APPENDIX 7D

MULTIVARIATE ANALYSIS OF BENTHIC INVERTEBRATE DATA - COMBINED STUDY AREA

APPENDIX 7D.1

MULTIVARIATE ANALYSIS - TEXT, TABLES, AND FIGURES

A Multivariate Analysis of Benthic Invertebrate Data Combined from Aberjona River Study Area and the Northern Study Area

Introduction

Baseline Ecological Risk Assessments (BERAs) have been prepared for the Northern and Southern Study Areas of the MSGRP RI by Metcalf & Eddy, Inc. for USEPA Region I. The Southern Study Area Risk Assessment, entitled *"Baseline Human Health and Ecological Risk Assessment Report, Wells G&H Superfund Site, Aberjona River Study, Operable Unit 3"* was released by USEPA in September 2004 (M&E, 2004). The Northern Study BERA is contained within Appendix 7A of this report. Both BERAs included benthic invertebrate surveys and habitat assessments, collected as part of the Triad sampling (defined in USEPA 1992). The data were evaluated separately in the two BERAs. Results in both of the BERAs indicated some patterns of community impairment associated with contaminant distributions, as well as effects of other habitat variables (hydrology, depth, dissolved oxygen concentrations) on the species composition and abundance of benthic invertebrates. To further evaluate the relative significance contaminant concentrations in sediments have on the benthic invertebrate community in the combined study area, a multivariate analysis of the benthic invertebrate data was conducted in conjunction with an analysis of environmental variables. Environmental variables included physical and chemical measurements made during the survey, as well as sediment concentrations of contaminants of concern.

Background

Two types of multivariate ordination techniques that are typically used in analyzing invertebrate data are correspondence analysis (CA) and canonical correspondence analysis (CCA). The CA is an indirect gradient analysis technique that uses only the invertebrate data to indicate differences among stations. This means that patterns of dissimilarity among stations that are determined from a CA are based exclusively on the invertebrate data, and do not incorporate environmental data (e.g., habitat and chemical data) to explain possible reasons (causes) behind the differences in invertebrate communities among stations.

The second type of multivariate ordination technique, the CCA, also determines patterns of dissimilarity among stations, but the CCA incorporates environmental data to explain patterns in the invertebrate communities that are directly related to the environmental data collected at the stations. As the CA is an indirect gradient analysis technique, the CCA is a direct gradient analysis technique in that it constrains the ordination directly to the environmental data to find patterns that explicitly relate the differences in invertebrate communities to differences in environmental variables among stations.

Multivariate ordination techniques (including CA and CCA) can provide several aspects (or dimensions) of community structure and these are expressed as ordination axes in the analysis. Several ordination axes are derived from a multivariate analysis (typically four axes), and each ordination axis is essentially a numeric representation of a specific pattern in the invertebrate communities among stations. The concept of patterns in data structure as represented by ordination axes is somewhat analogous to obtaining several different visual perspectives of a multi-faceted object: each vantage point can provide different and yet relevant information about the object. Each ordination axis represents a specific pattern of taxa structure among stations, which is based on differences in taxa richness and abundance among the stations. Consequently, the ordination axis also represents a gradient, and each station is assigned a derived value called a site score that places it along this gradient at a position relative to how different (i.e., similar or dissimilar) stations are with respect to the invertebrate structure. In other words, the degree of difference between any two stations is based on how numerically close the axis site scores are for the two stations; two stations with site scores that are numerically close indicate that the invertebrate communities of the stations are similar, and conversely, two stations with site scores that are relatively different indicates that the invertebrate communities of the stations are dissimilar.

The unit of strength of an ordination axis is the eigenvalue, which is somewhat analogous to a correlation coefficient, and the relative strength of the patterns in data structure are indicated by the magnitude of the eigenvalue. In a CA, the first axis always has the highest eigenvalue, and successive axes (e.g., 2-4) have successively lower eigenvalues. The same is generally true with a CCA, but if the ordination is constrained to a single environmental variable, for example, the first axis can have a lower eigenvalue than the second axis. This could occur when the environmental variable used to constrain the analysis does not explain a majority of the variance among the data, and the successive ordinations axes would have higher eigenvalues that indicate that other undefined environmental variables are responsible for the majority of variance in the data. However, if only a single environmental variable is considered relevant to an analysis, constraining the ordination to the variable in a CCA will indicate the community-structure pattern within the invertebrate data that is most strongly associated with the environmental variable.

Methods

Samples were collected at 5 reference stations and 15 non-reference locations south of Route 128 (Metcalf & Eddy, 2004), and at 5 reference stations and 8 non-reference stations north of Route 128 (Appendix 7A). Three reference locations were re-samples. Station MC-01 (S. Branch of Aberjona River) was re-sampled as 01IP, station MC-03 (Phillips Pond) was re-sampled as 03IP, and station MC-04 (Hall's Brook) was re-sampled as 04IP. A field duplicate was collected at MC-08, and is presented as a separate sample as MC-08FD. Samples for the Northern Study Area were collected in late June 1999 and in the Aberjona River study area (south of 128) in late June 2001.

Methods of data collection were similar for each study and were presented in each separate ERA. Triplicate sediment samples were collected by Eckman dredge, and taxonomic identification and enumerations were conducted on each replicate by the same laboratory using methods in USEPA (1999). For the multivariate ordinations, the counts from each replicate were added together to represent the abundance for each species at each station.

The environmental data included variables identified in the BERAs as showing influence on the distribution of benthic invertebrates among these stations. These variable included depth of water, dissolved oxygen concentration (DO) of the overlying water, total organic carbon content (TOC) of the sediment, acid volatile sulfide (AVS) concentration of the sediment and a ratio of arsenic concentration to iron concentration (As:Fe) measured in the sediment. In addition to these environmental variables, a sixth habitat variable was also assigned as "flow", which represented the flow regime and the relative depositional nature of the station. A value of 0 was used to represent pond (lentic) locations, 1 for still water areas within a wetland that may occasionally experience flow during high water conditions, 2 for stations adjacent to a channel or in a back channel that periodically (more frequently) experiences flow, and 3 for stream locations with low to moderate flow. The range of 0 to 3 for this variable represented stations from most to the least depositional, respectively, based on field observations.

The As:Fe variable was used to represent the gradient of contamination within the study area that was most frequently associated with toxicity, based on the laboratory toxicity studies**.** In separate laboratory toxicity tests, the As:Fe ratio at a station was determined to be significantly correlated to the survivability and growth of *in vitro* test organisms. Furthermore, over the combined study area, the site-specific As:Fe ratios and mean PEC quotients were strongly correlated (Spearman rho = 0.783, $p < 0.001$). The PEC quotient for each station was derived from the mean values of all the primary COPC sediment metal concentrations, divided by the probable effects concentrations (PEC) obtained from MacDonald *et al.*, 2000. Because the As:Fe ratio was most strongly related to toxicity, it was selected for use as a surrogate variable to represent the gradient of bioavailable sediment arsenic (fraction of the total) contamination among stations in the analyses

The taxa data were determined to show a unimodal response to environmental gradients and the data set had many 0 values (for taxa absent at some or many stations). Therefore, correspondence analysis (CA) and canonical correspondence analysis (CCA) were selected as the appropriate analyses methods to determine the relations between the environmental variables and the invertebrate community structure (Fitzpatrick, et al, 1988). Species data were square-root transformed, and down weighting of rare species was applied. Biplot scaling was utilized focusing on inter-sample distances. The environmental variables were evaluated individually for how well the data points fit a normal distribution. The data spread for Depth, As:Fe, AVS, and TOC were highly skewed, and accordingly these variables were log transformed to produce a more normal distribution. Additionally, all six environmental variables were standardized to the same scale (0 to 1) for use in the ordinations, so that data variability rather than magnitude was the factor of influence. A CA was used to determine the strongest patterns in the invertebrate data among the stations (represented by CA ordinations axes 1-4). The environmental dataset was subsequently incorporated into the CA so that the environmental variables could be independently compared with the ordination axes to determine which of the variables were most closely related to patterns of invertebrate community structure. The initial run of the CA indicated that station MC-05 had an extreme influence on the ordination axes, and this station was made supplementary in subsequent analyses.

A CCA was used to constrain the ordination to the As:Fe ratio (the surrogate for contamination, representing the bioavailable fraction of sediment arsenic), the results of which indicated the strongest pattern within the invertebrate data that was related to the gradient of bioavailable sediment arsenic among stations. An initial run of the CCA indicated that stations MC-05 and MC-07 were outliers in the gradient (i.e., had a larger As:Fe ratio and affect on taxa), and consequently these two stations were made supplementary in subsequent analyses. (See further explanation in the Results section). Using the taxa and site scores derived from the CCA analysis, the invertebrate data matrix (Table 2 of Appendix 7D.2) was resorted by rows and columns to indicate the pattern of the invertebrate community structure that was most strongly related to the gradient of contamination, represented by As:Fe ratio.

All multivariate ordinations were done with Canoco 4.5 software (ter Braak and Smilauer, 2002). All correlations and scatterplots were done with SYSTAT, version 8.0 statistical software (SPSS, Inc., 1998).

Results

The results of the two separate studies are in M&E (2004) and in Appendix 7A. Appendix 7D.2 of this RI provides a combined matrix of benthic invertebrate taxonomic data and a table of environmental data from the combined study area.

An ordination plot of the invertebrate site scores indicated that the reference stations were not different as a group from the other stations (Figure 1). The ordination plot only shows the first two axes of the CA, and the arrangement of stations on the plot can be considered to represent the first and second strongest dimensions of the invertebrate community structure. The position of the station on the plot is related to the composition of the species in the samples; two samples with similar species composition will be located closer together on the plot. The stations with greater water depth, including UF and station 4 from Mystic Lake, along with the two samples from the reference ponds (Phillips Pond, MC-03 and 03IP) are clustered together, indicating similar species compositions. Had the references stations been different, they would have been expected to appear together on the ordination plot as either a separate cluster, or at the extremes of either Axis 1 (horizontal scale -- first strongest dimension of community structure) or Axis 2 (vertical dimension -- second strongest dimension of community structure).

