Environment Canada
Water Science and Technology Directorate

Direction générale des sciences et de la technologie, eau
Environnement Canada

The Application of BEAST Sediment Quality Guidelines to the St. Marys River Area of Concern

D. Milani and L.C. Grapentine

NWRI Contribution No. 06-415

THE APPLICATION OF BEAST SEDIMENT QUALITY GUIDELINES TO THE ST. MARYS RIVER AREA OF CONCERN

D. Milani and L.C. Grapentine

Environment Canada
867 Lakeshore Road, P.O. Box 5050
Burlington, Ontario L7R 4A6

SUMMARY

This report describes sediment quality in the St. Marys River, identified as an Area of Concern (AOC) in 1985 due to water, sediment and biota quality issues. Impairments for the AOC specifically related to sediment contamination include restrictions on fish consumption, degradation of benthos, and restrictions on dredging. The benthic assessment of sediment (BEAST) methodology was applied to 31 sites along the river from Izaak Walton Bay to Little Lake George in the fall of 2002. The BEAST methodology involves the assessment of sediment quality based on multivariate techniques using data on benthic community structure, the functional responses of laboratory organisms in toxicity tests, and the physical and chemical attributes of the sediment and overlying water. Data from St. Marys River sites were compared to biological criteria developed for the Laurentian Great Lakes. Relationships between toxicity and contaminant concentrations were also evaluated by regression analysis.

There are exceedences of the provincial Lowest Effect Level for several metals along the river from the Algoma slag dump to Lake George Channel, with overall highest metal levels observed at Bellevue Marine Park. The Severe Effect Level (SEL) is exceeded for iron at several sites and for arsenic, nickel and manganese at one site along the Algoma slag dump. Total organic carbon is overall high along the river, exceeding the SEL in the Algoma Slip. Polycyclic aromatic hydrocarbon concentrations are high in the Algoma slip (up to 390 µg/g), and are elevated along the river compared to the upstream sites. Total petroleum hydrocarbon concentrations are highest in the downstream reaches of the study area followed by the Algoma slip; highest concentrations (up to 19050 µg/g) are at Bellevue Marine Park.

There is no strong evidence of benthic community alteration and, with the exception of the Algoma slip, there is a trend towards increased abundance and higher diversity of taxa in the river compared to Great Lakes reference sites. Sediment at 6 sites is toxic; 5 of the 6 are located at Bellevue Marine Park and in Lake George Channel with acute toxicity to the midge *Chironomus* and sublethal (growth) effects to the mayfly *Hexagenia*. Toxicity to *Hexagenia* can be partially explained by petroleum hydrocarbons and sediment physical characteristics (grain size) are also important in the relationship. It is not clear what is causing toxicity to *Chironomus*.

A risk-based, decision-making framework for the management of contaminated sediment, recently developed by the Canada-Ontario Agreement Sediment Task Group, was applied to the St. Marys River study. The overall assessment of each site was achieved by integrating the information obtained both within and among the three lines of evidence. Most sites do not require further action. However, there is potential for adverse effects in the downstream areas of the river (Bellevue Marine Park and Lake George Channel), and a more comprehensive study may be warranted to determine the reasons for sediment toxicity, especially with respect to petroleum hydrocarbons. These downstream areas should also be monitored for changes in the status of benthic populations.

Abstract

The St. Marys River was identified as an Area of Concern (AOC) due to water, sediment and biota quality issues. Impairments for the AOC specifically related to sediment contamination include restrictions on fish consumption, degradation of benthos, and restrictions on dredging. The benthic assessment of sediment (BEAST) methodology was applied to 31 sites along the river from Izaak Walton Bay to Little Lake George in the fall of 2002. The BEAST method involves the assessment of sediment quality based on a multivariate technique using data on benthic community structure, the functional responses of laboratory organisms in toxicity tests, and the physical and chemical attributes of the sediment and overlying water. Data from test sites were compared to biological criteria developed for the Laurentian Great Lakes. Results show several metals elevated above sediment quality guidelines along the river, with highest concentrations at Bellevue Marine Park, Lake George Channel and the Algoma slip; total organic carbon is also elevated in these areas of the river. Organic contaminants such as polycyclic aromatic hydrocarbons (highest in Algoma slip) and petroleum hydrocarbons (highest in Bellevue Marine Park) are also elevated above guidelines or upstream reference areas. There is strong evidence of toxicity at six sites, mainly at Bellevue Marine Park and Lake George Channel, with acute toxicity to the midge *Chironomus* and chronic (reduced growth) toxicity to the mayfly *Hexagenia*. Toxicity to *Hexagenia* can be partially explained by petroleum hydrocarbons. There is no strong evidence of benthic community alteration and, and with the exception of the Algoma slip, generally there is a trend towards increased abundance and higher diversity of taxa in the river compared to Great Lakes reference sites. A risk-based, decision-making framework for the management of contaminated sediment, recently developed by the Canada-Ontario Agreement Sediment Task Group, was applied to the St. Marys River study. Most sites do not require any further actions. However, there is potential for adverse effects in the downstream areas of the river (Bellevue Marine Park and Lake George Channel), and a more comprehensive study may be warranted to determine the reasons for sediment toxicity, especially with respect to petroleum hydrocarbons.

Résumé

On a attribué à la rivière St. Marys le statut de secteur préoccupant (SP) en raison de problèmes de qualité de l'eau, des sédiments et du biote. Les problèmes du SP en relation directe avec la contamination des sédiments comprennent des restrictions relatives à la consommation du poisson, la dégradation du benthos et des restrictions aux travaux de dragage. À l'automne 2002, on a appliqué la méthodologie d'évaluation des sédiments benthiques BEAST à 31 sites le long de la rivière, de la baie Izaak Walton au Petit lac George. La méthode BEAST consiste à évaluer la qualité des sédiments au moyen d'une technique multivariée utilisant des données sur la structure des communautés benthiques, les réponses fonctionnelles des organismes en laboratoire lors d'essais de toxicité et les attributs physiques et chimiques des sédiments et de l'eau sus-jacente. Nous avons comparé les données des sites d'essai à des critères biologiques élaborés pour les Grands Lacs laurentiens. Les résultats indiquent la présence de plusieurs métaux dans des concentrations dépassant les valeurs seuils des lignes directrices sur la qualité des sédiments le long de la rivière, les concentrations les plus fortes ayant été observées au parc marin Bellevue, dans le chenal du lac George et dans la zone de mouillage d'Algoma; la teneur en carbone organique total est elle aussi élevée dans ces secteurs de la rivière. La concentration en contaminants organiques tels que les hydrocarbures aromatiques polycycliques (surtout dans la zone de mouillage d'Algoma) et en hydrocarbures pétroliers (surtout au parc marin Bellevue) s'élève également au-delà des lignes directrices ou des données des sites de référence en amont. Six sites présentent des signes évidents de toxicité, surtout au parc marin Bellevue et dans le chenal du lac George, avec une toxicité aiguë pour le moucheron *Chironomus* et une toxicité chronique (croissance réduite) pour l'éphémère *Hexagenia*. La toxicité pour l'*Hexagenia* peut s'expliquer en partie par la présence d'hydrocarbures pétroliers. Il n'y a aucun signe évident d'altération des communautés benthiques; à l'exception de la zone de mouillage d'Algoma, on observe une tendance générale à une abondance et à une diversité accrues des taxons dans la rivière, comparativement aux sites de référence des Grands Lacs. Un cadre décisionnel axé sur le risque pour la gestion des sédiments contaminés, mis au point récemment par le Groupe de travail sur les sédiments de l'Accord Canada-Ontario, a été appliqué à l'étude de la rivière St. Marys. La plupart des sites ne nécessitent aucune mesure supplémentaire. Cependant, il pourrait y avoir des effets négatifs dans les secteurs d'aval de la rivière (parc marin Bellevue et chenal du lac George), et il pourrait être justifié de réaliser une étude plus complète afin de déterminer les causes de la toxicité des sédiments, en particulier pour ce qui est des hydrocarbures pétroliers.

ACKNOWLEDGEMENTS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1   INTRODUCTION

1.1   Background and NWRI Mandate

In the 1970s, 42 locations in the Great Lakes where the aquatic environment was severely degraded were identified as "problem areas" by the International Joint Commission (IJC). Of these, 17 are along Canadian lakeshores or in boundary rivers shared by the US and Canada. The IJC's Great Lakes Water Quality Board recommended in 1985 that a Remedial Action Plan (RAP) be developed and implemented for each problem area. The RAP approach and process is described in the 1987 Protocol to the Great Lakes Water Quality Agreement (GLWQA). The goal is to restore the "beneficial uses" of the aquatic ecosystem in each problem area, which were now called "Areas of Concern" (AOCs). Fourteen possible "impairments of beneficial use", which could be caused by alterations of physical, chemical or biological conditions in the area, are defined in Annex 2 of the GLWQA.

The Canadian government's commitment to the GLWQA was renewed in 2000 with the Great Lakes Basin 2020 (GL2020) Action Plan, under which the efforts of eight federal departments to "restore, conserve, and protect the Great Lakes basin" over the next five years were to be co-ordinated. Environment Canada's contribution included the funding of detailed chemical and biological assessments of sediments in Canadian AOCs. The National Water Research Institute (NWRI) was given the responsibility of conducting and reporting on these assessments.

Under the terms of reference for NWRI's mandate, the Benthic Assessment of Sediment ('BEAST') methodology of Reynoldson and co-workers (1995; 2000) was applied to the AOC assessments (see description below). The study described in this document was conducted to supplement existing data to complete an overall assessment of sediments in the St. Marys River that are, or have been, exposed to industrial effluents.

1.2   The BEAST

The BEAST is a predictive approach for assessing sediment quality using multivariate techniques (Reynoldson et al. 1995; 2000; Reynoldson and Day 1998). The approach utilizes data from nearshore reference sites that were sampled from the Laurentian Great Lakes over a three-year period. Information includes benthic community structure (the type and number of

invertebrate taxa present), selected habitat variables, and responses (survival, growth and reproduction) of four benthic invertebrates in laboratory toxicity tests. The reference sites establish normal conditions for selected endpoints, and determine the range of 'normal' biological variability. As a result, expected biological conditions are predicted by applying relationships developed between biological and habitat conditions.

1.3   St. Marys River Area of Concern

The St. Marys River was identified as an AOC by the International Joint Commission in 1985 due to water, sediment and biota quality issues, such as phosphorus, bacteria, oil and grease, metals and organic contaminants, fish consumption advisories and impacted biota. The St. Marys River AOC has been the subject of two major remedial action plan (RAP) reports – Stage 1: Environmental Conditions and Problem Definition (St. Marys River RAP Team 1992) and Stage 2: Remedial Strategies for Ecosystem Restoration (St. Marys River RAP Team 2002). Nine beneficial use impairments were identified in Stage 1 RAP report. Those related to sediment contamination included restrictions on fish consumption, degradation of benthos and restrictions on dredging.

Recently, a synthesis of chemical and biological assessments performed in the AOC was conducted (Golder Associates 2004). This report focused on assessments performed from 1992 to 2000 that would not have formed part of the Stage 1 RAP report of 1992. The Golder report identifies that while improvements have been made, several problematic areas in the river still exist, including the Algoma slip, Bellevue Marine Park and Lake George Channel.

In October 2002, the National Water Research Institute of Environment Canada undertook a sampling program to define the general status of contamination in the river. Areas identified in Stage 1 as being contaminated sediment concerns were revisited, and upstream sites were included in the study. This report presents the results of these investigations and provides a spatial description of the state of the sediments in St. Marys River along with the degree of contamination.

2   METHODS

2.1   Sample Collection

Thirty-one sites were sampled along the St. Marys River from Izaak Walton Bay to Little Lake
George 5 – 8 October 2002. Site co-ordinates and depth are provided in Table 1, and sampling
locations are shown in Figure 1. The location of the sites was established in the field using a
Magnavox MX300 differential Global Positioning System. The following areas of the river were
sampled:

1   *Izaak Walton Bay (4 sites).*   A reference area located at the west end of the river,
upstream of Point aux Pins Bay. Previous sampling in this area showed low contaminant
levels and good quality of benthos.

2   *Point aux Pins Bay (5 sites).* A reference area located upstream of the Algoma slag
dump. Previous sampling in this area showed improvements over earlier surveys with
respect to benthos quality. However, accumulation of wood debris and elevated metal
(cadmium, cyanide, copper) and nutrient (total organic carbon, nitrogen) levels above
sediment quality guidelines have been noted.

3   *South Shore US Reference (1 site).*   A reference location on the south shore of St. Marys
River on the US side, just upstream of Tannery Bay.

4   *Algoma Slag Dump (6 sites).* The slag dump is adjacent to the river at the west end of
Sault Ste. Marie (Ontario) and has been identified as a potential source of metal and
organic compounds. Elevated metals, PAHs, petroleum hydrocarbons and nutrients (total
organic carbon and nitrogen) have been noted in this area.

5   *Algoma Slip (2 sites).* The slip is located just east of the slag dump. Two creeks (East
Davignon and Bennett) enter the slip at the north end and are possible contaminant
routes. Elevated levels of PAHs, petroleum hydrocarbons, metals and nutrients above
sediment quality guidelines have been noted. The upper section of slip was dredged in
1995 resulting in a reduction in contaminant levels. However, there is still significant
sediment contamination and therefore benthic recovery may be limited.

6   *Bellevue Marine Park (6 sites).* A depositional area located along the Sault Ste. Marie
waterfront, below Algoma Steel Inc. and St. Marys Paper. Accumulation of wood fibres

3

and detritus and elevated levels of petroleum hydrocarbons, PAHs, and oils and grease from upstream sources have been noted in this area.

7   *Lake George Channel (5 sites).* Located at the east end of the study area between Bellevue Marine Park and Little Lake George. There are a number of depositional areas in the channel where sediment contaminant accumulation from upstream sources including the East End Waste Water Treatment Plant has occurred.

8   *Little Lake George (2 sites).* Located east of Lake George Channel. Sources of contaminants to this area include upstream sources and storm water outfalls.

At each test site, samples were collected for chemical and physical analyses of the surficial (top 10 cm) sediment and overlying water, benthic community structure and whole sediment toxicity tests. Environmental variables measured at each site are listed in Table 2. Sampling techniques are described in Reynoldson et al. (1995; 1998a).

Prior to sediment collections, water samples were obtained using a van Dorn sampler, taken at 0.5 meter from the bottom. Temperature, conductivity, pH and dissolved oxygen were measured on site using Hydrolab apparatus. Samples for alkalinity, total phosphorus, total nitrogen, nitrates/nitrites (NO_3/NO_2) and ammonia (NH_3) were dispensed to appropriate containers and stored (4°C) for later analysis.

A 40 cm × 40 cm mini-box corer was used to obtain the benthic community and sediment chemistry samples (18 sites). Benthic community samples were subsampled from the mini-box core using 10 cm (6.5 cm diameter) acrylic tubes. Samples were sieved through a 250-μm mesh screen and the residue preserved with 5% formalin for later identification. The remaining top 10-cm of sediment from each box core was removed, homogenized in a Pyrex dish and allocated to containers for chemical and physical analyses of the sediment. At each of 13 sites where a mini-box corer could not be used (due to a high proportion of sand or compact clay preventing the box core from sealing or from penetrating the sediment), three ponar grabs were collected for benthic community structure analysis and one ponar grab was collected for chemical and physical properties of the sediment. Each community structure ponar sample was sieved in its entirety and the residue preserved as described above. Benthic community samples were

4

transferred to 70% ethanol after a minimum of 72 hours in formalin. Sediment samples were
kept at 4°C with the exception of the organic contaminant samples, which were frozen (-20°C).
Five mini-ponar grabs were collected per site for the laboratory toxicity tests (approximately 2 L
sediment per replicate). Each of the five sediment grabs was placed in separate plastic bag,
sealed, and stored in a bucket at 4°C.

2.2 Sediment and Water Physico-Chemical Analyses

Overlying Water

Analyses of alkalinity, total phosphorus, NO_3/NO_2, NH_3 and total Kjeldahl nitrogen were
performed by the Environment Canada's National Laboratory for Environmental Testing
(NLET) (Burlington, ON) by procedures outlined in Cancilla (1994) and NLET (2000).

