0.820	0.205		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Appendix I. (continued)

Repeated Measures Analysis on the Number of EPT (Log Transformed), Fall 1989 to 1995

Source	DF	SS	MS	F	P
Year	6	10.832	1.805	7.335	0.000*
Year x Area	12	2.000	0.167	0.677	0.756**
Error	24	5.907	0.246		
Temporal 1989 vs 1990 - 1995					
Spatial BG vs DS					
Hypothesis	1	4.561	4.561	3.200	0.148**
Error	4	5.701	1.425		
Spatial NF vs FF					
Hypothesis	1	1.105	1.105	0.776	0.428**
Error	4	5.701	1.425		
Temporal 1994 vs 1995					
Spatial BG vs DS					
Hypothesis	1	0.233	0.233	1.099	0.354**
Error	4	0.848	0.212		
Spatial NF vs FF					
Hypothesis	1	0.026	0.026	0.125	0.742**
Error	4	0.848	0.212		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)

Appendix I. (concluded)

Repeated Measures Analysis on the Number of Chironomidae (Log Transformed), Fall 1989 to 1995

Source	DF	SS	MS	F	P
Year	6	32.780	5.463	19.705	0.000*
Year x Area	12	7.136	0.595	2.145	0.054**
Error	24	6.654	0.277		
Temporal 1989 vs 1990 - 1995					
<u>Spatial BG vs DS</u>					
Hypothesis	1	5.471	5.471	0.514	0.513**
Error	4	42.537	10.634		
<u>Spatial NF vs FF</u>					
Hypothesis	1	82.205	82.205	7.730	0.050*
Error	4	42.537	10.634		
Temporal 1994 vs 1995					
<u>Spatial BG vs DS</u>					
Hypothesis	1	0.329	0.329	1.116	0.350**
Error	4	1.179	0.295		
<u>Spatial NF vs FF</u>					
Hypothesis	1	0.252	0.252	0.856	0.407**
Error	4	1.179	0.295		

* Significant ($p < 0.05$)
** Not Significant ($p > 0.05$)