Station MC-05 does not appear in the ordination plot because it was treated as supplementary in the analysis (Figure 1). When MC-05 was included in the analysis it had an overwhelming influence on the ordination, because it was represented by a single chironomid (*Heterotrissocladius* sp.) that was not observed at any other station. Therefore, station MC-05 was so drastically different from any other station that including it in the ordination had the undesirable effect of the other stations appearing to be relatively similar. By making station MC-05 supplemental, the data from that sample was not used to influence the station scores of the ordination axes.

Station MC-07 is shown as most dissimilar to all of the other stations in the ordination plot (Figure 1) after MC-05 was treated as supplementary in the analysis. MC-07 was also distinct from the other stations, as it also had a very sparse benthic community with a single individual of *Chaoborus punctipenis* present in the three grab samples. However, this species was also observed at MC-02 and in both samples from Phillips Pond (MC-03 and 03-IP), causing the observed similarity of MC-07 to these stations in the CA.

The ordination plot also shows the closer clustering of the samples from south of Route 128 from the 38-acre wetland and the Cranberry Bog (reaches 1 & 2 of the Aberjona River Study

Area), indicating the underlying similarities in species composition. The samples from the Northern Study Area (samples from the Hall's Brook Holding Area and Hall's Brook Holding Area Wetlands, MC-06 through MC-13) are generally found outside this cluster of samples, indicating different species composition.

The addition of the environmental variables in the CA is shown in Figure 2. The sample locations in the CA are still defined by the taxa composition among stations, and are consequently identical to those in Figure1, because a CA is not (by definition) dependent on the environmental data to discern patterns among the stations. The environmental variables in Figure 2 overlay the same station points that have identical position coordinates in Figure 1, which facilitates evaluating relations between environmental variables and the invertebrate community structure among stations. On the ordination plot showing the addition of the environmental data (Figure 2), each arrow represents an environmental variable, which is labeled at the end of the arrow. The direction of the arrow indicates potential importance of an environmental variable to the invertebrate community structure along the gradient of stations to which the arrow is most closely aligned, and the length of the arrow represents the strength of that correlation. For example, Figure 2 shows that the alignment of the "Depth" variable indicates that the greatest depths are seen in Phillips Pond and Mystic Lake samples, and further implies that depth is an important factor influencing the invertebrate assemblages at these stations. The angles between the arrows of any two environmental variables indicate the degree of correlation between them (Leps and Smilauer, 2003). At roughly 90 degrees apart, the variables "Depth"and TOC appear essentially non-correlated. However, DO and AVS concentrations are likely to be correlated, and the variables "Flow" (depositional character of the station) and "Depth" are shown as reciprocals of each other.

It is important to understand that the ordination plots shown in Figures 1 and 2 are relevant only to the two strongest patterns in invertebrate structure among stations, because only two dimensions can be shown in the plot (i.e., X and Y coordinates depicted as axes one and two). The patterns among the stations and environmental variables in Figure 2 indicate that the two strongest patterns in the invertebrate data are not closely related to As:Fe, the variable representing the gradient of contamination. The patterns in Figure 2 further indicate that the habitat-related variables were more influential on the invertebrate community than the gradient of contamination. This result is often the consequence of not having closely standardized sampling locations, which is not necessarily a fault in the study design when sample locations are limited. Under these circumstances, it is necessary to recognize that habitat variables can often be the most influential in determining which invertebrate taxa are present at a station, and that invertebrate patterns associated with gradients of contamination may not be as strong, but can still be relevant (Rogers et al, 2002).

Another way to evaluate the degree of association between the environmental variables and the invertebrate samples is to calculate correlation coefficients between the invertebrate site scores (derived from the CA) and the individual environmental variables (Table 1). This procedure has the added advantage of evaluating site scores beyond the first- and second-ordination axes, so if an environmental variable happens to be more strongly related to the third or forth ordination axis (as explained above), the results will be apparent in a relatively high correlation coefficient for the variable on the relevant axis.

The values in Table 1 indicate the relations were not strong between the invertebrate community and variable that represent contamination (As:Fe) on the first three ordination axes, and that the mainly habitat-related variables were most influential in defining the three strongest patterns of community structure. However, the eigenvalues of the four ordination axes were relatively strong (0.557 to 0.348), which indicates that even the fourth ordination axis represents a strong pattern in the invertebrate community structure.

Based on the environmental data used in the analysis, the strongest factors affecting the invertebrate community were AVS content of the sediment, depth of the sampling location, DO, flow regime, and to a less extent, TOC. Additionally, these relations were the most significant in terms of probability values, with all having p-values less than 0.05 along at least one of ordination axes 1-3 (Table 2). None of the habitat-related environmental variables had significant correlations with ordination axis 4, although the correlation with As:Fe was highly significant (Table 2). Furthermore, the relation between Axis 4 and As:Fe was determined to be even stronger when the values of As:Fe were log transformed (Tables 1 and 2, last row). Therefore, because Axis 4 had a relatively high eigenvalue (0.348) and also had a strong correlation with As:Fe and no other environmental variable, the gradient of bioavailable sediment arsenic was likely an important factor that influenced the pattern of invertebrate community structure represented by Axis 4. Consequently, the CCA was used to assess the likelihood and significance of a pattern in the invertebrate community structure that could be related directly As:Fe.

The CCA was run by constraining the ordination of the invertebrate data to only the variable As:Fe. In addition to making station MC-05 supplementary, the initial CCA run indicated that station MC-07 did not contribute to the relation, because the single taxon collected there (see description, above) did not provide enough information to indicate how the station responded to the gradient of contamination. Therefore, stations MC-07 and MC-05 were made supplementary in the final CCA. The results of the CCA indicated that a strong relation existed between As:Fe and the invertebrate community structure, but the CCA additionally indicated that other environmental factors were somewhat more influential in the differences among stations. These results are consistent with the results of the CA and the associated correlation analyses, which found that As:Fe was most strongly correlated on the fourth ordination axis of the CA. However, a correlation between the CCA axis 1 site scores and the log As:Fe was very strong ($r = 0.874$, $p < 0.001$), and appeared relatively consistent over the entire gradient of contamination (Figure 3).

The site and species scores that were derived from the CCA were used to resort the invertebrate data matrix to indicate the pattern of the invertebrate community structure that corresponded to As:Fe (Table 4 of Appendix D.2). The pattern in the resorted matrix indicates how the overall taxa structure of the invertebrate communities changes from the less to the more contaminated stations. *Lumbriculus* , for example, was seen only at the less contaminated stations, whereas *Clinotanypus* (a chironomid) was generally seen at only the more contaminated stations.

<u>Conclusions</u>

Multivariate analysis of the benthic invertebrate data from the combined study areas (Wells G&H and Industri-Plex Superfund Sites) indicates that environmental variables such as depth, DO, TOC, and AVS have the strongest influence on the benthic community structure. Based on the study design, which included stations selected over a variety of habitat types, the large variation in the benthic community corresponding to habitat variables is expected. However, after accounting for these variables, the CCA shows a portion of the community structure is strongly correlated to sediment As:Fe ratio (estimator of the bioavailability of sediment arsenic) (r = 0.874, $p < 0.001$). These results are consistent with results of the toxicity testing which showed subtle reductions in growth and survival of test organisms that were more strongly correlated to As:Fe ratios than sediment arsenic alone or other detected sediment contaminants. The levels of contaminants observed outside of the HBHA Pond correspond to detectable but small changes in community composition correlated to contaminant concentrations in the sediment, particularly with As:Fe ratios. The analysis indicates that the benthic community shows shifts in community composition which is associated with the sediment As:Fe ratio. The community analyses also support the conclusions that the community structure at the two deep stations in HBHA Pond are uniquely impaired and dissimilar to other study area and reference stations. This analysis supports the conclusions for the combined BERAs that there are severe impacts to benthic invertebrates in HBHA Pond and lower impacts to benthic communities downgradient of the HBHA Pond (in the HBHA Wetlands and in the Well G&H 38-Acre Wetland) which were strongly associated with sediments with high As:Fe ratios.

References

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USEPA 1999. Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition, USEPA Office of Water, EPA 841-B-99-002 (http://www.epa.gov/owow/monitoring/rbp/).

	AX1	AX2	AX3	AX4
Eigenvalues[1]	0.557	0.468	0.435	0.348
Cumulative Variance[2]	27.1	54.2	56.6	69.3
DEPTH	0.381	0.703	0.540	-0.125
DO	0.315	-0.682	-0.489	0.164
FLOW	-0.470	-0.665	-0.473	0.112
As:Fe	0.130	-0.067	0.054	-0.607
AVS	0.633	-0.117	0.315	-0.270
TOC	-0.467	0.206	-0.180	0.265

Table 1. Correlation matrix of the invertebrate community structure with environmental variables. The values in this table are the Pearson correlation coefficients between the four expressions of the Invertebrate Community Site Score (see Figure 2, above) and the environmental (physical and chemical) variables collected at the stations. The variables Depth, As:Fe, AVS, and TOC were log transformed to produce a normal distribution of the data. AX1 to AX4 are scores from the first four axes of the ordination. The Environmental variables are presented in Table 3 of Appendix D2.

[1] Eigenvalues measure the importance of each axis (values range between 0 and 1)

[2] The cumulative percentage of the variance of the species-environment relation explained by each axis.