Particle Size

Percents gravel, sand, silt, and clay were performed by the Sedimentology Laboratory at NWRI
(Burlington, ON) following the procedure of Duncan and LaHaie (1979).

Sediment Trace Metals and Nutrients

Freeze dried sediment was analyzed for trace elements (hot aqua regia extracted), major oxides
(whole rock), loss on ignition, total organic carbon, total phosphorus, and total nitrogen by
Caduceon Laboratory (Ottawa, ON), using USEPA/CE (1981) standard methodologies or in
house procedures.

Organic Contaminants

Frozen sediment samples were analyzed for petroleum hydrocarbons (PHCs), polycyclic
aromatic hydrocarbon (PAHs), and total organic carbon by Maxxam Analytics (Mississauga,
ON). Analytic methods for PHCs were based on Canada wide standards using Ontario Standard
Operating Procedures 0754 and 0755 (CCME 2001). Procedures for organic contaminant
analyses are provided in APHA (1995). Polycyclic aromatic hydrocarbons were analyzed by
GC/MS based on EPA method 8170, and total organic carbon was determined by EPA method
410.4.

2.3 Taxonomic Identification

Invertebrates in the benthic community samples were sorted, identified to the family level, and counted at the Invertebrate Laboratory at NWRI (Burlington, ON). Slide mounts were made for Oligochaetae and identified to family using high power microscopy.

2.4 Sediment Toxicity Tests

Toxicity tests were performed at the Ecotoxicology Laboratory at NWRI (Burlington, ON). Overlying water used in toxicity tests was City of Burlington tap water (Lake Ontario), which was charcoal filtered and aerated for a minimum of three days prior to use. Water characteristics included: conductivity 273 – 347 µS/cm; pH 7.5 - 8.5; hardness 120 - 140 mg/L; alkalinity 75 - 100 mg/L; chloride ion 22 - 27 mg/L.

Four sediment toxicity tests were performed: *Chironomus riparius* 10-d survival and growth, *Hyalella azteca* 28-d survival and growth, *Hexagenia* spp. 21-d survival and growth, and *Tubifex tubifex* 28-d survival and reproduction. Sediment handling procedures and toxicity test methods are described elsewhere (Borgmann and Munawar 1989; Borgmann et al. 1989; Krantzberg 1990; Reynoldson et al. 1991; 1998b; Bedard et al. 1992; Day et al. 1994). For quality control purposes, each test set included control sediment, collected from Long Point Marsh, Lake Erie. All laboratory test organisms grow and reproduce well in this sediment, which is comprised on average of 70.33% silt, 29.13% clay, 0.54% sand, and 8.1% organic carbon. All tests passed an acceptability criterion based on percent control survival in Long Point sediment before being included in a data set, i.e., ≥ 80% for *H. azteca* and ≥70% for *C. riparius* (USEPA 1994; ASTM 1995); ≥80% for *Hexagenia* spp., and ≥75% for *T. tubifex* (Reynoldson et al. 1998b).

Water chemistry variables (pH, dissolved oxygen (mg/L), conductivity (µS/cm), temperature (°C), and ammonia (mg/L)) were measured in each replicate test beaker on day 0 (start of test) and at the completion of the test. Tests were run under static conditions in environmental chambers at 23°C ±1 °C, under a photoperiod of 16L: 8D and an illumination of 500 - 1000 lux, with the exception of *T. tubifex* test which was run in the dark.

Hyalella azteca 28-Day Survival and Growth Test

The test was conducted for 28 days using 2 -10 day old organisms. On day 28, the contents of each beaker were rinsed through a 250-µm screen and the surviving amphipods counted. Amphipods were dried at 60°C for a minimum of 24 hours and dry weights recorded. (Initial weights were considered negligible.)

Chironomus riparius 10-Day Survival and Growth Test

The test was conducted for 10 days using first instar organisms. On day 10, the contents of each beaker were wet sieved through a 250-µm screen and the surviving chironomids counted. Chironomids were dried at 60°C for a minimum of 24 hours and dry weights recorded. (Initial weights were considered negligible.)

Hexagenia spp. 21-Day Survival and Growth Test

The test was conducted for 21 days using pre-weighed nymphs (between 5 - 8 mg wet weight/nymph). On day 21, the contents of each jar were wet sieved through a 500-µm screen and surviving mayfly nymphs counted. Nymphs were dried at 60°C for a minimum of 24 hours and dry weights recorded. Initial mayfly wet weights were converted to dry weights based on a relationship of wet weight to dry weight previously determined for laboratory mayflies by regression analysis). Growth was determined by final dry weight minus initial dry weight.

Tubifex tubifex 28-Day Survival and Reproduction Test

The test was conducted for 28 days using sexually mature worms (gonads visible). On day 28, the contents of each beaker were rinsed through a 500-µm and 250-µm sieve sequentially. The number of surviving adults, full cocoons, empty cocoons, and large immature worms were counted from the 500-µm sieve and the number of small immature worms counted from the 250-µm sieve. Survival and reproduction were assessed using four endpoints: number of surviving adults, total number of cocoons produced per adult, the percent cocoons hatched, and total number of young produced per adult.

2.5 Data Analysis

BEAST Analysis

Test sites were assessed using BEAST methodology (Reynoldson and Day 1998; Reynoldson et al. 2000). The BEAST model predicts the invertebrate community group that should occur at a test site based on natural environmental conditions. Multiple discriminant analysis was used to predict the test sites to one of five reference community groups using a previously computed relationship between five environmental variables (latitude, longitude, depth, total organic carbon, and alkalinity) and the community groups (Reynoldson et al. 1995; 2000). For each test site, the model assigned a probability of it belonging to each of five reference faunal groups. Community structure assessments were conducted at the family level, as this taxonomic detail is shown to be sensitive for the determination of stress (Reynoldson et al. 2000). Data from the ponar samples were adjusted with conversion factors to be comparable to invertebrate densities determined using the box corer in the present and reference site assessments. The conversion factors were those used by Reynoldson et al. (1989). To adjust for sampler efficiency, taxon counts from the ponar samples were divided by 0.69; except for the chironomids, oligochaetes and sphaeriids, where 0.52, 0.55 and 0.75 were used, respectively. All ponar counts were then adjusted to number per 33 cm^2 (area of box corer subsampling tube). Community data for the test sites were merged with the reference site invertebrate data of the matched (group to which the test site has the highest probability of belonging) reference group only and ordinated using hybrid multidimensional scaling (HMDS; Belbin 1993), with Bray-Curtis distance site × site association matrices calculated from raw data. Toxicity data were analysed using HMDS, with Euclidean distance site × site association matrices calculated from standardized data. Toxicity endpoints for the test sites were compared to those for all reference sites. (There are no distinct groups as with the community structure assessment.) Principal axis correlation (Belbin 1993) was used to identify relationships between habitat attributes and community or toxicity responses. This did not include organic contaminant data, which were not measured in the reference sediments. Significant endpoints and environmental attributes were identified using Monte-Carlo permutation tests (Manly 1991). Test sites were assessed by comparison to confidence bands of appropriate reference sites. Probability ellipses were constructed around reference sites, establishing four categories of difference from reference: equivalent /non-toxic (within the 90% probability ellipse), possibly different/ potentially toxic (between the 90 and

8

99% ellipses), different/toxic (between the 99 and 99.9% ellipses), and very different/severely toxic (outside the 99.9% ellipse) (Figure 2). Test site toxicological responses were compared to numerical criteria previously established for each category (non-toxic, potentially toxic and toxic) and species from reference site data (Reynoldson and Day 1998).

Test data were analysed in subsets to maintain the ratio of test:reference sites ≤0.10. Multiple discriminant analysis was performed and probability ellipses (Figure 2) were produced using the software SYSTAT (Systat Software Inc. 2002). HMDS, principal axis correlation, and Monte-Carlo tests were performed using the software PATN (Blatant Fabrications Pty Ltd. 2001).

Sediment Toxicity and Contaminant Concentrations

As the BEAST assessment does not incorporate any information on organic contaminants in the sediment (organic contaminant concentrations were not measured in reference sediments), additional analyses of relationships between sediment toxicity (using all toxicity test endpoints) and contaminant concentrations for St. Marys River sites were conducted. These should aid in identifying causes of toxicity (e.g., organic contaminants, inorganic compounds, sediment grain size).

Relationships between sediment toxicity and sediment contamination for the St. Marys River sites were assessed graphically and by regression analysis. Initially, to examine general and dominant patterns in the data, comparisons between the toxicity responses and contaminant conditions were made based on integrative, compound variables (from either summation or multivariate ordination of measurement variables). After this, to better detect less dominant (though significant) relationships between two or a few variables, analyses were conducted using the original measurement variables (i.e., toxicity endpoints and concentrations of individual compounds).

The sediment toxicity data for St. Marys River sites were ordinated again by HMDS, as a single group and without the reference site data. To identify and relate the most important of the toxicity endpoints to the HMDS axes, principal axis correlation was conducted. Extractable concentrations in sediment of 9 metals (As, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn) were ordinated by

principal components analysis (PCA). The eigenanalysis was performed on the correlation matrix. Total petroleum hydrocarbon (PHC) and polycyclic aromatic hydrocarbon (PAH) variables were integrated by summing the concentrations of the individual compounds. Data for all variables were log(x)-transformed.

Both the integrated descriptors of sediment toxicity (axes scores from the HMDS) and individual toxicity endpoints (survival of *Chironomus* and growth of *Hexagenia*) were plotted against the integrated contaminant descriptors (from PCA and summation of organic contaminants) as well as individual log(x)-transformed sediment contaminant (9 metals, PHCs and PAHs), 3 sediment nutrient variables, and grain size. To determine whether toxicity was better explained by joint consideration of the contaminant descriptors, multiple linear regression involving the contaminant descriptors as predictors was calculated with each toxicity descriptor as the response variable. The degree to which individual sediment variables account for toxicity was assessed by fitting regression models using "best subset" procedures (Draper and Smith 1998; Minitab 2000.) The best models were those having maximum explanatory power (based on $R^2_{adjusted}$), minimum number of nonsignificant predictors, and minimum amount of predictor multicollinearity.

2.6 Quality Assurance/Quality Control

Field Replication

At three randomly selected sites (126, 176, and 196), triplicate overlying water and sediment samples were collected for determination of within-site and among-sample variability. Variability in a measured analyte was expressed as the coefficient of variation (CV = standard deviation / mean $\times$ 100).

Laboratory

For sediment trace metal and nutrient analyses (performed by Caduceon Laboratory), quality control procedures included repeat measurements, and control charting of influences, standards and blanks. Reference material was used in each analytical run. Calibration standards were run before and after each run. Run blanks and reference standards were run 1 in 15 samples and repeats were run 1 in 10 samples.

For sediment organic contaminant analyses (performed by Maxxam Analytics), quality control measures included method blanks, repeat measurements, analysis of reference standards, and the percent recoveries of spiked blanks, matrix spikes and surrogate spikes.

Community Structure Sorting

To evaluate control measures for benthic invertebrate enumeration (on a monthly basis), a previously sorted sample was randomly selected, re-sorted, and the number of new organisms found counted. The sorting efficiency, expressed as the percent of organisms missed (% OM), was calculated using the equation:

% OM = # Organisms missed / Total organisms found × 100

A desired sorting efficiency is %OM < 5%. If the %OM was > 5%, two more replicate samples were randomly selected and the %OM calculated. The average %OM was calculated based on the three samples re-sorted, and represents the standard sorting efficiency for that month. The average %OM is based on only one replicate sample if %OM is < 5%.

3   RESULTS AND DISCUSSION

3.1 Sediment and Water Physico-Chemical Properties

Overlying Water

Conditions of overlying water 0.5 m above the sediment are generally similar for St. Marys River sites for the variables measured (Table 3). The range across variables are: alkalinity 7 mg/L, conductivity 71 µS/cm, dissolved oxygen 1.5 mg/L, NO_3/NO_2 0.22 mg/L, NH_3 0.04 mg/L, pH 1.5, temperature 4.0 °C, total Kjeldahl nitrogen (TKN) 0.5 mg/L, and total phosphorus (TP) 0.04 mg/L; suggesting homogeneity in the water mass across most sampling sites. The lowest pH (6.5, 6.8) is noted at the two sites in Little Lake George. Dissolved oxygen concentrations are ≥ 10 mg/L. The sites in the Algoma slip (182, 192) are most dissimilar from the rest of sites, with the highest conductivity, phosphorus, nitrogen, and nitrates/nitrites.

Particle Size / Sediment Trace Metals and Nutrients

Percents sand, silt, clay and gravel are shown in Table 4. There are a variety of substrate types in the river but generally sediments consist mainly of silt, ranging from 0 to 78% (median 46%) and/or sand, ranging from 2 to 91% (median 38%). Percent clay ranges from 3 to 50 % (median 12%), and gravel ranges from 0 to 4.5%. Sites that contain gravel are in the upstream bays and along the slag dump mainly. The highest percentage of fines (silt and clay) is in sediments adjacent to Bellevue Marine Park, although within each area, differences can be seen in substrate type among sites (e.g., half the Bellevue Marine Park sites are a silty-sand and the other half are a very fine silty-clay). Substrate types are important as they can affect contaminant bioavailability, benthic assemblages and toxicological responses.

Sediment nutrient and trace metal concentrations are shown in Table 5. Total organic carbon (TOC) ranges from 0.4 to 30.6% (median 3.7%), total nitrogen (TN) ranges from 186 to 4497 µg/g (median 1160 µg/g) and TP ranges from 175 to 811 µg/g (median 477 µg/g). The highest TOC (>SEL) is observed in the Algoma slip (16.0%, 30.6%) and at the east end of Bellevue Marine Park (14.0%). Total organic carbon was also measured in frozen sediment samples (see Section 2.2). Percent TOC in the frozen samples range from 0.3 to 7.1% along the river and is highest at Bellevue Marine Park (range 3.9 to 7.1%) (Appendix A; Table A1). Generally, TOC in the frozen samples are similar to those in the freeze dried samples; however, there are some notable differences. For the two sites in the Algoma slip, the freeze dried samples have higher TOC (16%, 30%) than the frozen samples (5.5%, 5.6%). Bellevue Marine Park site 6991 has higher TOC in the freeze dried sample (14% vs. 4.8% in frozen sample), while Point aux Pins Bay site 126 (replicate 1) and Little Lake George site 6902 have lower TOC in the freeze dried samples (0.4% vs. 6% in the frozen samples). The geometric mean slope, estimated by the S_y/S_x, where S_y and S_x = standard deviation of logged *Y*-values and *X*-Values, respectively (Legendre and Legendre 1998), is 0.77, indicating a fair overall agreement in measurement of sediment total organic carbon.

Metals exceeding the provincial Severe Effect Level (SEL) include arsenic (As, 1 site), iron (Fe, 8 sites), manganese (Mn, 2 sites) and nickel (Ni, 2 sites) (Table 5). The highest concentrations of As, cobalt (Co), Fe, Mn, Ni and zinc (Zn) are observed at site 241, which is located at the

Algoma slag dump. Site 6902, which is located at the outlet of Little Lake George, has elevated Mn and Ni above SELs. With the exception of site 241 (slag dump) and 192 (Algoma slip), Fe is highest at the Bellevue Marine Park. Reference areas upstream of the slag dump have the lowest trace metal concentrations in the river.

Upstream Reference - Izaak Walton Bay (IWB) (4 sites)

Sites in IWB have firm substrates (silty sand – with gravel at one site), with the exception of site 6903 (which is separate from the other sites along the north shore of the area – see Figure 1), which consists of a fine silty sediment (68% silt). Total organic carbon ranges from 0.4 to 2.2% and trace metal concentrations are below the LELs, with the exception of chromium (Cr) and copper (Cu) at 6903. (6903 also has the highest TOC, TP, and TN.) During sampling, vegetation was noted at sites 243 and 245 and organic material was noted on visual inspection of 6903 sediment.