	AX1	AX2	AX3	AX4
DEPTH	**0.029**	**<0.000**	**0.001**	0.490
DO	0.074	**<0.000**	**0.004**	0.361
FLOW	**0.006**	**<0.000**	**0.005**	0.535
As:Fe	0.470	0.713	0.767	**<0.000**
AVS	**<0.000**	0.525	0.079	0.135
TOC	**0.007**	0.258	0.325	0.143

Table 2. The probability matrix for the above correlation coefficients (uncorrected), which indicates the significance of the relations seen in Table 1, above. Assuming alpha at a level of 0.05, the bolded values indicate significant correlations.

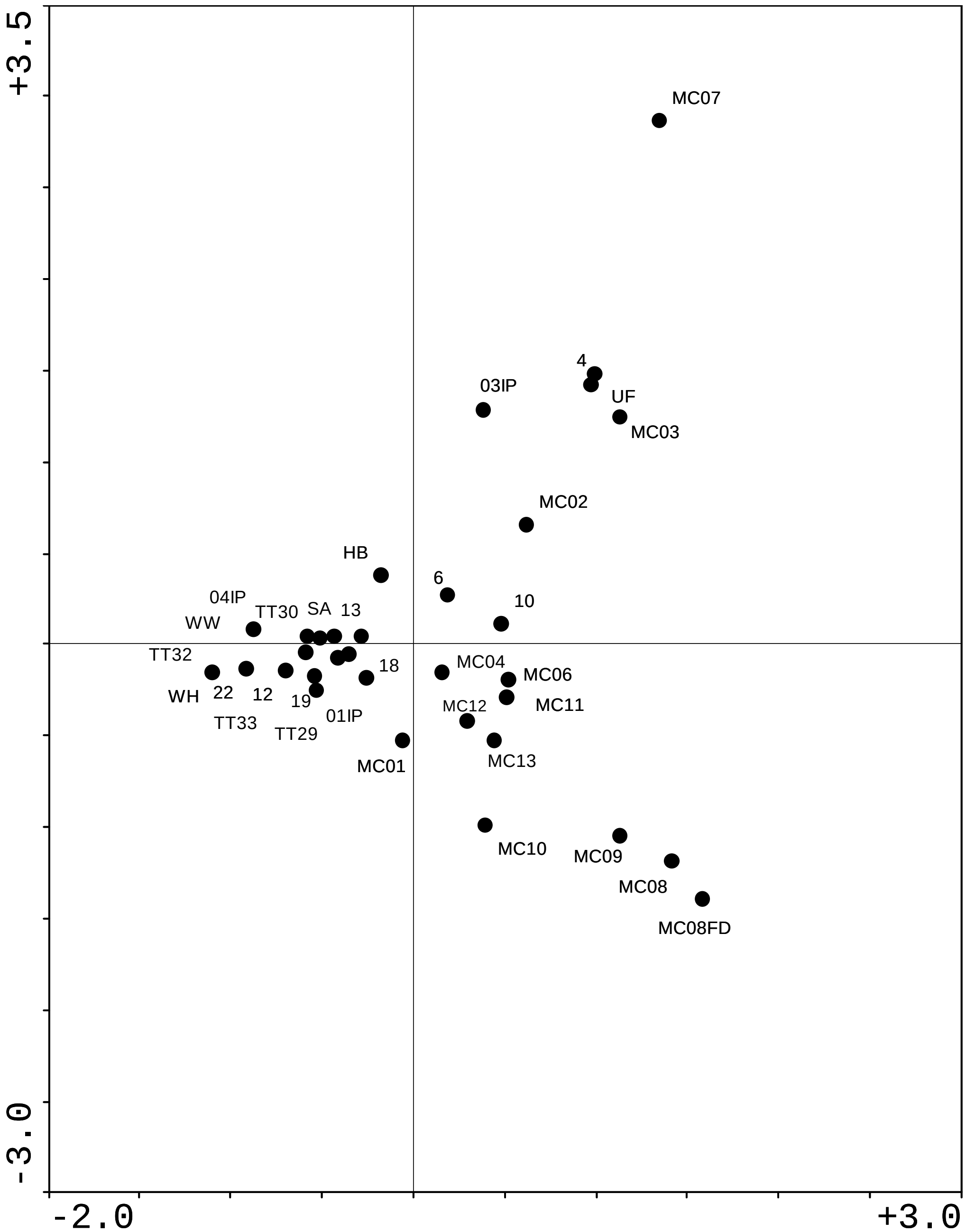

Figure 1. Ordination biplot (first two ordination axes of CA) of invertebrate data collected from the combined study area. The points on the figure represent the stations and their relative distance from one another represents the difference among the stations on the basis of the invertebrate assemblages. The scales on the ordinate and abscissa represent the relative differences among stations. Station MC-05 was designated as supplemental in the analysis, and does not appear in the figure because it had no taxa in common with any of the other stations.

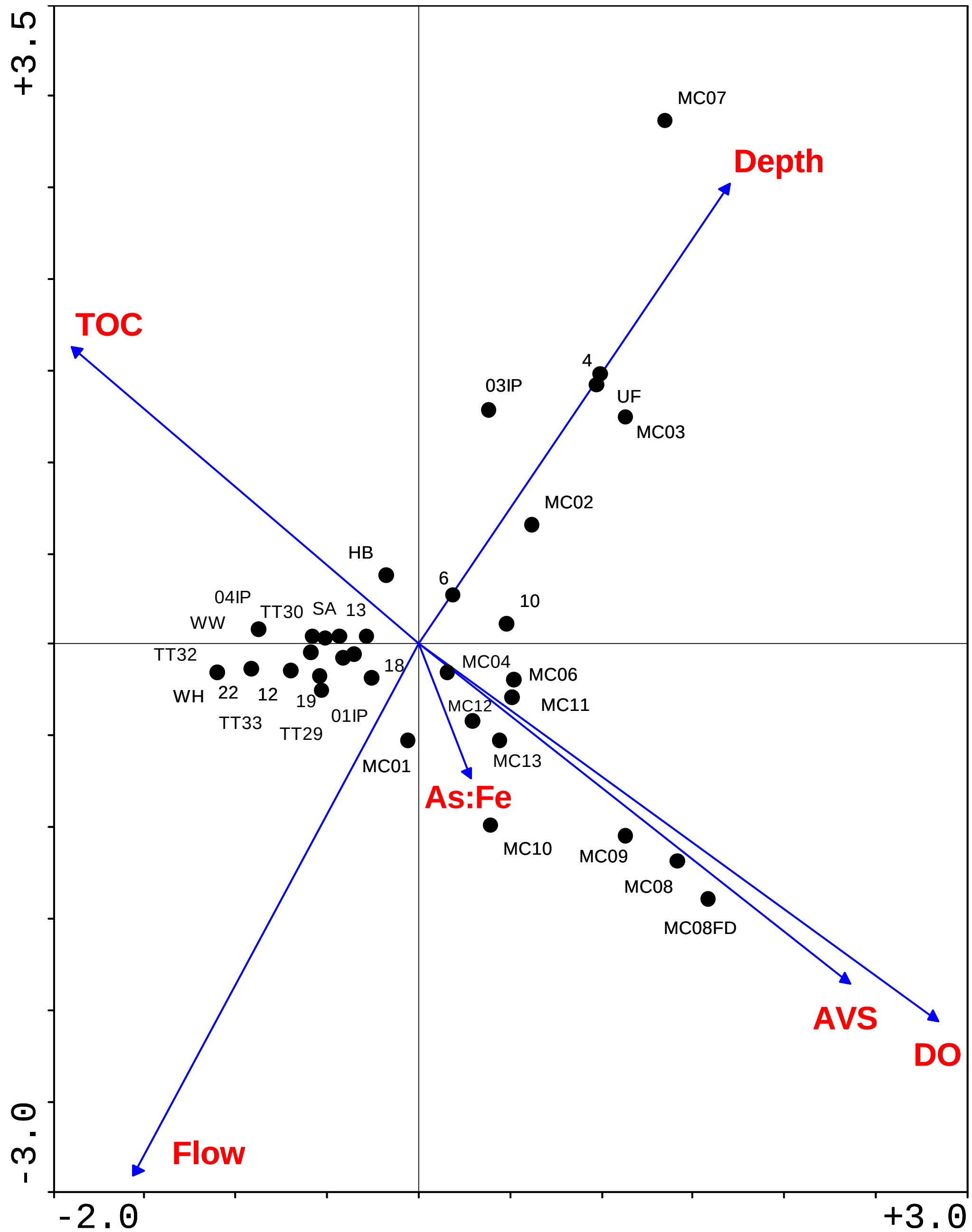

Figure 2. Ordination biplot from figure 1, overlain with environmental variables to show the potential influence of the variables on invertebrate assemblages. The length and direction of an arrow indicates, respectively, the strength and the association of a correlation between the environmental variable and the station-distribution pattern to which the arrow is most closely aligned. Two arrows that are aligned with a station-distribution pattern, but occur in an opposite direction, indicate an inverse relation (e.g., Depth and Flow).

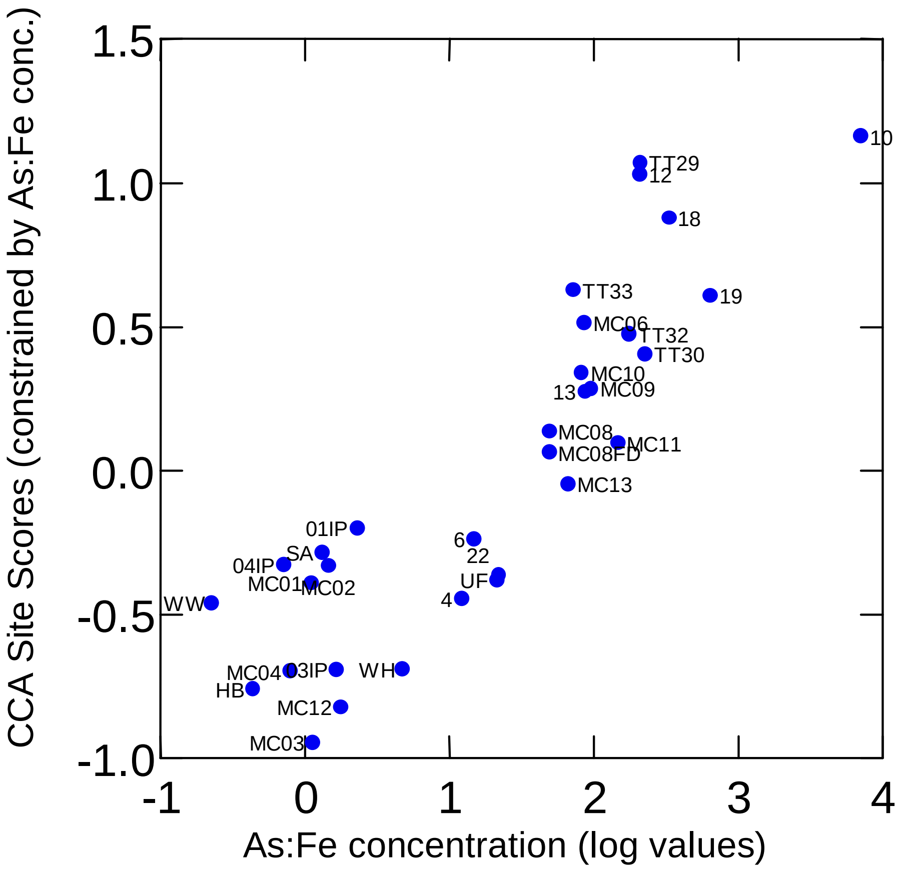

Figure 3. Scatterplot showing the relation between the primary-axis site scores derived from the CCA and the log As:Fe concentration. The units for the CCA site scores (ordinate scale) are relative, and represent structural (taxa) differences in invertebrate assemblages among stations. Correlation statistics (Pearson) for the relation: $r = 0.874$, $p < 0.001$

APPENDIX 7D.2

MULTIVARIATE ANALYSIS - DATA MATRICES

Table 1. Species Codes Assigned For Each Taxa Identified In the Combined Northern and Southern Study Areas

Phylum	Class	Order	Family	Sub-Family	Tribe	Genus/Species/Variety	Species Code
Annelida	Hirudinea	Pharyngobdellida	Erpobdellidae			Erpobdella punctata	T001
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae			Alboglossiphonia heteroclita	T002
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae			Batracobdella phalera	T003
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae			Glossiphonia complanata	T004
Annelida	Hirudinea	Rhynchobdellida	Glossiphoniidae			Helobdella stagnalis	T005
Annelida	Hirudinea	Rhynchobdellida	Piscicolidae			Myzobdella lugubris	T006
Annelida	Oligochaeta	Lumbricina	Lumbricidae			Eisenia sp.	T007
Annelida	Oligochaeta	Lumbricina	Lumbricidae			Lumbricidae	T008
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae			Eclipidrilus lacustris	T009
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae			Lumbriculus variegatus	T010
Annelida	Oligochaeta	Lumbriculida	Lumbriculidae			Stylodrilus heringianus	T011
Annelida	Oligochaeta	Tubificida	Enchytraeidae			Enchytraeus sp.	T012
Annelida	Oligochaeta	Tubificida	Enchytraeidae			Fridericia sp.	T013
Annelida	Oligochaeta	Tubificida	Enchytraeidae			Lumbricillus sp.	T014
Annelida	Oligochaeta	Tubificida	Naididae			Chaetogaster diaphanus	T015
Annelida	Oligochaeta	Tubificida	Naididae			Dero digitata	T016
Annelida	Oligochaeta	Tubificida	Naididae			Dero flabelliger	T017
Annelida	Oligochaeta	Tubificida	Naididae			Nais communis	T018
Annelida	Oligochaeta	Tubificida	Naididae			Nais variabilis	T019
Annelida	Oligochaeta	Tubificida	Naididae			Ophidonais serpentina	T020
Annelida	Oligochaeta	Tubificida	Naididae			Pristina aequiseta	T021
Annelida	Oligochaeta	Tubificida	Naididae			Pristina leidyi	T022
Annelida	Oligochaeta	Tubificida	Naididae			Slavina appendiculata	T023
Annelida	Oligochaeta	Tubificida	Naididae			Stylaria lacustris	T024
Annelida	Oligochaeta	Tubificida	Tubificidae			Aulodrilus limnobius	T025
Annelida	Oligochaeta	Tubificida	Tubificidae			Aulodrilus pigueti	T026
Annelida	Oligochaeta	Tubificida	Tubificidae			Aulodrilus pluriseta	T027
Annelida	Oligochaeta	Tubificida	Tubificidae			Ilyodrilus templetoni	T028
Annelida	Oligochaeta	Tubificida	Tubificidae			Limnodrilus claparedianus	T029
Annelida	Oligochaeta	Tubificida	Tubificidae			Limnodrilus hoffmeisteri	T030
Annelida	Oligochaeta	Tubificida	Tubificidae			Limnodrilus udekemianus	T031
Annelida	Oligochaeta	Tubificida	Tubificidae			Tubifex tubifex	T032
Arthropoda	Arachnoidea	Acariformes	Hydraphantidae			Tartarothyas sp.	T033
Arthropoda	Arachnoidea	Acariformes	Hydryphantidae			Protzia sp.	T034
Arthropoda	Arachnoidea	Acariformes	Hydryphantidae			Pseudohydryphantes sp.	T035
Arthropoda	Arachnoidea	Acariformes	Hygrobatidae			Hygrobates sp.	T036
Arthropoda	Arachnoidea	Acariformes	Pionidae			Piona sp.	T037
Arthropoda	Arachnoidea	Acariformes				Acariformes	T038

Table 1. Species Codes Assigned For Each Taxa Identified In the Combined Northern and Southern Study Areas

Phylum	Class	Order	Family	Sub-Family	Tribe	Genus/Species/Variety	Species Code
Arthropoda	Crustacea	Amphipoda	Crangonictidae			Crangonyx obliquus richmondensis	T039
Arthropoda	Crustacea	Amphipoda	Crangonictidae			Crangonyx pseudogracilis	T040
Arthropoda	Crustacea	Amphipoda	Gammaridae			Gammarus pseudolimnaeus	T041
Arthropoda	Crustacea	Amphipoda	Talitridae			Hyalella azteca	T042
Arthropoda	Crustacea	Cladocera	Chydoridae			Chydorus sphaericus	T043
Arthropoda	Crustacea	Cladocera	Chydoridae			Leydigia sp.	T044
Arthropoda	Crustacea	Cladocera	Daphnidae			Ceriodaphnia reticulata	T045
Arthropoda	Crustacea	Cladocera	Daphnidae			Daphnia ambigua	T046
Arthropoda	Crustacea	Cladocera	Daphnidae			Daphnia pulex	T047
Arthropoda	Crustacea	Cladocera	Macrothricidae			Ilyocryptus sordidus	T048
Arthropoda	Crustacea	Decapoda	Cambaridae	Cambarinae		Orconectes sp.	T049
Arthropoda	Crustacea	Decapoda	Cambaridae	Cambarinae		Orconectes virilis	T050
Arthropoda	Crustacea	Isopoda	Asellidae			Caecidotea communis	T051
Arthropoda	Crustacea	Ostracoda	Candoniidae			Candona sp.	T052
Arthropoda	Crustacea	Ostracoda	Cyprididae			Cypria palustera	T053
Arthropoda	Crustacea	Ostracoda	Darwinulidae			Darwinula stevensoni	T054
Arthropoda	Insecta	Coleoptera	Dytiscidae			Hydroporus sp.	T055
Arthropoda	Insecta	Coleoptera	Dytiscidae			Hygrotus sp.	T056
Arthropoda	Insecta	Coleoptera	Dytiscidae			Ilybius sp.	T057
Arthropoda	Insecta	Coleoptera	Dytiscidae			Laccornis sp.	T058
Arthropoda	Insecta	Coleoptera	Haliplidae			Peltodytes sp.	T059
Arthropoda	Insecta	Coleoptera	Hydrophilidae			Helophorus sp.	T060
Arthropoda	Insecta	Coleoptera	Hydrophilidae			Hydrobiomorpha sp.	T061
Arthropoda	Insecta	Coleoptera	Hydrophilidae			Tropisternus sp.	T062
Arthropoda	Insecta	Coleoptera	Scirtidae			Cyphon sp.	T063
Arthropoda	Insecta	Coleoptera	Scirtidae			Prionocyphon sp.	T064
Arthropoda	Insecta	Coleoptera				Coleoptera	T065
Arthropoda	Insecta	Collembola	Sminthuridae			Bourletiella sp.	T066
Arthropoda	Insecta	Diptera	Ceratopogonidae			Alluaudomyia sp.	T067
Arthropoda	Insecta	Diptera	Ceratopogonidae			Bezzia sp.	T068
Arthropoda	Insecta	Diptera	Ceratopogonidae			Ceratopogon sp.	T069
Arthropoda	Insecta	Diptera	Ceratopogonidae			Culicoides sp.	T070
Arthropoda	Insecta	Diptera	Ceratopogonidae			Monohelea sp.	T071
Arthropoda	Insecta	Diptera	Ceratopogonidae			Sphaeromias sp.	T072
Arthropoda	Insecta	Diptera	Chaoboridae			Chaoborus punctipennis	T073
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Pentaneurini	Ablabesmyia mallochi	T074
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Pentaneurini	Ablabesmyia parajanta	T075
Arthropoda	Insecta	Diptera	Chironomidae			Chironomid pupa	T076