Upstream Reference - Point aux Pins Bay (PPB) (5 sites)

Four of the five sites were situated in varying distances from shore (479m, 741m, 1090m and 1535m). Substrates are firm (sand ≥ 38%) with the exception of site 52-479 (closest to shore), which is a soft substrate consisting mainly of silt (78%). Small amounts of gravel (≤ 1.2%) are present at 2 of the 5 sites. Metal concentrations are low generally (< LELs) with the exception of 52-479, where As and Cu concentrations are > LEL, and TOC is high (7.6%) compared to the other sites (range 0.4 to 1.7%). Bark chips were noted during sampling at 52-479 and 52-1090 and vegetation noted at 52-1535.

Upstream Reference – US south shore (1 site)

This site (6904), located upstream of Tannery Bay on the south shore, consists mainly of sand (60%), with similar amounts of silt and clay. Total organic carbon is low (0.8%) as are metal concentrations, with no exceedences of the LELs except for cadmium (Cd) (1.0 µg/g). This site was originally located in Tannery Bay; however, the bay was boomed off and inaccessible at the time of sampling; therefore, the site was moved just upstream of the bay.

Algoma Slag Dump (6 sites)

Four of the six sites along the slag dump have firm substrates (48 to 90% sand with gravel at 3 sites), and the remaining 2 sites consist of fine silty sand. Total organic carbon ranges from 0.5 to 5.6% and is highest at the eastern end of the area. Trace metal concentrations are < SEL with the exception of site 241: As (54 µg/g), Fe (13.2% - highest found in the St. Marys River sampling area), Mn (3553 µg/g) and Ni (90 µg/g). Site 241 also has the highest concentration of Zn (564 µg/g) and Cr (69 µg/g). The LELs are exceeded for Cr (3 sites), Cu (3 sites), Mn (2 sites), Ni (4 sites), lead (Pb) (1 site) and Zn (2 sites). In a 1989 study, 1 site (of 16) exceeded the SEL for As (39.5 µg/g) and Zn (1300 µg/g) and at other sites in the slag dump area, Fe (a maximum of 17%) and Mn (maximum of 3600 µg/g) exceeded the SELs (Kauss 2000). There were numerous exceedences of the LEL for 9 metals in the 1989 study, similar to that found in the current study. In a 1999 study, SEL exceedences were again noted for Fe and Mn and there were numerous exceedences of the LEL for several metals (JWEL 2002). Vegetation was noted at sites 201 and 242.

Algoma Slip (2 sites)

The site closest to the head of the slip (182) consists of a firm sandy silt substrate, whereas the site midway down the slip (192) has a silty clay substrate (hard compact red clay). Total organic carbon is very high (1.6 and 3.1× greater than the SEL) and is highest overall in the sampled areas of the river. Iron is slightly above the SEL at site 192, and the LEL is exceeded for Cr, Cu, Mn and Zn at both sites and for Ni at site 192. Pope and Kauss (1995) found Fe > SEL at 3 of 17 sites sampled in the slip in 1990 and Mn > SEL at 3 of 17 sites; metal concentrations were higher at head of slip. The slip was again sampled in 1995 (post dredge) with metal exceedences of SEL limited to Fe and Mn. In the current study, Mn concentrations do not exceed the SEL. A visible oil slick and strong odour was noted at site 182 (head of slip) during sampling and iron ore pellets were present at site 192 (midway down the slip). An attempt to collect a sample close to the mouth of the slip failed due to the presence of large amounts of gravel and the site was subsequently dropped.

Bellevue Marine Park (BMP) (6 sites)

Three sites (6981, 6983, 6984) have a coarse silty sand substrate (36 to 48% sand) and the other 3 sites (6986, 6991, 6992) have a fine silty clay substrate (72 to 74% clay). Heavy organic matter and vegetation was observed in the area during sampling. Total organic carbon is high, ranging from 4.7 to 14.1% (TOC > SEL at 6991). The LEL is exceeded for several metals: As (3 sites), Cd (1 site), Cu (all sites), Cr (all sites), mercury (Hg) (2 sites), Mn (5 sites), Ni (5 sites), Pb (all sites), Zn (all sites). The sites with the finer substrates have higher sediment metal concentrations. Percent iron is high, ranging from 2.7 to 6.4%, exceeding the SEL at 4 of the 6 sites. These results are similar to that found in a 1995 study, where the SEL was exceeded for Cr at 1 site and for Fe at 14 of 20 sites (Kilgour and Morton 1995). Exceedences of the LEL in the 1995 study were also noted for the same metals that exceed the LEL in the current study.

Lake George Channel (LGC) (5 sites)

One site (172) has a firm sandy substrate (90% sand), and remaining sites have sandy silt substrates (38 to 54% silt). Total organic carbon ranges from 0.6 to 7.7%, and is relatively high at 4 of the 5 sites. Heavy organic material was noted in the sediment at two sites (172, 175) during sampling. The LEL is exceeded for As (4 sites), Cr (all sites), Cu (4 sites), Hg (1 site), Mn (1 site), Ni (all sites), Pb (4 sites) and Zn (3 sites). Trace metals are below the SELs with the exception of Fe at one site (172). These results are similar to that found in 1999, where 3 of 22 sites sampled in LGC exceeded the SEL for Fe (JWEL 2002). Exceedences of the LELs were also noted for the some of the same metals that exceed the LELs in the current study.

Little Lake George (LLG) (2 sites)

Due to low water levels, sites were moved from their original locations in the central portion of the lake to the mouth of the channel (6901) and the outlet (6902) of LLG. Site 6901 consists of a fine silty-clay substrate (70% silt, 20% clay), and site 6902 has a firmer silty-sand substrate (60% silt, 21% sand, 19% clay). Total organic carbon is high at the mouth (6.5%) and low at the outlet (0.4%). Low trace metal concentrations are observed with SEL exceedences limited to Fe (5.3%) at 6901, and Mn (1216 μg/g) and Ni (78 μg/g) at 6902.

Organic Contaminants

Concentrations of petroleum hydrocarbons (PHCs) and polycyclic aromatic hydrocarbons (PAHs) are provided in Appendix A; Tables A2 and A3, respectively.

Petroleum Hydrocarbons (PHCs)

Total PHC concentrations (sum of F1 to F4 compounds) range from below detection (1 site at the western end of the slag dump) to a maximum of 19,050 µg/g (site 6986 - Bellevue Marine Park) (Appendix A; Table A2). The F1 PHCs (C6-C10 hydrocarbons) are not detected at any sites. The F2 PHCs (C10-C16 hydrocarbons) are detected at 16 of the 31 sites and range from 12 to 260 µg/g (median 63 µg/g). The highest concentrations are found in the BMP, followed by the site at the mouth of LLG (6901) and the site at the head of the Algoma slip (182). Compounds in the range of C16-C34 hydrocarbons (F3) are present at 30 of the 31 sites in the range of 16 to 3900 µg/g (median 410 µg/g). Similar to the F2 compounds, F3 compounds are highest along the BMP, followed by sites 6901 (LLG) and 182 (Algoma slip). The F4 compounds (C34-C50 hydrocarbons) are detected at 22 of the 31 sites, in the range of 23 to 4400 µg/g (median 410 µg/g), and again are highest in the BMP followed by sites in the LGC and at the mouth of LLG. At several sites, PHCs analysis did not reach baseline at C50. In these cases, F4 compounds were analyzed gravimetrically. Five of the six sites in the BMP, as well as three sites in LGC, the LLG and Algoma slip sites, and one site along the slag dump contain the heavy F4 hydrocarbons (Appendix A; Table A2). Benzene (0.29 to 0.68 µg/g), toluene (0.17 to 0.39 µg/g) and total xylenes (0.19 to 0.52 µg/g) are detected at the two sites in the Algoma slip, with slightly higher concentrations noted at the head of the slip. Total PHCs, analyzed at 14 sites at Bellevue Marine Park in 1995, ranged from 350 to 112,500 µg/g (median 4828 µg/g) (Bedard and Petro 1997). With the exception of 1 site from the 1995 study (located farthest upstream, nearshore to the Ontario Ministry of Natural Resources property), total PHC concentrations in the Bellevue park area in the current study are generally higher, ranging from 367 to 19,050 µg/g (median 11,400 µg/g).

Polycyclic Aromatic Hydrocarbons (PAHs)

Total PAHs (sum of 16 PAH compounds) in the sediment are detected at 24 of the 31 sites and range from below detection (9 sites upstream of the slag dump) to 389 µg/g (Algoma slip)

(Appendix A; Table A3). Total PAHs do not exceed the SEL (adjusted for TOC) at any site. The LEL is exceeded in the slip and at half the sites at Bellevue Marine Park and at half the sites at the slag dump. The highest concentrations are observed in the Algoma slip (49 and 389 µg/g), followed by the sites along the slag dump (range 0.1 to 23 µg/g) and BMP sites (range 2 to 7 µg/g). PAHs are not detected or are in very low concentrations at sites upstream of the slag dump. Sediments were analyzed for PAHs at 8 sites along the river in 1992 and at 14 sites in 1995, including 1 upstream site, 1 site in the Algoma slip, 15 sites in the BMP, 2 sites in LGC and 1 site in LLG (Bedard and Petro 1997). With the exception of the Algoma slip, PAH concentrations in the current study are lower than those reported in 1992 and 1995. A maximum PAH concentration of 292 µg/g was observed in the Algoma slip in 1992 (389 µg/g in current study). Total PAHs in the BMP ranged from 11 to 85 µg/g (1992 and 1995, Bedard and Petro 1997), while in the current study, PAHs range from 2 to 7 µg/g. In LGC, PAHs were reported as 11 and 14 µg/g (1992) and range from 0.7 to 2.8 in the channel in the current study. The upstream site sampled in 1992 had a PAH concentration of 0.97 µg/g, while sites in a similar location range from below detection to 0.06 µg/g.

3.2 Benthic Community Structure

The BEAST discriminant model matched all 31 St. Marys River sites to Reference Group 1 (Table 6). The probabilities are high, ranging from to 62.9 to 99.9 % (mean 83%, median 85%). Group 1 has a total of 108 sites: 39 from Georgian Bay, 24 from North Channel, 21 from Lake Ontario, 16 from Lake Erie, 4 from Lake Huron, and 4 from Lake Michigan. This reference group is characterized mainly by Chironomidae (midge, ~40% occurrence), followed by Tubificidae (oligochaete worm, ~17% occurrence), and Sphaeriidae (fingernail clam, ~15% occurrence). To a lesser degree, Asellidae (isopod), Naididae (oligochaete worm), and Sabellidae (polychaete worm) are also present (between ~4 to 6% occurrence). Other families such as Haustoriidae (amphipod), Valvatidae (snail), Dreissenidae (zebra mussel) and Gammaridae (amphipod) are present occasionally (≤ 2% occurrence). Table 7 shows the mean abundances per 33cm^2 (area of the box core subsampling tube) of the predominant reference group taxa, and taxon diversity at the St. Marys River sites. Complete invertebrate family counts are provided in Appendix B; Table B1. Overall, St. Marys River sites are dominated by Chironomidae and Tubificidae, which are present at all sites, and Sphaeriidae, Naididae and Asellidae, which are

present at most sites (84 to 94 %). Invertebrate family diversity at St. Marys River sites range from 3 to 19 taxa (mean 11.5 taxa); most sites are close to or greater than the reference mean (8 taxa).

Upstream Reference - Izaak Walton Bay (IWB) (4 sites)

Diversity is high in IWB, with the number of taxa per site ranging from 10 to 17 (> the reference mean of 8 taxa); 3 of 4 sites are >2 standard deviations (SD) above the reference mean (Table 7). There are increased abundances of chironomids and tubificids at all sites (4.5 to 9.5×, and 3.8 to 7.4× , respectively). Sabellids are present in increased abundance at 2 of the 4 sites. Generally, reference families with ≤ 2% expected occurrence are absent or present in decreased abundance at IWB sites.

Upstream Reference - Point aux Pins Bay (PPB) (5 sites)

Diversity is high in PPB, with the number of taxa ranging from 12 to 17 (> the reference mean); 3 sites are > 2 SD above the reference mean (Table 7). Chironomids are in increased abundance at all sites (1.9 to 6.1×), and tubificids are in increased abundance at 1 of the 5 sites. Remaining families are below the reference mean or absent generally, with few exceptions (asellids and naidiids at site 52-479 and sabellids at site 126). Site 52-741 has the lowest abundance of all taxa that have ≥ 4% expected occurrence at reference sites.

Upstream Reference – US south shore (1 site)

This site (6904) is diverse, with 13 taxa present (Table 7). Chironomids and tubificids are in increased abundance (6.0× and 10.3×, respectively), while the other predominant reference families (≥ 3.6% expected occurrence) are present in decreased abundance. Reference families with ≤ 2.2% expected occurrence are absent from site 6904.

Algoma Slag Dump (6 sites)

The number of taxa present is equal to or greater than the reference mean, ranging from 8 to 17; 4 of the 6 sites are > 2 SD above the reference mean (Table 7). Chironomids and tubificids are in increased abundance at all sites (3.5 to 5.3× and 1.5 to 10.1×, respectively). Sphaeriids,

asellids, and naidiids are also present at all sites in decreased abundance generally, except for sites 196 (increased naidiids and sabellids) and 201 (increased asellids). Reference families with $\leq 2.2\%$ expected occurrence are absent or present in low abundance at test sites (except Gammaridae at site 201). Site 241 has the lowest abundances (below the reference mean or absent) of all predominant reference taxa, and has the lowest taxon diversity. Benthic communities sampled at sites along the slag dump in 1999 showed moderate degradation with reduced density, although diversity was high with possible substrate influences (JWEL 2002). Tubificid worms and chironomids dominated the benthos, and isopods, mayflies, clams and snails were also present, in similar composition as that found in the current study.

Algoma Slip (2 sites)

Taxon diversity is low (3 taxa) at site 182 (head of slip) and is just above the reference mean at site 192 (midway down slip) (Table 7). Chironomids are in very low abundance at both sites (0.12× and 0.17× mean) and tubificid abundances are close to the reference mean for both sites. All other dominant reference site taxa are absent or present in very low abundance. The slip is the only sampled area where fingernail clams (Sphaeriidae) are not present. A benthic community assessment performed in 1990 from the head to the mouth of the slip showed impaired benthic communities, with reduced diversity and abundance of taxa at 12 of the 17 locations, likely due to PAHs (Pope and Kauss 1995). In 1995, the head of the slip was dredged, and 11 sites were sampled in 1999 in this area. While conditions have improved in this area since 1990, when no taxa were found, oligochaetes (generally Tubificidae) were the only taxa found in 1999 (JWEL 2002). Sampling was limited in the slip in the current study making it difficult to assess whether there have been improvements. At the one site that was sampled at the head of the slip in the current study, three taxa were found (chironomids, a mayfly family, oligochaetes), indicating possible improvement since 1999.

Bellevue Marine Park (BMP) (6 sites)

Diversity in BMP ranges from 7 to 19 taxa; 3 sites (6983, 6986 and 6991) are just below the reference mean and 1 site (6984) is > 2 SD of the reference mean (Table 7). Site 6986 is the only site with decreased abundance of chironomids (0.53× mean), while remaining sites have abundances close to or 1.6 to 2.4× higher than the reference mean. Tubificids are in increased

abundance at all sites (1.4 to 14.6×). The highest abundances of tubificids occur in the BMP (as well as Lake George Channel- see below) compared to other the sampled areas of the river. Sphaeriids, naidiids and asellids are present at all sites in BMP. Sphaeriid abundances are similar at all sites (as low as 0.45× the reference mean), and naidiids are present in higher abundance at the sites with finer substrates (6986, 6991 & 6992). Asellid abundances are highest in BMP (1.9 to 44.72× greater than the reference mean) and are in greater abundance at the sites with firm substrates. Site 6986 (fine substrate) has the lowest abundances of tubificids, chironomids, sphaeriids and asellids and taxon diversity below the reference mean. (This site also has the highest concentration of PHCs – see Section 3.1.) In 1992, reduced benthic diversity was found correlated with elevated PAH concentrations and organic enrichment (Arthur and Kauss 2000). In 1995, when benthic communities were sampled at 18 sites in the BMP, a combination of substrate type and contaminant concentrations explained the variation in abundances of taxa observed at sites in this area (Kilgour et al. 2001). Increases in mayflies and caddisflies at some sites were noted as being the most noticeable improvement made since 1985 (Kilgour et al. 2001). Similar results were found in the current study, with mayflies (Ephemeridae) found at 3 of the 6 sites and several families of caddisflies found at 4 of the 6 sites, but in low abundance (Appendix B; Table B1).

Lake George Channel (LGC) (5 sites)

Diversity in the channel ranges from 7 to 13 taxa per site with 1 site (172) below the reference mean (Table 7). Chironomids are increased (1.4 to 4.2×) at all sites except 172, and tubificids are increased at all sites (4.2 to 19.9×). Sphaeriids are present at all sites, in increased abundance at two sites and in decreased abundance at three sites. Reference families with ≤ 2.2% expected occurrence are absent or present in low abundance at LGC sites. Site 172 (very sandy substrate) has the lowest numbers of tubificids, chironomids and sphaeriids but the highest abundance of naidiids. Site 6900 has the greatest abundance of sabellids. In 1992, benthic communities showed evidence of organic enrichment, but no clear evidence of effects due to contaminants (Arthur and Kauss 2000). In 1999, benthic communities in LGC showed moderate impairment, with high abundances of tubificids and chironomids and reduced diversity, possibly related to substrate type and organic enrichment (JWEL 2002).

Little Lake George (LLG) (2 sites)

The number of taxa present at the 2 LLG sites is 10 and 14; both above the reference mean (Table 7). Abundances of chironomids and tubificids are increased (4.0 to 6.6× and 9.4 to 9.9×, respectively). Sphaeriids and asellids are also present, in increased abundance at 6901 (mouth of lake) and decreased abundance at 6902 (outlet of lake). Sabellids are also increased at 6902. Reference families with ≤ 2.2% expected occurrence are absent or present in low abundance at LLG sites. In 1992, benthic communities in LLG were dominated by oligochaetes, chironomids and isopods, and there was slight impairment of communities attributable to organic enrichment (Arthur and Kauss 2000). In the current study, site 6901 is organically enriched (TOC = 6.5%) and has increased chironomids, tubificids, sphaeriids and asellids, similar to that found in the Arthur and Kauss (2000) study. Site 6902, which has low TOC (0.4 %), has increased chironomids, tubificids and sabellids.

BEAST (Benthic Community) Evaluation

Results of the BEAST evaluation (multidimensional scaling with 90, 99, 99.9% probability ellipses around reference sites) are summarized in Table 7. Ordination plots are provided in Appendix C; Figures C1 to C3 (stress ≤ 0.16). Three separate ordinations were performed each with a subset of 10 – 11 St. Marys sites. A spatial map showing the level of benthic community alteration compared to Great Lakes reference is provided in Figure 3.

St. Marys River sites fall into the following bands (Table 7, Figure 3):

Band 1 (equivalent to reference):   16 sites
Band 2 (possibly different):   15 sites
Band 3 (different):   0 sites
Band 4 (very different):   0 sites

Sites that fall in Band 2 (possibly different than reference) are located in Izaak Walton Bay (3), Point aux Pins Bay (1), upstream of Tannery Bay (1), the Algoma slag dump (4), Bellevue Marine Park (2), Lake George Channel (2) and Little Lake George (2). Macroinvertebrate families that are most highly correlated to the ordination axes scores are Chironomidae and Tubificidae for 2 of the 3 ordinations (Figures C1 and C3; $r^2 \geq 0.464$). For the ordination shown

in Figure C2, Chironomidae is the most significant family although the correlation is not high (r^2 = 0.350), and Tubificidae is not significant. Examination of the relationship between environmental variables and ordination axes scores reveals no high correlations ($r^2 \leq 0.247$). For each ordination, the most highly correlated variables are: NO_3/NO_2, P_2O_5 and Fe (as Fe_2O_3) (r^2: 0.147 to 0.167) for the ordination shown in Figure C1; pH, V, and alkalinity (r^2: 0.128 to 0.134) for the ordination shown in Figure C2, and; K_2O, NO_3/NO_2, and dissolved oxygen (DO) (r^2: 0.200 to 0.247) for the ordination shown in Figure C3. Several upstream sites and sites along the slag dump are associated with increased abundances of Chironomidae (shown as a vector in Appendix C; Figure C3). The contribution of organic contaminants is not known since they were not included in the BEAST assessments.

3.3 Sediment Toxicity Tests

Mean species survival, growth and reproduction in St. Marys River sediment is shown in Table 8. The established numerical criteria for each category (non-toxic, potentially toxic and toxic) for each species are included. Conductivity, pH, temperature, dissolved oxygen and ammonia, measured in the overlying water at the start and end of the tests, are shown in Appendix D; Table D1. Ammonia concentration is high ($\geq$ 5 ppm) in one or two replicate beakers at the start of the test for sites 176 (*Chironomus* and *Hyalella*), 52-1535 (*Hyalella*), and 6904 (*Tubifex*); however, it is 0 ppm at the end of these tests. Toxicity is evident in three areas of the river: Point aux Pins Bay, Bellevue Marine Park and Lake George Channel; potential toxicity (to *Hexagenia* growth) is observed in Little Lake George.

Upstream Reference - Point aux Pins Bay (PPB) (5 sites)
There is acute toxicity to the amphipod *Hyalella azteca* at one site: 52-479 (37.3% survival), and a reduction in *Chironomus riparius* survival at two sites: 52-1535 and 52-741 (61.3 to 65.3% survival). In 1999, PPB was sampled as a reference location and there was no toxicity to *C. tentans* (or *Hexagenia*) found (JWEL 2002). Results from the current study generally indicate that this area is inappropriate as a reference location due to observed toxicity. (Bark chips are also present at two sites including 52-479 – see section 3.1.) There is no toxicity to *Hyalella* at 52-1535 where high ammonia (5-6 mg/L) was observed in 2 of the 5 replicate beakers at the start of the test (Appendix D; Table D1). (Ammonia was 0 at the end of this test.)

Bellevue Marine Park (BMP) (6 sites)

There is acute toxicity (41 to 52% survival) to *Chironomus* at two sites: 6986 and 6991. Chronic toxicity (negative growth) to the mayfly *Hexagenia* spp. is evident at 6991, and there is low mayfly growth at sites 6986 and 6992. (Sites 6986, 6991 and 6992 have fine substrates.) In a 1995 Ministry of Environment study of the Bellevue Marine Park area (Bedard and Petro 1997), survival of *Chironomus tentans* was reduced at 3 of 13 sites (survival ranged from 58 to 76%). Midge mortality was correlated to sediment physical characteristics, PAHs, and PHCs. Slightly reduced mayfly growth was also found.

Lake George Channel (LGC) (5 sites)

There is acute toxicity (53.3 to 56.7% survival) to *Chironomus* at three sites: 170, 175 and 176. These results differ from a study performed in LGC in 1999, where three sites were sampled (including sites 170 and 176) and there was no toxicity observed for *Chironomus tentans* (or *Hexagenia*) (JWEL 2002). There is no toxicity to *Hyalella* at 176, where high ammonia concentration is observed in 1 of the 5 replicate beakers at the start of the test (Appendix D; Table D1). For *Chironomus*, high ammonia (5-6 mg/L) was recorded in 1 of the 5 replicate beakers at the start of the test for site 176; however, survival is low in all five replicate beakers indicating that ammonia was not likely a contributing factor. (Ammonia was 0 at the end of this test.)

Little Lake George

There is low mayfly growth at site 6901 located at the mouth of LLG. (This site has a high TOC but a silty-clay substrate.)

Algoma Slip / Slag Dump

No toxicity is observed in the Algoma slip or slag dump area in the current study. However, lowest *Tubifex tubifex* reproduction is observed at site 182 at the head of the slip (followed by two sites along the slag dump), and chironomid growth in the slip is lower overall than in other areas of the river (Table 8). In toxicity tests performed in 1999 at three sites in the slip, mean mayfly survival was significantly reduced at site 182 (63% survival) compared to reference locations. Mayfly growth was also significantly lower than that seen in reference sediment, and

mean midge survival was significantly reduced at 2 of 3 sites (44 to 62% survival) (JWEL 2002). In the current study, midge and mayfly survival is high at both sites in the slip (≥88%), which may suggest some improvement in the slip since 1999; however, mayfly and midge growth are lower in the slip than at sites upstream of the slip, and sampling in the slip was limited to two sites.

<u>Evidence of Enrichment</u>

Hyalella growth is > 2 SD higher than the mean of reference sites at upstream sites 6903 and 52-741, located in Izaak Walton Bay and Point aux Pins Bay, respectively. Both sites have a moderate amount of TOC (2.2% and 1.7%); visible organic material was noted at 6903 at the time of sampling.

BEAST (Toxicity) Evaluation

Results of the BEAST toxicity evaluation are summarized in Table 8. Ordinations are shown in Appendix E; Figures E1 to E3 (stress ≤ 0.11). Each figure represents a separate ordination with a subset of St. Marys River sites. A spatial map showing the level of toxicity compared to Great Lakes reference is provided in Figure 4.

St. Marys River sites fall into the following bands (Table 8, Figure 4):

Band 1 (non-toxic):   21 sites
Band 2 (potentially toxic):   4 sites
Band 3 (toxic):   5 sites
Band 4 (severely toxic):   1 site

Sites in Band 2 are in Point aux Pins Bay (2) and Lake George Channel (2). Sites in Band 3 are in Bellevue Marine Park (2) and Lake George Channel (3). The site in Band 4 is in Point aux Pins Bay.

Toxicity endpoints that are most highly correlated ($r^2 ≥ 0.725$) to axes scores include *Chironomus* and *Hyalella* survival and *Tubifex* % cocoons hatched. Monte-carlo random permutation tests reveal that these relationships are significant in the ordination space (i.e., not

just random artefacts of the data). No measured environmental variables are highly correlated (r^2 ≤ 0.168) to axes scores in any ordination. Toxicity endpoints and environmental variables contributing most to the ordination are shown as vectors in each figure.

Bellevue Marine Park sites located in Band 3 (6986, 6991) are associated with low midge survival and amphipod growth (being located in the opposite direction of the vector line for *Chironomus* survival and *Hyalella* growth) (Appendix E; Figure E1). These sites are oriented along a gradient of increasing TOC (shown as a vector in Figure E1). Toxic sites in LGC (170, 175, 176) are separated as a discrete group on the first axis (Appendix E; Figure E2). The sites score high on Axis 1, which is negatively correlated with *Chironomus* survival, indicating that these LGC sites are associated with low midge survival. The toxic site in PPB (52-479) is associated with low amphipod survival (Appendix E; Figure E3).

3.4 Toxicity – Contaminant Relationships

Examination of relationships between sediment toxicity and sediment contaminants both graphically and by regression analysis aids in identifying possible causes of toxicity attributable to organic contaminants (as well as inorganic compounds, sediment nutrients and sediment grain size). The ordination of the multiple measurements of sediment toxicity by HMDS for all the St. Marys River sites produced three descriptors of sediment toxicity (Appendix F; Figure F1). The resultant axes represent the original 10-dimensional among-site resemblances very well (stress = 0.05). Principal axis correlation produces a vector for each toxicity endpoint along which the projections of sites in ordination space are maximally correlated. The most highly correlated endpoints are *Chironomus* survival (r^2 =0.998) and *Hyalella* survival (r^2 =0.963), followed by *Tubifex* percent cocoons hatched and *Tubifex* young production (r^2 =0.449, 0.441, respectively). Total petroleum hydrocarbons (TPHC) is the only significant (p≤0.05) environmental variable (r^2 = 0.346). *Chironomus* survival (shown as a vector in Appendix F; Figure F1) is negatively correlated with Axis 1; therefore, the greater the toxicity of a site, the higher its score for Axis 1. Most sites are separated along the first axis, and decreased midge survival is associated with sites in the BMP and LGC as well as sites upstream in PPB. Site 6900 (LGC) is separated on the second axis and is associated with increased *Tubifex* percent cocoons hatched (Figure F1, top).

Site 52-479 (PPB) is separated along the third axis, and is associated with decreased amphipod survival (Figure F1, bottom).

Integrated Toxicity Descriptors – Contaminant Relationships

Nine metals (As, Cr, Cu, Fe, Hg, Mn, Ni, Pb, and Zn) were ordinated by principal components analysis (PCA). The first 3 principal components account for 80%, 8% and 6% of the total variation, respectively. All measurement variables were negatively loaded for PC1, and loadings are of a similar magnitude. This component – denoted as "metPC1" – is used as a descriptor of general metal contamination. Sites elevated in metals score low for PC1. Total PAHs and PHCs were integrated by summing the concentrations of the individual compounds.

The integrated descriptors of sediment toxicity (Axis 1, 2 and 3 scores from the HMDS) plotted against the contaminant descriptors metPC1, and log(x)- transformed total PAHs, total PHCs as well as sediment nutrient and grain size are shown in Appendix F; Figure F2. The strongest relationship by multiple linear regression is for Axis 2, with 21.1% of the variation explained by total PHCs and total nitrogen (TN).

ToxAxis 2 = 1.75 + 0.208 log total PHCs - 0.750 log TN (p=0.014, $r^2_{adjusted}$ = 21.1%)

Individual Toxicity Descriptors - Contaminant Relationships

Relationships among individual measurement variables were evaluated by plotting the most sensitive endpoints, *Chironomus* survival and *Hexagenia* growth, against concentrations of total PAHs, total PHCs, F3 and F4 PHCs, and the integrated metal toxicity descriptor (metPC1) (Appendix F; Figure F3), as well as the individual concentrations of metals (As, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Zn), sediment nutrients (TP, TN, TOC) and particle size (percents clay, sand, silt) (Appendix F; Figures F4 and F5). In multiple linear regression models, predictor coefficients that are negative indicate that decreased survival or growth is related to an increased contaminant or nutrient concentration or particle size fractions, while positive coefficients indicate that decreased survival or growth is related to a decreased contaminant or nutrient concentration or particle size fraction.

<u>Chironomus survival</u>

47.8% of the variability is explained by total PAHs, Fe, Mn, and TOC. Predictors are significant at $p < 0.001$ (Fe, Mn), 0.03 (TOC), and 0.06 (PAHs).

Chironomus survival $= -0.725 - 0.0772$ log total PAHs $- 1.02$ log Fe $+ 0.933$ log Mn $+ 0.170$ log TOC ($p = \leq 0.001$)

<u>Hexagenia growth</u>

43.8% of the variability is explained by total PHCs, Cu, sand and silt. All predictors are significant ($p \leq 0.048$).

Hexagenia growth $= -6.45 - 0.897$ log total PHCs $+ 3.16$ log Cu $+ 6.89$ Sand $+ 3.78$ Silt ($p = 0.001$)

More variability is explained when looking at individual endpoints (rather than the integrated toxicity descriptor.) Approximately 48% of the variability in *Chironomus* survival is related to PAHs and a combination of metals (Fe, Mn) and total organic carbon. However, the partial F-test (= t-test) for the PAH predictor is not significant at $p \leq 0.05$, and PAH concentrations at the sites showing acute toxicity to *Chironomus* (6986, 6991, 170, 172, 176), are not high, ranging from 0.7 to 5.2 µg/g. Furthermore, there are much higher concentrations of PAHs in the Algoma slip with no effect on *Chironomus* survival. Approximately 44% of the variability in *Hexagenia* growth is related to total PHCs, Cu, sand, and silt. The sites that are toxic to *Hexagenia* (6986, 6991, 6992, 6901) have high PHC concentrations, ranging from 15670 to 23450 µg/g. (These are the highest PHC concentrations; remaining sites in the river range from non-detectable to 10740 µg/g with a median of 328 µg/g.) Thus, toxicity to *Hexagenia* appears to be at least partially explained by PHCs. Bedard and Petro (1997) found that concentrations of petroleum hydrocarbons best explained most of the toxicity endpoints in a 1995 study at Bellevue Marine Park, and that a combination of chemical and physical characteristics of the sediment were required to explain toxicity.

3.5 Quality Assurance/Quality Control

Field Replication

Variability among field-replicated sites, expressed as the coefficient of variation (CV), is shown in Appendix G; Table G1. Differences in variability are seen among sites and among the parameters from the same site. The CVs range from 0.5 to 104.5% and are generally low for field-replicated samples (samples were taken from three separate box core drops), with overall mean CVs ranging from 7.5 – 19.6% and overall median CVs ranging from 3.6 to 8.8%. The highest variability is noted for grain size analyses (% sand, silt, clay) for Point aux Pins Bay site 126.