Table 1. Species Codes Assigned For Each Taxa Identified In the Combined Northern and Southern Study Areas

Phylum	Class	Order	Family	Sub-Family	Tribe	Genus/Species/Variety	Species Code
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Chironomus decorus	T077
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Chironomus tentans	T078
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Cladopelma sp.	T079
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Coelotanypodini	Clinotanypus pinguis	T080
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Coelotanypodini	Clinotanypus sp.	T081
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Corynoneurini	Corynoneura taris	T082
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Orthocladiini	Cricotopus bicinctus	T083
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Orthocladiini	Cricotopus sylvestris	T084
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Orthocladiini	Cricotopus trifasciatus	T085
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Cryptochironomus fulvus	T086
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Dicrotendipes modestus	T087
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Dicrotendipes nervosus	T088
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Einfeldia natchitocheae	T089
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Einfeldia sp.	T090
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Endochironomus nigricans	T091
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Glyptotendipes lobiferus	T092
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Orthocladiini	Heterotrissocladius marcidus	T093
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Orthocladiini	Heterotrissocladius sp.	T094
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae		Hudsonimyia sp.	T095
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae		Larsia sp.	T096
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae		Limnophyes sp.	T097
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Tanytarsini	Micropsectra sp.	T098
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Microtendipes caelum	T099
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae		Monopelopia sp.	T100
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Natarsiini	Natarsia sp.	T101
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Parachironomus abortivus	T102
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	parachironomus hirtalatus	T103
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Pentaneurini	Paramerina sp.	T104
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Orthocladiini	Parametriocnemus lundbecki	T105
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae		Paraphaenocladius sp.	T106
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Tanytarsini	Paratanytarsus sp.	T107
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Paratendipes albimanus	T108
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Paratendipes subaequalis	T109
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Phaenopsectra flavipes	T110
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Polypedilum convictum	T111
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Polypedilum halterale	T112
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Polypedilum illinoense	T113

Table 1. Species Codes Assigned For Each Taxa Identified In the Combined Northern and Southern Study Areas

Phylum	Class	Order	Family	Sub-Family	Tribe	Genus/Species/Variety	Species Code
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Polypedilum scalaenum	T114
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Polypedilum trigonus	T115
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Polypedilum tritum	T116
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Procladiini	Procladius bellus	T117
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Procladiini	Procladius culiciformis	T118
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Procladiini	Procladius sp.	T119
Arthropoda	Insecta	Diptera	Chironomidae	Prodiamesinae		Prodiamesa olivacea	T120
Arthropoda	Insecta	Diptera	Chironomidae	Prodiamesinae		Prodiamesa sp.	T121
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Orthocladiini	Psectrocladius sp.	T122
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae		Psectrotanypus sp.	T123
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae		Pseudorthocladius sp.	T124
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae		Pseudosmittia sp.	T125
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Orthocladiini	Rheocricotopus robacki	T126
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Tanytarsini	Rheotanytarsus sp.	T127
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Stictochironomus sp.	T128
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Tanypodini	Tanypus punctipennis	T129
Arthropoda	Insecta	Diptera	Chironomidae	Orthocladiinae	Tanytarsini	Tanytarsus guerlus	T130
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Pentaneurini	Thienemannimyia sp.	T131
Arthropoda	Insecta	Diptera	Chironomidae	Chironominae	Chironomini	Tribelos jucundus	T132
Arthropoda	Insecta	Diptera	Chironomidae	Tanypodinae	Pentaneurini	Zavrelimyia sp.	T133
Arthropoda	Insecta	Diptera	Culicidae			Aedes sp.	T134
Arthropoda	Insecta	Diptera	Dolichopodidae			Hydrophorus sp.	T135
Arthropoda	Insecta	Diptera	Ephydridae			Ephydra sp.	T136
Arthropoda	Insecta	Diptera	Ephydridae			Ephydridae	T137
Arthropoda	Insecta	Collembola	Isotomidae			Isotomurus sp.	T138
Arthropoda	Insecta	Diptera	Ptychopteridae			Bittacomorpha sp.	T139
Arthropoda	Insecta	Diptera	Ptychopteridae			Ptychoptera sp.	T140
Arthropoda	Insecta	Diptera	Simuliidae			Simulium sp.	T141
Arthropoda	Insecta	Diptera	Stratiomyidae			Allognosta sp.	T142
Arthropoda	Insecta	Diptera	Stratiomyidae			Brachypremna sp.	T143
Arthropoda	Insecta	Diptera	Syrphidae			Eristalis sp.	T144
Arthropoda	Insecta	Diptera	Tipulidae			Ormosia sp.	T145
Arthropoda	Insecta	Diptera	Tipulidae	Limoniinae		Pilaria sp.	T146
Arthropoda	Insecta	Diptera	Tipulidae			Pseudolimnophila sp.	T147
Arthropoda	Insecta	Diptera	Tipulidae			Tipula sp.	T148
Arthropoda	Insecta	Diptera	Tipulidae			Tipulidae	T149
Arthropoda	Insecta	Diptera				Diptera	T150
Arthropoda	Insecta	Ephemeroptera	Siphlonuridae			Siphlonuridae	T151

Table 1. Species Codes Assigned For Each Taxa Identified In the Combined Northern and Southern Study Areas

Phylum	Class	Order	Family	Sub-Family	Tribe	Genus/Species/Variety	Species Code
Arthropoda	Insecta	Hemiptera	Corixidae	Corixinae		Cenocorixa sp.	T152
Arthropoda	Insecta	Hemiptera	Corixidae	Corixinae		Trichocorixa sp.	T153
Arthropoda	Insecta	Megaloptera	Corydalidae			Nigronia sp.	T154
Arthropoda	Insecta	Megaloptera	Sialidae			Sialis sp.	T155
Arthropoda	Insecta	Odonata	Libellulidae			Plathemis sp.	T156
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae		Agraylea multipunctata	T157
Arthropoda	Insecta	Trichoptera	Hydroptilidae	Hydroptilinae		Oxyethira sp.	T158
Arthropoda	Insecta	Trichoptera	Leptoceridae			Oecetis sp.	T159
Arthropoda	Insecta	Trichoptera	Limnephilidae			Limnephilus sp.	T160
Cnidaria	Hydrozoa	Hydroida	Hydridae			Hydra americana	T161
Mollusca	Gastropoda	Basommatophora	Ancylidae			Ferrissia sp.	T162
Mollusca	Gastropoda	Basommatophora	Lymnaeidae			Pseudosuccinea columella	T163
Mollusca	Gastropoda	Basommatophora	Lymnaeidae			Stagnicola sp.	T164
Mollusca	Gastropoda	Basommatophora	Physidae			Physella heterostropha	T165
Mollusca	Gastropoda	Basommatophora	Planorbidae			Helisoma anceps	T166
Mollusca	Gastropoda	Basommatophora	Planorbidae			Planorbella trivolvis	T167
Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae			Amnicola limosa	T168
Mollusca	Gastropoda	Mesogastropoda	Bithyniidae			Bithynia tentaculata	T169
Mollusca	Gastropoda	Mesogastropoda	Hydrobiidae			Gillia altilis	T170
Mollusca	Gastropoda	Mesogastropoda	Valvatidae			Valvata tricarinata	T171
Mollusca	Gastropoda					Gastropoda	T172
Mollusca	Pelecypoda	Prionodesmacea	Sphaeriidae			Musculium sp.	T173
Mollusca	Pelecypoda	Prionodesmacea	Sphaeriidae			Pisidium sp.	T174
Mollusca	Pelecypoda	Prionodesmacea	Sphaeriidae			Sphaerium sp.	T175
Nematoda		Araeolaimida				Aphanolaimus sp.	T176
Nematoda		Dorylaimida				Actinolaimus sp.	T177
Nematoda		Dorylaimida				Alaimus sp.	T178
Nematoda		Dorylaimida				Dorylaimus sp.	T179
Nematoda		Dorylaimida				Microlaimus sp.	T180
Nematoda		Enoplida				Rhabdolaimus sp.	T181
Nematoda		Enoplida				Tobrilus sp.	T182
Nematoda		Mononchida				Miconchus sp.	T183
Nematoda		Mononchida				Mononchus sp.	T184
Nemertea	Enopla	Hoplonemertea	Prostomatidae			Prostoma graecense	T185
Platyhelminthes	Turbellaria	Neorhabdocoela				Neorhabdocoela	T186
Platyhelminthes	Turbellaria	Tricladida	Planariidae			Hymanella retenuova	T187
Platyhelminthes	Turbellaria	Tricladida	Planariidae			Phagocata woodworthi	T188

Table 2. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas (See Table 1 for taxa codes)