Laboratory

Laboratory repeat measurements for sediment metals, major oxides and nutrients, and corresponding analyses of reference materials for Caduceon Laboratory are shown in Appendix G; Table G2. The overall mean relative percent difference (RPD) for sample repeat measurements $[=(x_1 - x_2)/ ((x_1+ x_2)/2) \times 100]$ is 4.9% (range: 0 to 31%). The RPD is highest for TOC (31%) and Pb (27%). Mean recovery for reference materials is 99%, ranging from 89 to 127%.

Quality control measures for Maxxam Analytics Laboratory consisted of method blanks, analysis of reference standards, and the percent recoveries of spiked blanks, matrix spikes and surrogate spikes. Results are provided in Appendix G; Tables G3 and G4 and generally show good results. For PHC, percent recoveries for matrix spikes and spiked spikes range from 66 to 117% (mean 89%) (Table G3). The RPD for sample repeat measurements range from 1.1 to 9.0% (mean 5.0%), and surrogate (o-Terphenyl) recoveries range from 103 to 129% (mean 112%). For PAHs, percent recoveries for spiked blanks range from 59 to 109% (mean 86.5%), and the RPD for sample repeats range from to 0.7 to 14.3 % (mean 2.9%) (Table G4). Percent recovery for matrix spikes range from 18 to 103% (mean 72%). (Due to the nature of the sample selected for the matrix spike, some percent recoveries were below the control limits.) Surrogate (2-Fluorobiphenyl, D14-Terphenyl and D5-Nitrobenzene) recoveries range from 45 to 101% (mean 71%). For TOC, the QC standard recoveries range from 100 to 102%, and the percent recovery in spiked blanks range from 100 to 102%.

Community Structure Sorting

The mean percent sorting efficiency for St. Marys River samples is 2.98%. This is an acceptable low level, indicating that a good representation of the benthic community present at test sites was achieved. This value represents the average for four sorters over a four month period.

3.6 Decision–Making Framework for Sediment Contamination

A risk-based, decision-making framework for the management of sediment contamination was recently developed by the Canada-Ontario Agreement Sediment Task Group using four lines of evidence (sediment chemistry, toxicity, community structure and potential for biomagnification). This decision framework was developed from the Sediment Triad and BEAST frameworks, and is described in Grapentine et al. (2002) and Chapman and Anderson (2005). The overall assessment of a test site is achieved by integrating the information obtained both within and among the four lines of evidence. This framework was applied to the St. Marys River study using three lines of evidence (chemistry, toxicity, benthic community structure). A biomagnification component was not conducted in the study as there did not appear to be concern for chemicals that are known to biomagnify (e.g., Hg, PCBs).

The decision matrix for the weight of evidence categorization of St. Marys sites is shown in Table 9. Exceedences of LELs and SELs, and PAH and PHC concentrations are included in the table. For the sediment chemistry column, sites with metal exceedences of a sediment quality guideline (SQG) – low are indicated by "◐", and sites with SQG-high exceedences by "●" (except Fe and Mn). For toxicity and benthos alteration columns, sites that are located in Band 3 or Band 4 from the BEAST analysis are indicated by "●", sites in Bands 2 by "◐" and sites in Band 1 by "○". Interpretation of the overall assessment for management implications also considers the degree of degradation for each line of evidence.

For 20 of the 31 sites, no further actions are needed because there is no evidence of severe toxicity or benthos alteration. Eleven sites have elevated metal concentrations (>LEL), and are toxic and/or have potentially altered benthic communities. Subsequently, the reasons for these biological conditions need to be determined. Some sites show potential toxicity or possible benthos alteration but are not recommended for further action. In these sites adverse biological

conditions are not associated with elevated sediment contaminants, or the benthos alteration is not judged detrimental (decreased taxon richness, reduced average abundance).

4 CONCLUSIONS

4.1 Sediment Contaminants

There are exceedences of the Severe Effect Level mainly for iron, although exceedences for manganese, nickel and arsenic occur at one site along the slag dump and for manganese and nickel at the outlet of Lake George. Exceedences of the Lowest Effect Level (LEL), however, occur for several metals along the river mainly from the slag dump to Lake George Channel, where there are from 0 (site 122) to nine metals that exceed the LEL (~1/4 sites have 6 metal exceedences). Overall, the highest concentrations of metals occur at Bellevue Marine Park (with some exceptions for metals such as arsenic, iron, manganese and nickel). Downstream areas have high organic matter as does the Algoma slip, which also has the presence of iron ore pellets at one site. Total PAH concentrations are high in the Algoma slip (~50 and 390 µg/g), and are elevated along the river compared to the upstream sites. Total PAHs exceed the LEL at eight sites, in the area from the Algoma slag dump to Bellevue Marine Park. Total petroleum hydrocarbon concentrations are highest in the downstream reaches of the river (Bellevue Marine Park, Lake George Channel and Little Lake George), as well as in the Algoma slip, with overall highest concentrations at Bellevue Marine Park. These level are substantially greater than concentrations in upstream sites of Izaak Walton Bay and Point aux Pins Bay, and would be of concern if reported for lakefill (OMOE 2003)

4.2 Benthic Community Structure

There is no strong evidence of benthic community impairment (Figure 3). Sixteen of the 31 sites have communities that are equivalent to reference. The remaining 15 sites are only "possibly different" from reference and are situated in most sampling locations along the river. While the site at the head of the Algoma slip (site 182) falls in Band 1 (equivalent to reference), it has low taxon diversity (3 out of 38 taxa present). Overall, there is a trend of higher taxon diversity and increased abundance of two or more taxa compared to reference. Communities are dominated primarily by tubificid worms, midges and sphaeriids.

30

4.3 Toxicity

The majority of sites (21 of 31) are non-toxic. There is strong evidence of toxicity at 6 sites: 2 at Bellevue Marine Park, 3 in Lake George Channel and 1 in Point aux Pins Bay (Figure 4). There is acute toxicity to the amphipod *Hyalella* in Point aux Pins Bay, and acute toxicity to the midge *Chironomus* and sublethal effects to the mayfly *Hexagenia* at Bellevue Marine Park and in Lake George Channel. Toxicity (chronic) to *Hexagenia* appears to be partially explained by petroleum hydrocarbons. It is not clear what is causing toxicity to *Chironomus*.

4.4 Decision-making Framework for Sediment Contamination

For 20 of the 31 sites, no further actions are needed as there are elevated contaminants above sediment quality guidelines but no strong concurrence of community alteration and toxicity (Table 9). For sites at Bellevue Marine Park, the Algoma slag dump, Lake George Channel and Point aux Pins Bay (11 sites in total), there is the potential for adverse effects and a more comprehensive study is warranted to determine reasons for sediment toxicity, especially with respect to petroleum hydrocarbons. These areas should be monitored for changes in the status of benthic populations.

5 REFERENCES

APHA (American Public Health Association). 1995. Standard Methods for the Examination of Water and Wastewater, 19th ed., Washington, D.C.

Arthur, A., and P. Kauss. 2000. Sediment and benthic community assessment of the St. Marys River. Ontario Ministry of the Environment Report. April 2000. 55 pp.

ASTM (American Society for Testing & Materials) 1995. Standard test methods for measuring the toxicity of sediment-associated contaminants with freshwater invertebrates. In: Annual Book of ASTM Standards, Vol. 11.05, Philadelphia, PA, pp. 1204-1285.

Bedard, D., and S. Petro. 1997. Laboratory sediment bioassay report on St. Marys River sediments 1992 and 1995. Ontario Ministry of Environment and Energy. October 1997. 59 pp.

Belbin, L. 1993. PATN, pattern analysis package. Division of Wildlife and Ecology, CSIRO, Canberra, Australia.

Blatant Fabrications Pty Ltd. 2001. PATN Version 3.03. December 2, 2004.

Borgmann, U., and M. Munawar. 1989. A new standardised sediment bioassay protocol using the amphipod *Hyalella azteca* (Saussure). Hydrobiol.188/189: 425-431.

Borgmann, U., K.M. Ralph, and W.P. Norwood. 1989. Toxicity Test Procedures *for Hyalella azteca*, and Chronic Toxicity of Cadmium and Pentachlorophenol to *H. azteca*, *Gammarus fasciatus*, and *Daphnia magna*. Arch. Environ. Contam. Toxicol. 18: 756-764.

Cancilla, D. (ed.) 1994. Manual of analytical methods. Vol. 1. National Laboratory for environmental Testing, Canada Centre for Inland Waters, Environment Canada, Burlington, Ontario.

CCME. 2001. Canada-Wide Standards for Petroleum Hydrocarbons (PHC) in soil. Endorsed by CCME Council of Ministers, April 30 – May 1, 2001, Winnipeg, MN.

Chapman, P.M., and J. Anderson. 2005. A decision-making framework for sediment contamination. Integr. Environ. Assess. Manag. 1:163-173.

Day, K.E., R.S. Kirby, and T.B. Reynoldson. 1994. Sexual dimorphism in *Chironomus riparius* (Meigan): Impact on interpretation of growth in whole sediment toxicity tests. Eviron. Toxicol. Chem. 13: 35-39.

Draper NR, and H. Smith. 1998. Applied regression analysis, 3rd Edition, John Wiley & Sons, New York, NY.

Duncan, G.A., and G.G. LaHaie. 1979. Size analysis procedures in the sedimentology laboratory. National Water Research Institute Manual. Environment Canada, Burlington, Ontario.

Grapentine, L., J. Anderson, D. Boyd, G.A. Burton, C. Debarros, G. Johnson, C. Marvin, D. Milani, S. Painter, T. Pascoe, T. Reynoldson, L. Richman, K. Solomon, and P.M. Chapman. 2002. A decision making framework for sediment assessment developed for the Great Lakes. Human and Ecological Risk Assessment 8: 1641-1655.

Golder Associates Ltd. 2004. Synthesis of sediment and biological investigations in the St. Mary's River area of concern. Report to Environment Canada, Environmental Conservation Branch, Ontario Region. 04-1112-020. March 2004.

JWEL (Jacques Whitford Environment Ltd). 2002. Sediment and benthic community assessment of the St. Mary's River, 1999. Report to Ontario Ministry of the Environment. February 2002. 48 pp.

Kauss, P.B. 2000. Algoma slag dump (St. Mary's River) nearshore sediment quality and contaminant bioavailability study. Ontario Ministry of the Environment. OMOE Report, Aril 2000.

Kilgour, B.W., W.B. Morton, and P.B. Kauss. 2001. Sediment and benthic invertebrate community assessment of the Bellevue Marine Park area in the St. Mary's River. Draft report by Water Systems Analysts and Ontario Ministry of Environment, Environmental Monitoring and Reporting Branch. November 5, 2001.

Krantzberg, G. 1990. Sediment bioassay research and development. PDF03. Ontario Ministry of the Environment Research Advisory Committee, Toronto, Ontario, Canada.

Legendre and Legendre 1998. Numerical ecology, 2nd Edition. Elsevier, New York, NY.

Minitab, 2000. MINITAB User's guide 2: Data analysis and quality tools. Minitab Inc., State College, PA. [ISBN 0-925636-44-4]

NLET (National Laboratory for Environmental Testing) 2000. Schedule of services 2000-01. Environment Canada. National Water Research Institute, Burlington, Ontario.

OMOE (Ontario Ministry of the Environment). 2003. Fill quality guidelines for lakefilling in Ontario. Prepared by Persaud, D., A. Hayton, R. Jaagumagi and G. Rutherford. Standards Development Branch, Environmental Monitoring and Reporting Branch, Ontario Ministry of the Environment. March 2003. ISBN 0-7729-9329-7. PIBs 5040e.

Persaud, D., R. Jaagumagi, and A. Hayton. 1992. Guidelines for the protection and management of aquatic sediment quality in Ontario. ISBN 0-7729-9248-7. Ontario Ministry of the Environment, Water Resources Branch, Toronto.

Pope, R., and P.B. Kauss. 1995. Algoma slip sediment quality and benthic invertebrate community assessment . Ontario Ministry of Environment and Energy. July 1995.

Reynoldson T. B., R.C. Bailey, K.E. Day and R.H. Norris. 1995. Biological guidelines for freshwater sediment based on benthic assessment of sediment (the BEAST) using a multivariate approach for predicting biological state. Aust. J. Ecol. 20: 198-219.

Reynoldson, T.B. and K.E. Day. 1998. Biological guidelines for the assessment of sediment quality in the Laurentian Great Lakes. National Water Research Institute, Burlington, Ontario, Canada. NWRI Report No. 98-232.

Reynoldson, T.B., K.E. Day, and T. Pascoe. 2000. The development of the BEAST: a predictive approach for assessing sediment quality in the North American Great Lakes. In: Assessing the biological quality of fresh waters. RIVPACS and other techniques. J.F. Wright, D.W. Sutcliffe, and M.T. Furse (Eds). Freshwater Biological Association, UK. pp. 165 – 180.

Reynoldson, T.B., C. Logan, T. Pascoe and S.P. Thompson. 1998a. Methods Manual II: Lake Invertebrate sampling for reference-condition databases. National Water Research Institute, Burlington, Ontario, Canada.

Reynoldson, T.B., C. Logan, D. Milani, T. Pascoe, and S.P. Thompson. 1998b. Methods Manual IV: Sediment toxicity testing, field and laboratory methods and data management. NWRI Report No. 99-212.

Reynoldson, T.B., C. Logan, D. Milani, T. Pascoe, and S.P. Thompson. 1998c. Methods Manual III: Laboratory procedures for sample management. National Water Research Institute, Burlington , Ontario, Canada.

Reynoldson T. B., D.W. Schloesser, and B.A. Manny. 1989. Development of a benthic invertebrate objective for mesotrophic Great Lakes waters. J. Great Lakes Res. 15: 669-686.

Reynoldson, T.B., S.P. Thompson, and J.L. Bamsey. 1991. A sediment bioassay using the tubificid oligochaete worm *Tubifex tubifex*. Environ. Toxicol. Chem. 10: 1061-1072.

St. Marys River RAP Team. 1992. The St. Marys River Area of Concern, Environmental conditions and problem definitions. Remedial Action Plan Stage 1. Ontario Ministry of the Environment, Michigan Department of Natural Resources . March 1992.

St. Marys River RAP Team. 2002. Stage 2: Remedial Strategies for ecosystem restoration. December 2002.

SYSTAT Software Inc. 2002. SYSTAT for Windows. Version 10.2.

USEPA/CE (United States Environmental Protection Agency/Corps of Engineers). 1981. Procedures for handling and chemical analysis of sediment and water samples. Environmental laboratory, US Army Engineer Waterways Experiment Station, Vicksburg, Mississippi, pp 3-118. EPA/CE-81-1.

USEPA (U.S. Environmental Protection Agency). 1994. Methods for measuring the toxicity and bioaccumulation of sediment associated contaminants with freshwater invertebrates. Office of Research and Development, Report EPA/600/R-94/024.

Table 1.   St. Marys River site co-ordinates (UTM Nad 83) and site depth.

Location	Site	Site Depth (m)	Northing	Easting
Upstream Reference - Izaak Walton Bay	243	3.5	5146660.0	694446.5
	244	2.4	5147142.7	694319.2
	245	2.0	5148172.1	695023.3
	6903	4.0	5149317.4	694164.1
Upstream Reference - Point aux Pins Bay	52-1090	3.8	5151514.7	694898.5
	52-479	4.0	5152008.3	694551.5
	52-1535	2.2	5151158.9	695158.5
	52-741	4.2	5151787.6	694707.1
	126	4.0	5152089.0	695659.8
Upstream US	6904	4.5	5152328.2	699465.3
Algoma Slag Dump	240	7.0	5153130.8	698790.2
	122	7.5	5153098.0	699064.1
	201	2.0	5153378.0	699739.8
	241	5.5	5153749.9	700185.5
	196	8.5	5154165.0	700636.6
	242	9.0	5154607.8	701149.1
Algoma Slip	182	5.0	5155276.9	700981.9
	192	7.9	5154990.1	701167.8
Bellevue Marine Park	6981	1.9	5153383.3	705317.0
	6983	5.9	5153330.0	705530.9
	6984	1.5	5152892.3	706163.5
	6986	3.6	5153419.4	706023.0
	6992	5.9	5153328.7	706265.5
	6991	6.3	5152788.2	707079.8
Lake George Channel	170	3.9	5153653.5	710717.9
	172	1.5	5154102.1	710979.8
	175	5.8	5154671.1	711194.8
	176	4.0	5155546.7	711991.5
	6900	9.5	5157078.3	712863.0
Little Lake George	6901	1.3	5157728.2	714251.8
	6902	5.1	5156489.9	716729.3

Table 2.   Environmental variables measured at each site.

Field	Overlying Water	Sediment (top 10 cm)
Northing	Alkalinity	Trace Metals
Easting	Conductivity (on site)	Major Oxides
Site Depth	Dissolved Oxygen (on site)	Total Phosphorus
	pH (on site)	Total Nitrogen
	Temperature (on site)	Total Organic Carbon, LOI
	Total Kjeldahl Nitrogen	% Clay, Silt, Sand and Gravel
	NO_3/NO_2	
	NH_3	
	Total Phosphorus	

Table 3.   Measured environmental variables in overlying water. Values in mg/L dry weight unless otherwise noted.

Site	Alkalinity	Conduct. μS/cm	Dissolved O$_2$	NH$_3$	NO$_3$/NO$_2$	pH	Temp (°C)	Total Kjeldahl N	Total P
243	41.4	94.0	10.8	0.02	0.36	7.9	11.7	0.12	0.019
244	40.9	94.1	10.7	0.02	0.37	7.9	12.0	0.12	0.005
245	42.5	95.3	10.7	0.03	0.36	7.8	11.3	0.15	0.011
6903	41.3	94.0	11.4	0.02	0.37	7.8	11.7	0.13	0.003
52-1090	41.2	93.8	11.5	0.02	0.37	7.8	11.5	0.12	0.005
52-479	41.4	92.2	11.0	0.02	0.36	7.5	11.5	0.11	0.005
52-1535	41.1	93.9	11.2	0.02	0.38	7.9	12.4	0.12	0.007
52-741	41.3	90.1	11.2	0.03	0.36	7.3	11.4	0.16	0.007
126	41.2	93.6	10.8	0.03	0.37	7.8	11.6	0.15	0.005
6904	41.7	94.0	10.5	0.02	0.37	7.9	12.6	0.12	0.006
240	47.0	94.3	10.7	0.02	0.37	7.8	12.0	0.13	0.005
122	41.1	96.0	10.8	0.02	0.37	7.8	11.9	0.17	0.005
201	42.7	94.1	10.6	0.02	0.31	7.8	12.7	0.14	0.004
241	42.0	95.0	10.7	0.02	0.32	7.2	12.9	0.13	0.004
196	41.2	95.1	10.6	0.02	0.32	7.8	13.1	0.13	0.005
242	41.0	98.6	10.5	0.02	0.30	7.5	13.3	0.15	0.008
182	47.7	155.0	10.3	0.02	0.47	7.5	11.7	0.64	0.021
192	46.4	161.0	10.2	0.01	0.46	8.0	11.1	0.31	0.017
6981	40.7	97.0	10.1	0.02	0.32	7.5	14.8	0.12	0.005
6983	41.8	96.0	10.1	0.02	0.32	7.8	14.8	0.12	0.004
6984	40.8	96.2	10.5	0.02	0.34	7.9	15.0	0.11	0.003
6986	41.7	97.9	10.2	0.03	0.34	8.0	15.0	0.12	0.005
6991	40.8	97.9	10.7	0.02	0.35	8.0	15.1	0.11	0.003
6992	41.3	97.2	10.4	0.02	0.34	8.0	15.1	0.12	0.046
170	41.5	97.0	10.7	0.02	0.32	7.6	14.9	0.13	0.006
172	42.7	102.1	10.8	0.03	0.52	7.2	14.4	0.20	0.046
175	42.0	96.0	10.8	0.03	0.33	7.6	14.9	0.14	0.006
176	41.1	95.5	10.7	0.03	0.32	7.2	14.9	0.13	0.005
6900	41.4	96.1	10.3	0.03	0.32	7.3	14.9	0.13	0.004
6901	41.4	95.1	10.2	0.05	0.35	6.5	15.1	0.14	0.008
6902	41.1	95.0	10.0	0.03	0.34	6.8	14.9	0.11	0.011

Table 4. Physical characteristics of St. Marys River sediment (top 10 cm).

Location	Site	% Sand	% Silt	% Clay	% Gravel
Upstream Reference - Izaak Walton Bay	243	49.9	39.9	10.2	0
	244	56.1	30.8	9.9	3.2
	245	58.4	33.0	8.6	0
	6903	22.7	68.1	9.3	0
Upstream Reference - Point aux Pins Bay	52-1090	88.2	0.0	11.7	0.1
	52-479	10.1	77.8	12.1	0
	52-1535	84.4	11.3	3.1	1.2
	52-741	37.6	56.2	6.3	0
	126	44.2	35.4	20.4	0
Upstream US	6904	59.5	23.1	17.5	0
Algoma Slag Dump	240	55.4	37.5	6.3	0.8
	122	91.4	0.0	4.1	4.5
	201	23.6	70.0	6.4	0
	241	48.3	45.6	6.1	0
	196	29.1	56.5	14.5	0
	242	51.1	29.3	17.6	2.0
Algoma Slip	182	47.8	44.1	7.9	0.1
	192	13.0	37.0	50.0	0
Bellevue Marine Park	6981	37.4	48.7	13.9	0
	6983	36.3	48.8	14.9	0
	6984	47.6	40.3	12.1	0
	6986	2.0	74.1	24.0	0
	6991	3.0	74.1	22.9	0
	6992	7.9	71.5	20.7	0
Lake George Channel	170	37.1	38.4	24.5	0
	172	90.4	0.0	9.6	0
	175	27.6	54.2	18.2	0
	176	36.7	51.5	11.8	0
	6900	42.6	46.0	11.4	0
Little Lake George	6901	10.0	70.1	20.0	0
	6902	21.1	59.8	19.2	0

Table 5. Nutrient and trace metal concentrations in surficial sediment (top 10 cm). Values exceeding the provincial SEL are highlighted. Values in μg/g dry weight unless otherwise noted.

Site	% Al	As	% Ca	Cd	Co	Cr	Cu	% Fe	Hg	%K	% LOI	% Mg
243	0.27	<5	0.17	<1	3.2	10.7	7.2	0.7	0.01	0.01	2.4	0.13
244	0.37	<5	0.19	<1	6.2	14.1	7.7	1.0	0.01	0.12	2.9	0.18
245	0.30	<5	0.15	<1	4.7	11.4	6.0	0.7	0.01	0.09	2.2	0.14
6903	0.44	<5	0.29	<1	7.2	29.6	23.2	1.2	0.02	0.03	5.3	0.22
52-1090	0.17	<5	0.17	<1	5.0	13.8	6.4	0.5	0.01	0.01	3.7	0.07
52-479	0.39	6.9	0.32	<1	6.2	15.5	24.8	0.7	0.05	0.10	17.0	0.16
52-1535	0.13	<5	0.11	<1	4.8	6.9	3.5	0.4	0.01	0.06	1.1	0.06
52-741	0.22	<5	0.17	<1	5.5	10.2	7.1	0.5	0.02	0.06	3.6	0.09
126	0.18	<5	0.12	<1	3.6	9.3	4.4	0.5	0.01	0.05	1.6	0.08
6904	0.31	<5	0.19	1.0	3.6	12.0	10.5	0.8	0.01	0.02	2.2	0.15
240	0.43	<5	0.27	<1	6.8	23.8	14.9	1.3	0.02	0.14	4.9	0.24
122	0.27	<5	0.26	<1	4.1	14.7	5.4	1.0	0.01	0.09	1.8	0.20
201	0.60	5.0	0.43	<1	5.8	25.2	20.7	1.7	0.04	0.15	7.5	0.31
241	0.59	**54.0**	0.62	<1	34.0	69.0	9.0	**13.2**	0.10	0.20	7.1	0.41
196	0.63	4.0	0.34	<1	5.9	30.8	19.2	2.6	0.04	0.13	7.9	0.33
242	0.93	5.0	0.54	<1	10.0	26.6	20.4	3.1	0.01	0.12	8.2	0.67
182	0.65	5.0	2.05	<1	7.2	32.3	29.3	2.4	0.08	0.09	38.4	0.65
192	1.01	<5	2.22	<1	9.2	33.1	67.0	**4.2**	0.06	0.18	23.2	1.04
6981	0.51	9.0	0.33	<1	9.8	57.2	37.3	3.9	0.15	0.13	13.3	0.29
6983	0.60	5.0	0.33	<1	8.1	64.5	34.1	**4.1**	0.13	0.18	11.7	0.31
6984	0.40	<5	0.28	<1	6.3	38.9	24.1	2.7	0.09	0.04	8.3	0.22
6986	1.04	<5	0.47	1.0	8.3	71.2	87.3	**4.8**	0.06	0.20	15.4	0.52
6991	0.52	27.0	0.31	<1	9.4	89.5	67.5	**6.4**	0.24	0.18	25.3	0.26
6992	0.61	25.0	0.36	<1	9.5	83.7	63.4	**5.9**	0.22	0.15	18.9	0.33
170	0.81	8.7	0.36	<1	8.2	28.4	12.1	1.7	0.02	0.18	3.1	0.43
172	0.69	16.0	0.35	<1	8.4	63.9	75.1	**4.6**	0.31	0.16	13.8	0.31
175	0.45	5.0	0.30	<1	5.1	43.2	39.1	3.3	0.16	0.06	12.6	0.22
176	0.47	9.7	0.30	<1	7.2	63.8	26.7	3.1	0.17	0.12	6.7	0.21
6900	0.44	7.0	0.24	<1	8.7	37.5	25.3	2.6	0.17	0.13	7.4	0.20
6901	0.69	20.0	0.58	<1	9.3	69.5	61.3	**5.3**	0.18	0.19	13.1	0.34
6902	1.27	<5	2.10	<1	16.6	57.8	31.5	3.7	0.02	0.22	4.8	1.33
LEL	-	6.0	-	0.6	-	26	16	2%	0.2	-	-	-
SEL	-	33.0	-	10	-	110	110	4%	2.0	-	-	-

Table 5.   Continued.

Site	Mn	Ni	% P$_2$O$_5$	Pb	% SiO$_2$	Ti	Total N	%Total Organic C	Total P	V	Zn
243	86	4.5	0.14	3.6	79.7	383	623	0.8	294	16.6	21.0
244	169	14.0	0.18	9.0	80.5	467	590	0.6	366	19.7	19.6
245	129	8.3	0.11	5.3	81.2	356	628	0.4	276	14.9	17.1
6903	113	9.8	0.18	19.0	74.5	543	2152	2.2	500	31.1	49.3
52-1090	45	3.2	0.12	7.2	81.0	264	1086	1.5	412	11.2	17.5
52-479	77	16.0	0.16	17.8	68.0	391	2648	7.6	443	17.2	50.8
52-1535	42	7.6	0.10	3.7	83.1	277	443	0.4	289	12.1	11.5
52-741	52	7.7	0.13	3.9	80.5	367	776	1.7	327	11.2	17.7
126	48	7.9	0.13	4.3	83.0	315	536	0.5	315	11.4	13.9
6904	79	6.1	0.15	2.3	80.8	379	667	0.8	340	18.4	23.2
240	252	17.3	0.19	12.8	77.8	499	1020	2.4	379	22.5	37.9
122	295	14.3	0.13	8.0	82.6	399	186	0.5	175	15.9	17.0
201	274	18.6	0.21	14.7	74.2	599	2003	3.1	523	29.6	49.0
241	**3553**	**90.0**	0.25	11.0	56.3	511	960	4.5	620	39.7	564.0
196	442	16.5	0.20	42.7	70.4	605	1549	5.1	527	29.1	212.1
242	491	19.2	0.18	14.0	66.7	620	1131	5.6	435	32.5	90.5
182	972	15.6	0.14	23.0	41.5	492	4497	**30.6**	311	30.5	131.5
192	847	23.3	0.21	12.0	44.4	678	2386	**16.0**	462	33.9	137.8
6981	495	28.2	0.22	57.5	66.9	456	2661	7.9	746	26.0	142.0
6983	462	27.8	0.21	47.0	65.7	558	1473	6.5	466	29.8	158.2
6984	305	14.5	0.19	36.0	70.4	394	1160	4.7	540	20.4	126.0
6986	520	32.5	0.26	80.0	58.4	677	4313	7.5	678	43.7	286.1
6991	679	45.7	0.23	84.9	49.8	451	2369	**14.1**	551	27.7	346.5
6992	622	39.2	0.26	80.0	56.8	520	2145	9.6	556	33.1	267.0
170	187	22.3	0.20	9.4	74.6	719	753	0.6	616	33.1	34.1
172	471	33.0	0.28	82.0	62.1	471	2936	6.7	811	28.0	284.0
175	354	16.5	0.22	39.0	66.2	453	1988	7.7	669	23.9	157.5
176	286	18.4	0.21	48.2	71.9	482	1444	3.7	637	25.1	150.6
6900	243	20.1	0.21	34.2	73.6	443	1094	3.3	477	22.3	104.9
6901	586	41.4	0.21	82.0	59.2	555	3148	6.5	695	32.4	275.2
6902	**1216**	**78.4**	0.30	14.7	59.8	3934	511	0.4	636	117.7	64.4
LEL	460	16	-	31	-	-	550	1%	600	-	120
SEL	1100	75	-	250	-	-	4800	10%	2000	-	820

Table 6.   Probabilities of test sites belonging to Great Lakes faunal groups.

Location	Site	Probability of Reference Group Membership				
		Group 1	Group 2	Group 3	Group 4	Group 5
Upstream Reference - Izaak Walton Bay	243	**0.718**	0.041	0.092	0.000	0.149
	244	**0.716**	0.041	0.109	0.000	0.133
	245	**0.700**	0.044	0.122	0.000	0.134
	6903	**0.804**	0.028	0.030	0.000	0.138
Upstream Reference - Point aux Pins Bay	52-1090	**0.768**	0.033	0.051	0.000	0.149
	52-479	**0.938**	0.005	0.000	0.000	0.057
	52-1535	**0.702**	0.041	0.120	0.000	0.137
	52-741	**0.773**	0.031	0.043	0.000	0.152
	126	**0.687**	0.041	0.105	0.000	0.167
Upstream US	6904	**0.707**	0.039	0.082	0.000	0.173
Algoma Slag Dump	240	**0.745**	0.030	0.020	0.000	0.204
	122	**0.629**	0.043	0.092	0.000	0.237
	201	**0.866**	0.019	0.014	0.000	0.101
	241	**0.864**	0.013	0.004	0.000	0.118
	196	**0.838**	0.012	0.003	0.000	0.148
	242	**0.845**	0.010	0.002	0.000	0.143
Algoma Slip	182	**0.999**	0.000	0.000	0.000	0.001
	192	**0.979**	0.000	0.000	0.000	0.021
Bellevue Marine Park	6981	**0.955**	0.003	0.000	0.000	0.041
	6983	**0.906**	0.007	0.001	0.000	0.086
	6984	**0.916**	0.010	0.004	0.000	0.069
	6986	**0.940**	0.004	0.000	0.000	0.055
	6991	**0.978**	0.000	0.000	0.000	0.022
	6992	**0.949**	0.002	0.000	0.000	0.049
Lake George Channel	170	**0.707**	0.036	0.094	0.000	0.163
	172	**0.944**	0.005	0.001	0.000	0.050
	175	**0.926**	0.004	0.000	0.000	0.069
	176	**0.866**	0.014	0.008	0.000	0.111
	6900	**0.758**	0.018	0.009	0.000	0.214
Little Lake George	6901	**0.944**	0.005	0.001	0.000	0.051
	6902	**0.675**	0.036	0.101	0.000	0.188

Table 7.   Mean abundance of dominant macroinvertebrate families (per 33 cm^2), taxon diversity and BEAST difference-from-reference band. Families expected to be at St. Marys River sites that are absent are highlighted.