	Station																																
Taxa code	4	6	10	12	13	18	19	22	01IP	03IP	04IP	HB	MC01	MC02	MC03	MC04	MC05	MC06	MC07	MC08	MC08FD	MC09	MC10	MC11	MC12	MC13	SA	TT29	TT30	TT32	TT33	UF	WH	WW
T001					3				2			35													4				2					
T002									1			5																						
T003																														1				
T004												1																						
T005		2							1			239									6													
T006		6		1								1																						2
T007																												1						
T008																																	1	
T009					17	1	6				18																1		4	1				1
T010								5					12												2		1						79	2
T011							1	39	31		3																7				2		55	
T012																														3			7	
T013																														1				
T014	1			3	1	1		15			1																	1	5	3	1		7	12
T015	1	1																														27		
T016	2505	67	1	8	17	23	1		1		9	35		20				6			4	8		4				3		8	1	275		
T017																				14	32													
T018				1	5			11	1		2	5																2		33		1	3	
T019	1	1																																
T020	1	1																														2		
T021				11				5			1																1	1		24			3	8
T022												1																						
T023	134											8																		4		119		
T024	57																															506		
T025	32	12			8	254	6		543		380		4							14						24		4		12	1			
T026	1620	1	9		3	1			3											26	14								1			918		
T027	141	27			5						68	52				2				88	54				16							2		
T028	11	77	50	120	203	3301	108	14	148		80	6	440			10		138		308	290	54	4	136	2	198	9	910	4	177	247	6		
T029		37	1	1640	1315	900	37	76	385		11		96													10	52	2104	726	1460	799	4	13	69
T030	266	315			19				83		89	20	236			42		26		248	134	2		186	172	182	40					282		
T031	2	12							22				16														24							
T032		1										10																						
T033																									2									
T034							1																										2	1
T035																																		1
T036														1																				
T037	1																															1		
T038																																	3	
T039													16			2						10	4	2	4									
T040		1		5	70	2	2	35	13		1	22															8	12	71	80	4		40	10
T041		1			1																													
T042			1		79	3				2	52	586		1		12													28	43	1	5		
T043																						4												
T044																					2	2												
T045																				24	66	6												
T046															2																			
T047															1																			
T048																				2	8													
T049					2						1																			1				

Table 2. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas (See Table 1 for taxa codes)

	Station																																	
Taxa code	4	6	10	12	13	18	19	22	01IP	03IP	04IP	HB	MC01	MC02	MC03	MC04	MC05	MC06	MC07	MC08	MC08FD	MC09	MC10	MC11	MC12	MC13	SA	TT29	TT30	TT32	TT33	UF	WH	WW
T050																				16						4								
T051		1			21	1	1	301	3		11	105	32			52					2				226	4		1	5	11	1		102	1
T052																				20	84	2			2									
T053																				104	154	8												
T054																					14													
T055												1																						
T056								1																										
T057																																	1	
T058								7																										
T059																				8	4													
T060																													1					
T061													10																					
T062								2																									1	
T063																																	4	
T064																																	1	
T065																																	2	
T066												2																						1
T067				1																														1
T068						2	2	4	8		1			14													8	1	2					3
T069																												2		1				
T070						6	5	1																				2						
T071							8																					1						
T072			4		1	7	1							4				2		6									1			1		
T073										8				3	3				1															
T074												1		8		8										4								
T075																					4													
T076																				8	8													
T077	26	300		1	35	172	230	55	12	5	110	2			1	100		4		4	4	2		26	8	38	664	3	46	17	12	26		
T078													4																					
T079	12				1				1					6				2		2	4											16		
T080			1	3	5	33	1				2																	6	7		3			
T081																				4					4	10								
T082								5			1																							
T083							2													4	4													
T084																				36	28													
T085																														2		2		
T086	4	3			3						8							2							2				4	1		4		
T087	2																												5			1		
T088							1	1																						4	1			
T089																																1		
T090														2																				
T091																											2							
T092																				2	4													
T093								11																										
T094																	1																	
T095																														1				
T096		1			2							23																	1					
T097								1																									1	
T098	2	1			52			277	13		22	7															31		28	9	6		3	22

Table 2. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas (See Table 1 for taxa codes)

	Station																																	
Taxa code	4	6	10	12	13	18	19	22	01IP	03IP	04IP	HB	MC01	MC02	MC03	MC04	MC05	MC06	MC07	MC08	MC08FD	MC09	MC10	MC11	MC12	MC13	SA	TT29	TT30	TT32	TT33	UF	WH	WW
T099												1									4													
T100												1																						
T101		1			3		1				17	5															3		4		1			4
T102																					6													
T103	1																										1		1					
T104											1																							
T105																																	2	8
T106					2																													
T107											5	2									6			2					1	1				
T108									6		3																2		1					2
T109							1																											
T110					4		2	35	1		226																38		1	7	7		1	1
T111																													2					
T112	1	1																																
T113		2		1			6				1	1	8														1		2			1		
T114									1									2		40	22								3	4	3			2
T115					1							12																						18
T116		1						1	6	1	1	1																	5			2		1
T117																														1		3		
T118															1			2		18	10	2		4		22								
T119	10	8				1	3			2																					1			
T120								25			21																1				2			
T121																52									48	24								
T122	3					1				1					1	4												1						
T123	1	12			2	11	8		13		1																159		1					
T124																											1							
T125																													1					1
T126							6	3																										
T127																													4					
T128																46									2	2								
T129	1										1																					1		
T130													4	1						20	16													
T131											5																							
T132																4																		
T133								33																									3	
T134								1																										
T135				1																									1					
T136						1																												
T137				11																														
T138				3		1	2	1				1															2	1		1		13	16	12
T139									2				4																					
T140									2																									
T141	1																																	
T142																											1							
T143									5																									3
T144																										2								
T145									1				408																					
T146					1				10				32																					2
T147								1	1																									1

Table 2. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas (See Table 1 for taxa codes)

Taxa code	Station																																	
	4	6	10	12	13	18	19	22	01IP	03IP	04IP	HB	MC01	MC02	MC03	MC04	MC05	MC06	MC07	MC08	MC08FD	MC09	MC10	MC11	MC12	MC13	SA	TT29	TT30	TT32	TT33	UF	WH	WW
T148													50																					
T149					1				4		1	2																						1
T150				2			2					1																						
T151																					4													
T152																				12	6													
T153					1																													
T154													4																					
T155												1																						
T156					1																													
T157														1																				
T158	2																																	
T159																													1					
T160												1																						
T161								4																										
T162											1																			1	2			
T163						1																												
T164							7	6																			11	2		5			3	60
T165					10	2	18	41						5						10	16				2			2	6	9	1		3	3
T166																				2	4													
T167						1		32					8							2							3						73	2
T168	13	1																														1		
T169											1																							
T170																									2									
T171	42																															5		
T172								1																									1	
T173	3				30							51																	2					
T174	71				17	14	38	30	25		17	71				6											19	1	2	9	21	48	41	292
T175			1																	76	40											3		
T176		1		1	2	3	1	2			3																4		1			1	1	5
T177				1				1																										
T178																					2				2	4								
T179	2					2		2			3																2			1	5			
T180																											1							
T181				2																														
T182				5		5																						3		1				
T183																												1						
T184								2																										
T185																																		1
T186				3																														
T187	2																															1		
T188		1						21																						1			16	1

Table 3. Values of Environmental Variables used in the Ordination Analysis

Station	Variable						
	Depth	DO	Flow	AsFe	AVS	TOC	PEC
4	5	7.18	0	2.9	0.1275	210000	2.9
6	3.8	7.67	1	3.2	0.66	100000	1.7
10	1.4	3.73	1	46.7	5.97	680000	15.5
12	4.5	2.76	3	10.1	24.09	150000	8.3
13	0.3	4.1	3	6.9	0.68	300000	4.2
18	1.1	4.92	3	12.4	4.78	300000	11.7
19	0.8	4.9	2	16.5	5.63	290000	20.8
22	0.2	2.96	2	3.8	0.29	430000	4.5
01IP	0.3	4.47	3	1.4	0.8	270000	0.7
03IP	13	0.74	0	1.2	0.14	330000	1.0
04IP	0.4	5.9	3	0.9	0.065	290000	2.0
HB	0.8	6.92	3	0.7	0.07	250000	0.5
MC01	0.25	7.28	3	1.0	7.4	160000	0.7
MC02	1.5	5.5	0	1.2	120	370000	0.9
MC03	9.7	1.27	0	1.1	45	110000	1.0
MC04	1.3	6.24	3	0.9	4.3	120000	2.0
MC05	12.8	0.72	0	15.4	690	137500	8.6
MC06	1	7.72	0	6.9	81	108000	5.6
MC07	11.8	0.28	0	20.6	400	109500	13.8
MC08	0.5	12.5	3	5.4	210	87500	6.2
MC08FD	0.5	12.5	3	5.4	210	87500	6.2
MC09	1	7.71	1	7.2	240	175000	9.6
MC10	0.05	8.63	3	6.7	23	73500	5.7
MC11	3.5	11.7	1	8.7	33	108500	9.2
MC12	1.3	9.35	3	1.3	1.5	130000	0.7
MC13	1.4	7.9	3	6.2	3.2	140000	4.9
SA	0.7	5.73	2	1.1	0.16	170000	0.9
TT29	1	4.44	3	10.2	NA	NA	11.2
TT30	0.6	5.46	3	10.5	0.0395	240000	7.7
TT32	0.6	8.23	2	9.4	2.79	150000	3.6
TT33	0.5	4.55	3	6.4	1.95	86000	2.3
UF	7.1	2.57	0	3.8	15.71	360000	5.2
WH	1.2	3.4	2	2.0	1.95	815000	2.8
WW	0.8	3.74	2	0.5	0.65	760000	9.4

DO - Dissolved oxygen concetration in overlying water (for ISRT from samples in June, 1999)

Flow: 0= pond, 1 = wetland pond, 2 = vegetated wetland or back channel, 3 = stream channel with flow

AsFE - Ratio of arsenic concentration to iron concentration in sediment * 1000

AVS - Acid Volatile Sufide

TOC - Total Organic Carbon

PEC Quotient = mean of the ratio of the values for sediment inorganic concentration divided by PEC

PEC = Probable Effects Concentration (MacDonald et al, 2000)

Inorganics included were: arsenic, cadmium, chromium, copper, lead, mercury, and zinc

NA - not analyzed

Table 4. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas Sorted by site and species scores that were derived from the CCA (see Table 1 for taxa codes)