Family	Group 1 Mean	Occurrence in Gp. 1 (%)	Reference - Isaak Walton Bay				Reference - Point aux Pins Bay				
			243	244	245	6903	52-1090	52-479	52-1535	52-741	126
No. Taxa (±2 SD)	8 (2-14)	-	15	16	17	10	17	12	17	13	16
Chironomidae	13.4	39.9	126.93	111.57	82.97	60.00	56.79	44.80	81.87	25.12	41.20
Tubificidae	5.6	16.7	21.15	28.90	22.26	41.40	5.63	6.80	27.63	3.62	7.21
Sphaeriidae	4.9	14.5	0.36	2.02	1.12	3.60	3.20	1.40	2.43	0.52	1.62
Asellidae	1.8	5.5	0.0	0.12	1.28	4.20	3.72	5.20	0.15	0.95	0.0
Naididae	1.4	4.3	2.85	1.45	1.49	0.80	2.68	3.40	1.04	0.67	0.85
Sabellidae	1.2	3.6	7.30	0.09	17.59	0.0	1.07	0.0	0.03	0.0	3.56
Haustoriidae	0.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.01
Valvatidae	0.7	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Dreissenidae	0.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gammaridae	0.6	1.6	0.17	0.06	0.24	0.0	0.0	0.40	0.03	0.30	0.01
BEAST BAND	-	-	2	2	2	1	1	1	2	1	1

Table 7.   Continued.

Family	Group 1 Mean	Occurrence in Gp. 1 (%)	Ref. US	Algoma Slag Dump						Algoma Slip	
			6904	240	122	201	241	196	242	182	192
No. Taxa (±2 SD)	8 (2-14)	-	13	16	17	16	8	11	16	3	9
Chironomidae	13.4	39.9	80.57	70.47	53.67	63.40	46.69	53.13	54.46	1.60	2.29
Tubificidae	5.6	16.7	57.61	18.61	14.21	30.22	8.31	55.73	56.79	5.00	5.29
Sphaeriidae	4.9	14.5	0.63	1.39	3.69	0.03	0.30	0.73	0.60	0.0	0.0
Asellidae	1.8	5.5	1.25	1.69	0.03	32.91	0.03	0.0	0.95	0.0	0.03
Naididae	1.4	4.3	1.38	2.20	0.56	0.26	0.15	16.40	1.42	0.0	0.75
Sabellidae	1.2	3.6	0.12	0.0	0.03	0.0	0.0	8.60	0.59	0.0	0.03
Haustoriidae	0.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Valvatidae	0.7	2.0	0.0	0.0	0.15	0.06	0.0	0.0	0.0	0.0	0.0
Dreissenidae	0.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.09
Gammaridae	0.6	1.6	0.0	0.09	0.03	0.95	0.0	0.0	0.48	0.0	0.03
BEAST BAND	-	-	2	1	1	2	2	2	2	1	1

Table 7.	Continued.

Family	Group 1 Mean	Occurrence in Gp. 1 (%)	Bellevue Marine Park					
			6981	6983	6984	6986	6991	6992
No. Taxa (±2 SD)	8 (2-14)	-	13	7	19	7	7	12
Chironomidae	13.4	39.9	14.00	26.20	22.00	7.00	27.80	31.80
Tubificidae	5.6	16.7	65.20	72.20	37.60	7.80	45.00	82.00
Sphaeriidae	4.9	14.5	3.80	3.00	2.40	2.20	4.60	3.40
Asellidae	1.8	5.5	44.00	9.80	80.40	3.40	3.40	16.40
Naididae	1.4	4.3	0.80	0.60	0.60	2.80	1.20	9.40
Sabellidae	1.2	3.6	0.20	0.0	38.60	0.0	1.00	1.40
Haustoriidae	0.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0
Valvatidae	0.7	2.0	0.20	0.0	0.40	0.0	0.0	2.40
Dreissenidae	0.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0
Gammaridae	0.6	1.6	0.80	0.0	3.00	0.0	0.0	0.0
BEAST BAND	-	-	2	1	2	1	1	1

Table 7.	Continued.

Family	Group 1 Mean	Occurrence in Gp. 1 (%)	Lake George Channel					L. Lake George	
			170	172	175	176	6900	6901	6902
No. Taxa (±2 SD)	8 (2-14)	-	10	7	9	13	9	14	10
Chironomidae	13.4	39.9	19.20	9.50	29.00	42.67	56.40	89.00	54.00
Tubificidae	5.6	16.7	111.40	23.50	32.60	61.20	30.60	52.80	55.20
Sphaeriidae	4.9	14.5	7.00	0.25	8.40	3.93	1.40	16.80	2.40
Asellidae	1.8	5.5	1.20	2.25	2.40	0.07	0.0	24.20	0.40
Naididae	1.4	4.3	0.20	10.75	0.80	7.53	1.00	0.0	1.80
Sabellidae	1.2	3.6	0.0	0.25	2.00	0.67	25.80	0.20	14.40
Haustoriidae	0.7	2.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Valvatidae	0.7	2.0	0.0	0.0	0.0	0.07	0.0	0.20	0.20
Dreissenidae	0.6	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Gammaridae	0.6	1.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BEAST BAND	-	-	2	1	1	1	2	2	2

Table 8.   Percent survival and growth (mg) in sediment toxicity tests and BEAST difference-from-reference band. Toxicity, based on numeric criteria is highlighted yellow; potential toxicity is italicized and bolded.

Site	C. riparius Survival	C. riparius Growth	H. azteca Survival	H. azteca Growth	Hexagenia Survival	Hexagenia Growth	T. tubifex Survival	T. tubifex Cocoon/ad	T. tubifex % hatch	T. tubifex Young/ad	BEAST BAND
Ref. Mean	87.10	0.350	85.60	0.500	96	3.03	98	9.9	57.0	29.0	-
243	72.00	0.576	96.00	0.658	98	2.980	100	11.0	60.4	23.8	1
244	88.00	0.465	92.00	0.651	96	2.536	100	9.6	61.2	20.6	1
245	88.00	0.383	92.00	0.573	100	2.714	100	10.4	62.8	26.0	1
6903	76.00	0.462	89.33	0.807	100	2.688	100	11.1	60.1	32.4	1
52-1090	88.00	0.401	97.33	0.643	98	2.898	100	10.6	62.0	22.3	1
52-479	90.67	0.354	**37.34**	0.601	100	2.450	100	9.7	64.8	21.1	**4**
52-1535	*61.33*	0.246	94.66	0.362	98	2.692	100	9.9	60.4	22.5	2
52-741	*65.33*	0.337	95.00	0.833	100	2.678	100	10.2	60.7	24.9	2
126	73.33	0.461	94.67	0.739	100	2.724	100	10.4	62.8	24.5	1
6904	89.33	0.439	86.67	0.700	98	2.292	100	10.1	71.9	23.5	1
240	94.66	0.283	97.33	0.739	100	3.352	100	9.5	58.5	23.2	1
122	81.33	0.437	97.33	0.549	98	3.622	100	11.6	65.9	26.6	1
201	96.00	0.287	94.67	0.620	98	3.634	100	9.5	57.0	16.2	1
241	96.00	0.311	97.33	0.523	98	3.132	100	10.4	62.2	30.1	1
196	82.67	0.264	94.67	0.594	98	2.424	100	8.6	60.8	17.5	1
242	85.33	0.440	93.33	0.712	100	3.804	100	10.5	64.8	24.4	1
182	98.67	0.205	82.67	0.436	92	1.306	100	11.0	55.3	11.1	1
192	88.00	0.251	86.67	0.589	98	1.470	95	9.0	62.6	22.5	1
6981	73.34	0.502	92.00	0.698	100	3.870	100	11.3	57.4	30.2	1
6983	78.67	0.326	96.00	0.442	100	5.094	100	8.6	57.2	33.7	1
6984	73.33	0.427	85.33	0.713	100	1.778	100	11.2	61.5	28.4	1
6986	**52.00**	0.229	74.67	0.273	92	*0.381*	100	11.4	61.2	28.8	**3**
6991	**41.33**	0.158	77.33	0.296	86	**-0.070**	95	10.4	58.1	28.0	**3**
6992	80.00	0.309	84.00	0.371	96	*0.114*	100	11.4	68.5	24.6	1
170	**53.33**	0.560	93.33	0.560	98	2.974	100	9.9	69.0	18.2	**3**
172	69.33	0.364	76.00	0.253	94	5.178	100	12.4	65.2	32.9	2
175	**53.33**	0.421	96.00	0.366	100	3.728	100	10.6	65.8	22.9	**3**
176	**56.67**	0.449	89.33	0.545	86	1.486	100	11.1	70.6	23.1	**3**
6900	78.67	0.383	96.00	0.571	100	1.282	100	9.9	81.8	25.1	2
6901	78.67	0.316	89.33	0.603	92	*0.594*	100	9.9	71.3	22.1	1
6902	90.67	0.355	89.33	0.719	96	1.166	100	9.9	82.7	25.7	1
Non-Toxic	≥67.7	0.49 – 0.21	≥67.0	0.75 – 0.23	≥85.5	5.0 – 0.9	≥88.9	12.4 – 7.2	78.1 – 38.1	46.3 – 9.9	-
Potentially toxic	67.6 – 58.8	0.20 – 0.14	66.9 – 57.1	0.22 – 0.10	85.4 – 80.3	0.8 – 0	88.8 – 84.2	7.1 – 5.9	38.0 – 28.1	9.8 – 0.8	-
Toxic	< 58.8	< 0.14	< 57.1	< 0.10	< 80.3	-	< 84.2	< 5.9	< 28.1	< 0.8	-

Note: The upper limit for non-toxic category is set using 2 × SD of the mean and indicates excessive growth or reproduction.

Table 9.   Decision matrix for weight-of-evidence categorization of St. Marys River sites based on three lines of evidence. For the sediment chemistry column, sites with exceedences of the Severe Effect Level (SEL) for metals are indicated by "●", and sites with exceedences of the Lowest Effect Level (LEL) for metals by "◉". For the toxicity and benthos alteration columns, sites determined from BEAST analyses as toxic/severely toxic or different/very different from reference, respectively, are indicated by "●"; and sites determined as potentially toxic or possibly different from reference by "◉". Sites with no SQG exceedences, no sediment toxicity, or benthic communities equivalent to reference conditions are indicated by "○". Substances exceeding LELs and SELs are listed. Total polycyclic aromatic hydrocarbons (PAHs) and petroleum hydrocarbons (PHC) concentrations are provided. Some sites show potential toxicity or possible benthos alteration but are not recommended for further action. For these sites, adverse biological conditions are not associated with elevated sediment contaminants, or the benthos alteration is not judged detrimental (decreased taxon richness, reduced average abundance).

Location	Site	Sediment Chemistry	Toxicity	Benthos Alteration	LEL exceedences	SEL exceedences	PAHs* µg/g	PHCs µg/g	Assessment
Upstream Reference - Izaak Walton Bay	243	○	○	◉	TN		ND	39	No further actions needed.
	244	○	○	◉	TN		ND	16	No further actions needed.
	245	○	○	◉	TN		ND	24	No further actions needed.
	6903	◉	○	○	Cr, Cu, TN, TOC		0.02	137	No further actions needed.
Upstream Reference - Point aux Pins Bay	52-1090	○	○	○	TN, TOC		0.02	43	No further actions needed.
	52-479	◉	●	○	As, Cu, TN, TOC		0.06	341	Determine reasons for sediment toxicity.
	52-1535	○	◉	◉			ND	17	No further actions needed.
	52-741	○	◉	○	TN, TOC		ND	76	No further actions needed.
	126	○	○	○			ND	27	No further actions needed.
Upstream US	6904	○	○	◉	TN		ND	33	No further actions needed.
Algoma Slag Dump	240	◉	○	○	Ni, TN, TOC, PAHs		23.0	251	No further actions needed.
	122	○	○	○			2.3	ND	No further actions needed.
	201	◉	○	◉	Cu, Ni, TN, TOC		0.1	315	No further actions needed.
	241	●	○	◉	As, Cr, Fe, Mn, Ni, TN, TOC, TP, Zn	As, Fe, Mn, Ni	2.3	196	Determine reason for benthos alteration.
	196	◉	○	◉	Cr, Cu, Fe, Ni, Pb, TN, TOC, Zn, PAHs		9.2	3330	Determine reason for benthos alteration.
	242	◉	○	◉	Cr, Cu, Fe, Mn, Ni, TN, TOC, PAHs		9.3	375	Determine reason for benthos alteration.
Algoma Slip	182	◉	○	○	Cr, Cu, Fe, Mn, TN, TOC, Zn, PAHs	TOC	389.3	6850	No further actions needed.
	192	◉	○	○	Cr, Cu, Fe, Mn, Ni, TN, TOC, Zn, PAHs	Fe, TOC	49.1	3022	No further actions needed.

* ND = not detectable

Table 9.	Continued.

Location	Site	Sediment Chemistry	Toxicity	Benthos Alteration	LEL exceedences	SEL exceedences	PAHs µg/g	PHC µg/g	Assessment
Bellevue Marine Park	6981	⊙	○	⊙	As, Cr, Cu, Fe, Mn, Ni, Pb, TN, TOC, TP, Zn, PAHs		7.0	367	No further actions needed.
	6983	⊙	○	○	Cr, Cu, Fe, Mn, Ni, Pb, TN, TOC, Zn	Fe	4.0	10740	No further actions needed.
	6984	⊙	○	⊙	Cr, Cu, Fe, Pb, TN, TOC, Zn		2.3	5871	No further actions needed.
	6986	⊙	●	○	Cr, Cu, Fe, Mn, Ni, Pb, TN, TOC, TP, Zn	Fe	2.8	23450	Determine reasons for sediment toxicity.
	6991	⊙	●	○	As, Cr, Cu, Fe, Hg, Mn, Ni, Pb, TN, TOC, Zn, PAHs	Fe, TOC	5.2	16560	Determine reasons for sediment toxicity.
	6992	⊙	○	○	As, Cr, Cu, Fe, Hg, Mn, Ni, Pb, TN, TOC, Zn, PAHs	Fe	6.7	17220	No further actions needed.
Lake George Channel	170	⊙	●	⊙	As, Cr, Ni, TN, TP		0.7	32	Determine reasons for sediment toxicity and benthos alteration.
	172	⊙	⊙	○	As, Cr, Cu, Fe, Hg, Mn, Ni, Pb, TN, TOC, TP, Zn	Fe	1.7	8523	Determine reasons for sediment toxicity.
	175	⊙	●	○	Cr, Cu, Fe, Ni, Pb, TN, TOC, TP, Zn		2.8	5630	Determine reasons for sediment toxicity.
	176	⊙	●	○	As, Cr, Cu, Fe, Ni, Pb, TN, TOC, TP, Zn		1.6	4625	Determine reasons for sediment toxicity.
	6900	⊙	⊙	⊙	As, Cr, Cu, Fe, Ni, Pb, TN, TOC		2.8	5012	Determine reasons for sediment toxicity.
Little Lake George	6901	⊙	○	⊙	As, Cr, Cu, Fe, Mn, Ni, Pb, TN, TOC, TP, Zn	Fe	1.9	15670	No further actions needed.
	6902	●	○	⊙	Cr, Cu, Fe, Mn, Ni, TP	Mn, Ni	1.5	7261	No further actions needed.