			LESS CONTAMINATED SITES																	MORE CONTAMINATED SITES															
			MC07	MC03	MC12	HB	MC04	03IP	WH	WW	4	MC01	UF	22	MC02	04IP	SA	6	01IP	MC13	MC08FD	MC11	MC08	13	MC09	MC10	TT30	TT32	MC06	19	TT33	18	12	TT29	10
Genus/Species/Variety	TAXA Code	Sp/Site scores	-1.92	-0.94	-0.82	-0.76	-0.7	-0.69	-0.69	-0.46	-0.444	-0.39	-0.38	-0.36	-0.33	-0.33	-0.28	-0.24	-0.2	-0.05	0.064	0.098	0.138	0.276	0.286	0.341	0.407	0.476	0.515	0.611	0.629	0.88	1.031	1.073	1.165
Pseudohydryphantes sp.	T035	-2.2087								1																									
Prostoma graecense	T185	-2.2087								1																									
Bourletiella sp.	T066	-2.1631				2				1																									
Glossiphonia complanata	T004	-2.1309				1																													
Pristina leidyi	T022	-2.1309				1																													
Hydroporus sp.	T055	-2.1309				1																													
Monopelopia sp.	T100	-2.1309				1																													
Sialis sp.	T155	-2.1309				1																													
Limnephilus sp.	T160	-2.1309				1																													
Paramerina sp.	T104	-2.0559														1																			
Thienemannimyia sp.	T131	-2.0559														5																			
Bithynia tentaculata	T169	-2.0559														1																			
Tribelos jucundus	T132	-2.0398					4																												
Alboglossiphonia heteroclita	T002	-2.0286				5													1																
Parametriocnemus lundbecki	T105	-1.9944							2	8																									
Brachypremna sp.	T143	-1.9783								3									5																
Hydrobiomorpha sp.	T061	-1.975										10																							
Chironomus tentans	T078	-1.975										4																							
Tipula sp.	T148	-1.975										50																							
Nigronia sp.	T154	-1.975										4																							
Daphnia ambigua	T046	-1.9698		2																															
Daphnia pulex	T047	-1.9698		1																															
Ormosia sp.	T145	-1.9667										408							1																
Endochironomus nigricans	T091	-1.9385															2																		
Pseudorthocladius sp.	T124	-1.9385															1																		
Allognosta sp.	T142	-1.9385															1																		
Microlaimus sp.	T180	-1.9385															1																		
Chaoborus punctipennis	T073	-1.9174	1	3				8							3																				
Hygrobates sp.	T036	-1.9167													1																				
Einfeldia sp.	T090	-1.9167													2																				
Agraylea multipunctata	T157	-1.9167													1																				
Bittacomorpha sp.	T139	-1.9024										4							2																
Tartarothyas sp.	T033	-1.8681			2																														
Gillia altilis	T170	-1.8681			2																														
Tubifex tubifex	T032	-1.8587				10												1																	
Polypedilum trigonus	T115	-1.8472				12				18														1											
Ptychoptera sp.	T140	-1.7998																	2																
Helobdella stagnalis	T005	-1.7813				239												2	1		6														
Pilaria sp.	T146	-1.7197								2		32							10					1											
Limnodrilus udekemianus	T031	-1.672									2	16					24	12	22																
Stictochironomus sp.	T128	-1.6668			2		46													2															
Lumbriculus variegatus	T010	-1.6347			2				79	2		12		5			1																		
Tipulidae	T149	-1.5915				2				1						1			4					1											
Pseudolimnophila sp.	T147	-1.581								1				1					1																
Lumbricidae	T008	-1.5659							1																										
Acariformes	T038	-1.5659							3																										
Ilybius sp.	T057	-1.5659							1																										
Cyphon sp.	T063	-1.5659							4																										
Prionocyphon sp.	T064	-1.5659							1																										
Coleoptera	T065	-1.5659							2																										
Ablabesmyia mallochi	T074	-1.4642				1	8								8					4															
Paratendipes albimanus	T108	-1.4436								2						3	2		6								1								
Prodiamesa sp.	T121	-1.3693			48		52													24															
Tanypus punctipennis	T129	-1.309									1		1			1																			

Table 4. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas Sorted by site and species scores that were derived from the CCA (see Table 1 for taxa codes)

			LESS CONTAMINATED SITES																	MORE CONTAMINATED SITES															
			MC07	MC03	MC12	HB	MC04	03IP	WH	WW	4	MC01	UF	22	MC02	04IP	SA	6	01IP	MC13	MC08FD	MC11	MC08	13	MC09	MC10	TT30	TT32	MC06	19	TT33	18	12	TT29	10
Genus/Species/Variety	TAXA Code	Sp/Site scores	-1.92	-0.94	-0.82	-0.76	-0.7	-0.69	-0.69	-0.46	-0.444	-0.39	-0.38	-0.36	-0.33	-0.33	-0.28	-0.24	-0.2	-0.05	0.064	0.098	0.138	0.276	0.286	0.341	0.407	0.476	0.515	0.611	0.629	0.88	1.031	1.073	1.165
Prodiamesa olivacea	T120	-1.2032											25		21	1														2				
Planorbella trivolvis	T167	-1.1731							73	2		8		32			3						2									1			
Erpobdella punctata	T001	-1.1635			4	35													2					3			2								
Limnophyes sp.	T097	-1.1503							1					1																					
Gastropoda	T172	-1.1503							1					1																					
Corynoneura taris	T082	-1.1429												5		1																			
Stylodrilus heringianus	T011	-1.1284							55					39		3	7		31											1	2				
Simulium sp.	T141	-1.1194									1																								
Oxyethira sp.	T158	-1.1194									2																								
Tropisternus sp.	T062	-1.079							1					2																					
Nais variabilis	T019	-1.0586									1							1																	
Polypedilum halterale	T112	-1.0586									1							1																	
Aulodrilus pluriseta	T027	-1.0467			16	52	2				141		2			68		27			54		88	5											
Amnicola limosa	T168	-1.0321									13		1					1																	
Valvata tricarinata	T171	-1.025									42		5																						
Caecidotea communis	T051	-1.0226			226	105	52		102	1		32		301		11		1	3	4	2			21			5	11		1	1	1		1	
Larsia sp.	T096	-0.9743				23											1						2			1								
Hymanella retenuova	T187	-0.9671									2		1																						
Phagocata woodworthi	T188	-0.955							16	1				21				1										1							
Myzobdella lugubris	T006	-0.9545				1				2								6															1		
Piona sp.	T037	-0.9355									1		1																						
Ophidonais serpentina	T020	-0.9315									1		2					1																	
Zavrelimyia sp.	T133	-0.9272							3					33																					
Phaenopsectra flavipes	T110	-0.9129							1	1				35		226	38		1					4			1	7		2	7				
Slavina appendiculata	T023	-0.8653				8					134		119															4							
Polypedilum tritum	T116	-0.86				1		1		1			2	1		1		1	6								5								
Stylaria lacustris	T024	-0.8441									57		506																						
Chaetogaster diaphanus	T015	-0.837									1		27					1																	
Limnodrilus hoffmeisteri	T030	-0.7931			172	20	42				266	236	282			89	40	315	83	182	134	186	248	19	2				26						
Einfeldia natchitocheae	T089	-0.7517											1																					
Hygrotus sp.	T056	-0.7346												1																				
Laccornis sp.	T058	-0.7346												7																				
Heterotrissocladius marcidus	T093	-0.7346												11																				
Aedes sp.	T134	-0.7346												1																				
Hydra americana	T161	-0.7346												4																				
Mononchus sp.	T184	-0.7346												2																				
Microtendipes caelum	T099	-0.7233				1															4														
Cladopelma sp.	T079	-0.7082									12		16		6				1		4		2	1					2						
Musculium sp.	T173	-0.652				51					3													30			2								
Natarsia sp.	T101	-0.6502				5				4						17	3	1						3			4			1	1				
Crangonyx obliquus richmondensis	T039	-0.6264			4		2					16										2			10	4									
Pisidium sp.	T174	-0.6228				71	6		41	292	71		48	30		17	19		25					17			2	9		38	21	14		1	
Micropsectra sp.	T098	-0.6212				7			3	22	2			277		22	31	1	13					52			28	9			6				
Psectrocladius sp.	T122	-0.5989		1			4	1			3																					1		1	
Tanytarsus guerlus	T130	-0.5258										4			1						16		20													
Bezzia sp.	T068	-0.4307								3				4	14	1	8		8								2			2		2		1	
Alaimus sp.	T178	-0.419			2															4	2														
Hyalella azteca	T042	-0.4028				586	12	2					5		1	52								79			28	43			1	3			1
Clinotanypus sp.	T081	-0.3844			4															10			4												
Stagnicola sp.	T164	-0.3712							3	60				6			11											5		7					2	
Dero digitata	T016	-0.3633				35					2505		275		20	9		67	1		4	4		17	8			8	6	1	1	23	8	3	1
Cryptochironomus fulvus	T086	-0.343			2						4		4			8		3						3			4	1	2						
Psectrotanypus sp.	T123	-0.3297									1					1	159	12	13					2			1			8		11			
Parachironomus hirtalatus	T103	-0.2622									1						1										1							

Table 4. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas Sorted by site and species scores that were derived from the CCA (see Table 1 for taxa codes)

			LESS CONTAMINATED SITES																
			MC07	MC03	MC12	HB	MC04	03IP	WH	WW	4	MC01	UF	22	MC02	04IP	SA	6	01IP
Genus/Species/Variety	TAXA Code	Sp/Site scores	-1.92	-0.94	-0.82	-0.76	-0.7	-0.69	-0.69	-0.46	-0.444	-0.39	-0.38	-0.36	-0.33	-0.33	-0.28	-0.24	-0.2
Enchytraeus sp.	T012	-0.244							7										
Isotomurus sp.	T138	-0.2217				1			16	12			13	1			2		
Aulodrilus limnobius	T025	-0.2167									32	4				380		12	543
Dorylaimus sp.	T179	-0.1672									2			2		3	2		
Gammarus pseudolimnaeus	T041	-0.1642																1	
Paratanytarsus sp.	T107	-0.1627				2										5			
Aulodrilus pigueti	T026	-0.113									1620		918					1	3
Candona sp.	T052	-0.108			2														
Aphanolaimus sp.	T176	-0.063							1	5			1	2		3	4	1	
Alluaudomyia sp.	T067	-0.0535								1									
Dero flabelliger	T017	-0.0196																	
Ilyocryptus sordidus	T048	-0.0196																	
Darwinula stevensoni	T054	-0.0196																	
Peltodytes sp.	T059	-0.0196																	
Ablabesmyia parajanta	T075	-0.0196																	
Chironomid pupa	T076	-0.0196																	
Cricotopus sylvestris	T084	-0.0196																	
Glyptotendipes lobiferus	T092	-0.0196																	
Parachironomus abortivus	T102	-0.0196																	
Siphlonuridae	T151	-0.0196																	
Cenocorixa sp.	T152	-0.0196																	
Helisoma anceps	T166	-0.0196																	
Lumbricillus sp.	T014	0.0146							7	12	1			15		1			
Pseudosmittia sp.	T125	0.0313								1									
Nais communis	T018	0.067				5			3				1	11		2			1
Cypria palustera	T053	0.0715																	
Ferrissia sp.	T162	0.0932														1			
Orconectes virilis	T050	0.0947																	
Chironomus decorus	T077	0.1043		1	8	2	100	5			26		26	55		110	664	300	12
Ceriodaphnia reticulata	T045	0.1101																	
Protzia sp.	T034	0.1542							2	1									
Procladius bellus	T117	0.1732											3						
Pristina aequiseta	T021	0.1768							3	8				5		1	1		
Orconectes sp.	T049	0.1951														1			
Polypedilum scalaenum	T114	0.197								2									1
Procladius culiciformis	T118	0.2439		1															
Polypedilum illinoense	T113	0.2719				1						8	1			1	1	2	
Procladius sp.	T119	0.2781						2			10							8	
Crangonyx pseudogracilis	T040	0.288				22			40	10				35		1	8	1	13
Eristalis sp.	T144	0.3231																	
Leydigia sp.	T044	0.39																	
Cricotopus trifasciatus	T085	0.5118											2						
Dicrotendipes modestus	T087	0.5901									2		1						
Physella heterostropha	T165	0.6299			2				3	3				41	5				
Paraphaenocladius sp.	T106	0.6694																	
Trichocorixa sp.	T153	0.6694																	
Plathemis sp.	T156	0.6694																	
Eclipidrilus lacustris	T009	0.6816								1						18	1		
Actinolaimus sp.	T177	0.6836												1					
Chydorus sphaericus	T043	0.7995																	
Sphaerium sp.	T175	0.9514											3						
Limnodrilus claparedianus	T029	1.1615							13	69		96	4	76		11	52	37	385
Cricotopus bicinctus	T083	1.2784																	
Ilyodrilus templetoni	T028	1.3092			2	6	10				11	440	6	14		80	9	77	148

			MORE CONTAMINATED SITES															
			MC13	MC08FD	MC11	MC08	13	MC09	MC10	TT30	TT32	MC06	19	TT33	18	12	TT29	10
Genus/Species/Variety	TAXA Code	Sp/Site scores	-0.05	0.064	0.098	0.138	0.276	0.286	0.341	0.407	0.476	0.515	0.611	0.629	0.88	1.031	1.073	1.165
Enchytraeus sp.	T012	-0.244									3							
Isotomurus sp.	T138	-0.2217									1		2		1	3	1	
Aulodrilus limnobius	T025	-0.2167	24			14	8				12		6	1	254		4	
Dorylaimus sp.	T179	-0.1672									1			5	2			
Gammarus pseudolimnaeus	T041	-0.1642					1											
Paratanytarsus sp.	T107	-0.1627		6	2					1	1							
Aulodrilus pigueti	T026	-0.113		14		26	3			1					1			9
Candona sp.	T052	-0.108		84		20		2										
Aphanolaimus sp.	T176	-0.063					2			1			1		3	1		
Alluaudomyia sp.	T067	-0.0535														1		
Dero flabelliger	T017	-0.0196		32		14												
Ilyocryptus sordidus	T048	-0.0196		8		2												
Darwinula stevensoni	T054	-0.0196		14														
Peltodytes sp.	T059	-0.0196		4		8												
Ablabesmyia parajanta	T075	-0.0196		4														
Chironomid pupa	T076	-0.0196		8		8												
Cricotopus sylvestris	T084	-0.0196		28		36												
Glyptotendipes lobiferus	T092	-0.0196		4		2												
Parachironomus abortivus	T102	-0.0196		6														
Siphlonuridae	T151	-0.0196		4														
Cenocorixa sp.	T152	-0.0196		6		12												
Helisoma anceps	T166	-0.0196		4		2												
Lumbricillus sp.	T014	0.0146					1			5	3			1	1	3	1	
Pseudosmittia sp.	T125	0.0313								1								
Nais communis	T018	0.067					5				33					1	2	
Cypria palustera	T053	0.0715		154		104		8										
Ferrissia sp.	T162	0.0932									1			2				
Orconectes virilis	T050	0.0947	4			16												
Chironomus decorus	T077	0.1043	38	4	26	4	35	2		46	17	4	230	12	172	1	3	
Ceriodaphnia reticulata	T045	0.1101		66		24		6										
Protzia sp.	T034	0.1542											1					
Procladius bellus	T117	0.1732									1							
Pristina aequiseta	T021	0.1768									24					11	1	
Orconectes sp.	T049	0.1951					2				1							
Polypedilum scalaenum	T114	0.197		22		40				3	4	2		3				
Procladius culiciformis	T118	0.2439	22	10	4	18		2				2						
Polypedilum illinoense	T113	0.2719								2			6			1		
Procladius sp.	T119	0.2781											3	1	1			
Crangonyx pseudogracilis	T040	0.288					70			71	80		2	4	2	5	12	
Eristalis sp.	T144	0.3231	2															
Leydigia sp.	T044	0.39		2				2										
Cricotopus trifasciatus	T085	0.5118									2							
Dicrotendipes modestus	T087	0.5901								5								
Physella heterostropha	T165	0.6299		16		10	10			6	9		18	1	2		2	
Paraphaenocladius sp.	T106	0.6694					2											
Trichocorixa sp.	T153	0.6694					1											
Plathemis sp.	T156	0.6694					1											
Eclipidrilus lacustris	T009	0.6816					17			4	1		6		1			
Actinolaimus sp.	T177	0.6836														1		
Chydorus sphaericus	T043	0.7995						4										
Sphaerium sp.	T175	0.9514		40		76												1
Limnodrilus claparedianus	T029	1.1615	10				1315			726	1460		37	799	900	1640	2104	1
Cricotopus bicinctus	T083	1.2784		4		4							2					
Ilyodrilus templetoni	T028	1.3092	198	290	136	308	203	54	4	4	177	138	108	247	3301	120	910	50

CLICK TO CONTINUE

Table 4. Matrix of Invertebrate Abundace at Each Station for the Cominbed Northern and Southern Study Areas Sorted by site and species scores that were derived from the CCA (see Table 1 for taxa codes)

			LESS CONTAMINATED SITES																	MORE CONTAMINATED SITES															
			MC07	MC03	MC12	HB	MC04	03IP	WH	WW	4	MC01	UF	22	MC02	04IP	SA	6	01IP	MC13	MC08FD	MC11	MC08	13	MC09	MC10	TT30	TT32	MC06	19	TT33	18	12	TT29	10
Genus/Species/Variety	TAXA Code	Sp/Site scores	-1.92	-0.94	-0.82	-0.76	-0.7	-0.69	-0.69	-0.46	-0.444	-0.39	-0.38	-0.36	-0.33	-0.33	-0.28	-0.24	-0.2	-0.05	0.064	0.098	0.138	0.276	0.286	0.341	0.407	0.476	0.515	0.611	0.629	0.88	1.031	1.073	1.165
Dicrotendipes nervosus	T088	1.6378												1														4		1	1				
Batracobdella phalera	T003	1.7753																										1							
Fridericia sp.	T013	1.7753																										1							
Hudsonimyia sp.	T095	1.7753																										1							
Ceratopogon sp.	T069	1.9737																										1						2	
Diptera	T150	2.0481				1																								2			2		
Ephydridae	T137	2.1017																															11		
Rhabdolaimus sp.	T181	2.1017																															2		
Neorhabdocoela	T186	2.1017																															3		
Eisenia sp.	T007	2.114																																1	
Miconchus sp.	T183	2.114																																1	
Hydrophorus sp.	T135	2.1865																									1						1		
Helophorus sp.	T060	2.2713																									1								
Polypedilum convictum	T111	2.2713																									2								
Rheotanytarsus sp.	T127	2.2713																									4								
Oecetis sp.	T159	2.2713																									1								
Tobrilus sp.	T182	2.3783																										1				5	5	3	
Rheocricotopus robacki	T126	2.5951												3																6					
Clinotanypus pinguis	T080	2.7855														2								5			7			1	3	33	3	6	1
Culicoides sp.	T070	2.9561												1																5		6		2	
Ephydra sp.	T136	3.1293																														1			
Pseudosuccinea columella	T163	3.1293																														1			
Sphaeromias sp.	T072	3.4095											1		4								6	1			1		2	1		7			4
Monohelea sp.	T071	4.2089																												8				1	
Paratendipes subaequalis	T109	4.9496																												1					