0
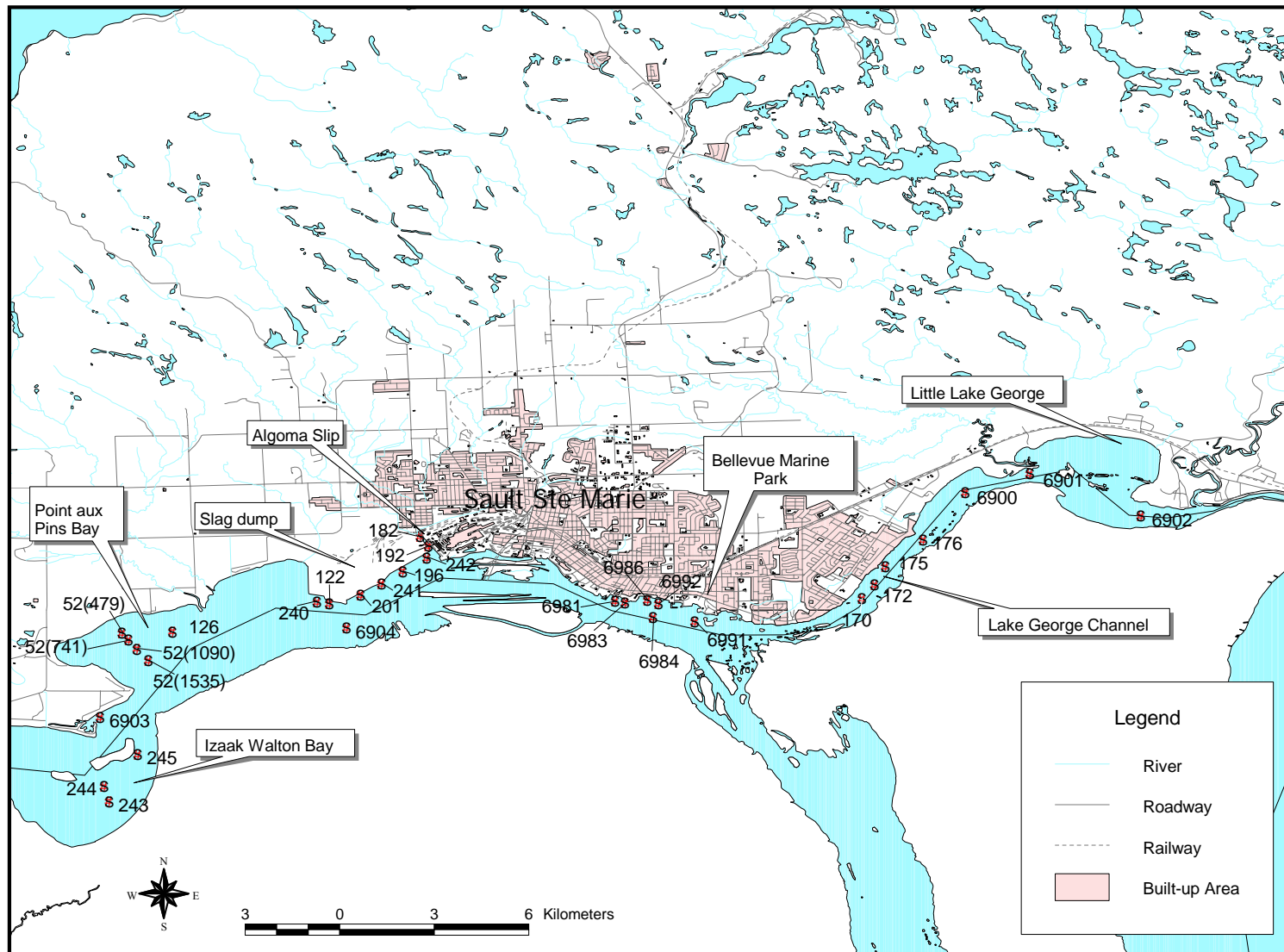
Figure 1.   Sampling locations in the St. Marys River, 2002.
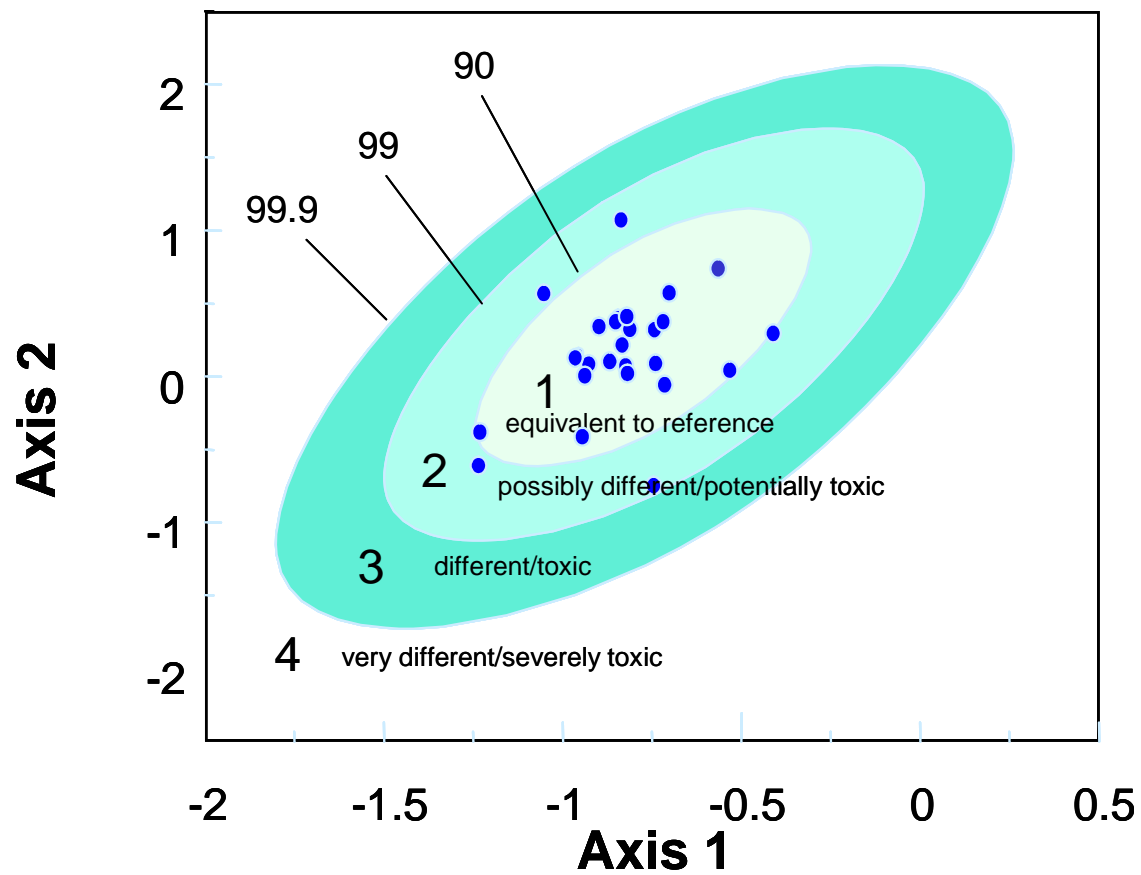
Figure 2.   The use of 90, 99, and 99.9% probability ellipses around reference sites to determine the level of departure from reference condition.
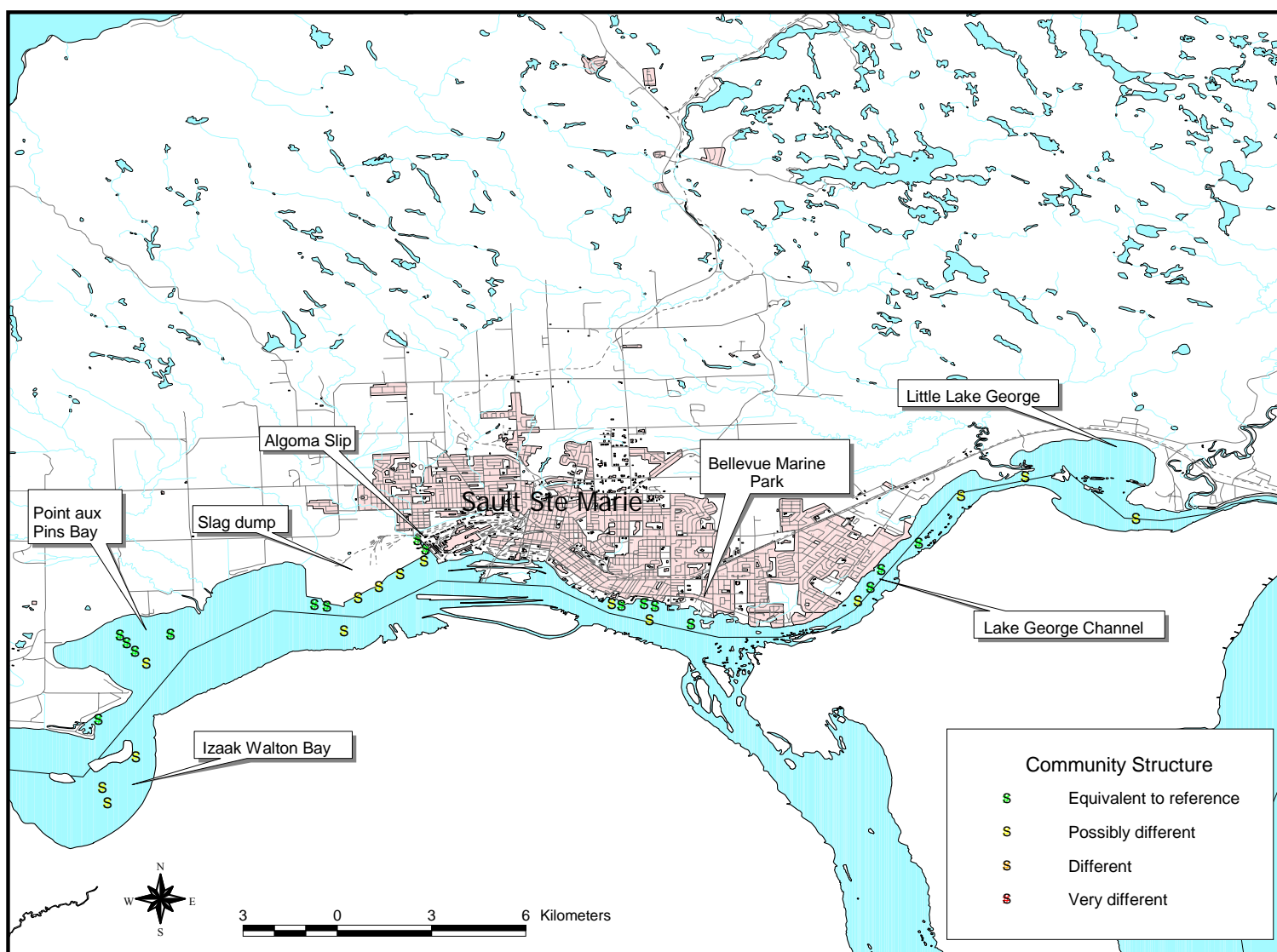
Figure 3.   Spatial distribution of sites indicating the level of benthic community alteration compared to Great Lakes reference sites.
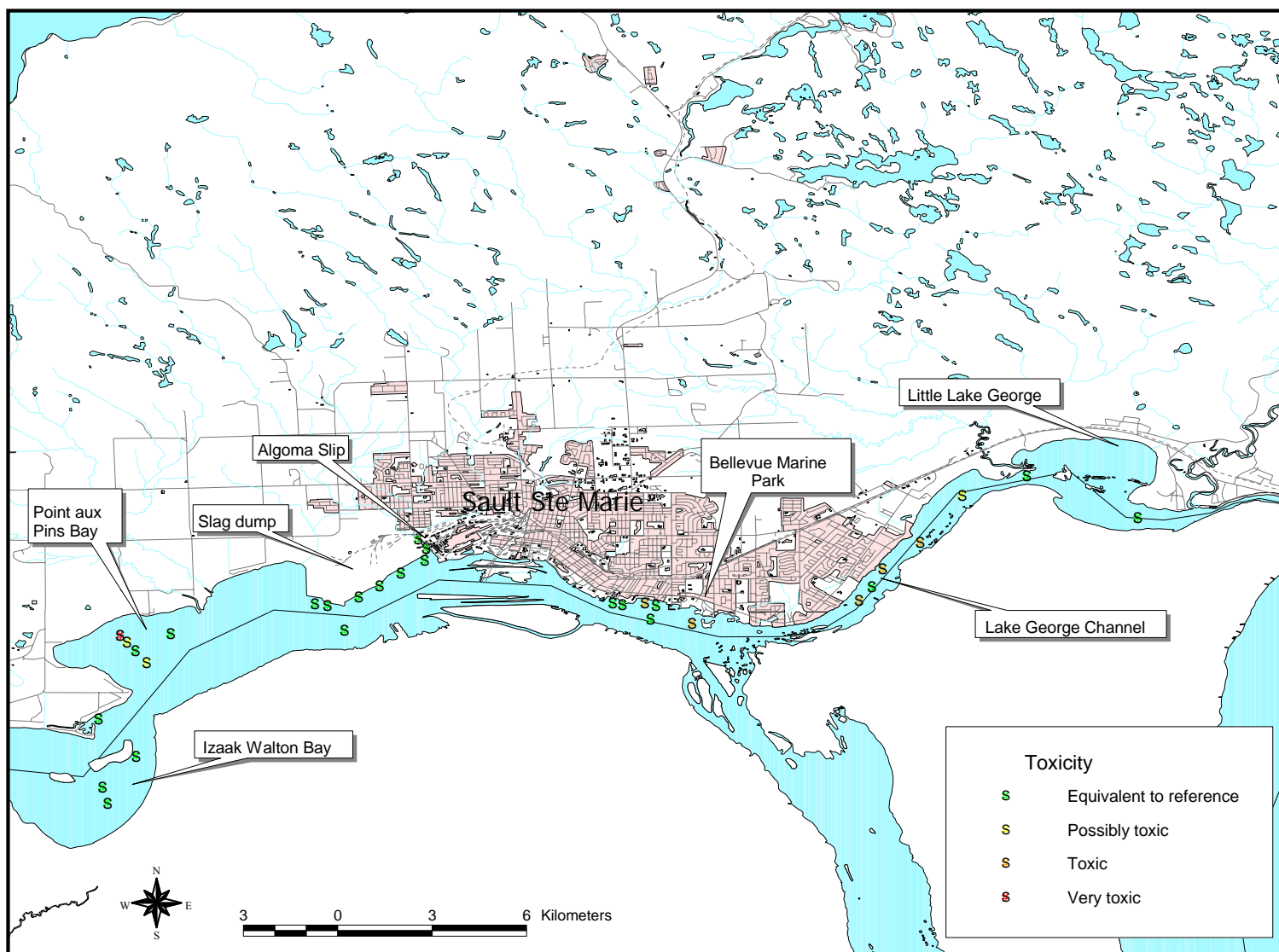
Figure 4.   Spatial distribution of sites indicating the level of toxicity compared to Great Lakes reference sites.

49

APPENDIX A   **Organic Contaminant Concentrations**

Table A1.   Total organic carbon in freeze dried and frozen sediment samples.

Site	%TOC freeze dried	%TOC frozen
243	0.8	0.8
244	0.6	0.6
245	0.4	0.6
6903	2.2	2.0
52-1090	1.5	1.1
52-479	7.6	5.9
52-1535	0.4	0.3
52-741	1.7	1.5
126	0.4, 0.6, 0.5	5.9, 0.6, 0.6
6904	0.8	0.7
240	2.4	1.7
122	0.5	0.3
201	3.1	3.7
241	4.5	1.5
196	5.4, 4.8, 5.0	3.7, 4.0, 4.0
242	5.6	4.0
182	30.6	5.5
192	16.0	5.6
6981	7.9	3.9
6983	6.5	5.2
6984	4.7	4.0
6986	7.5	6.1
6991	14.1	4.8
6992	9.6	7.1
170	0.6	1.0
172	6.7	6.1
175	7.7	5.9
176	3.6, 3.7, 3.7	4.6, 5.0, 4.2
6900	3.3	4.8
6901	6.5	6.1
6902	0.4	6.0

Table A2.   Petroleum hydrocarbons (PHCs) (µg/g) in St. Marys River sediments.

PETROLEUM HYDROCARBONS (CCME)	Units	6900	6901	6902	DL	6903	DL	6904	DL	6981	DL	6983	6984	6991	6992	6986	DL
Petroleum Hydro. - CCME																	
Benzene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	ND	ND	ND	ND	0.02
Toluene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	ND	ND	ND	ND	0.02
Ethylbenzene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	ND	ND	ND	ND	0.02
o-Xylene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	0.02	ND	0.02	ND	ND	ND	ND	ND	0.02
p+m-Xylene	ug/g	ND	ND	ND	0.04	ND	0.04	ND	0.04	ND	0.04	ND	ND	ND	ND	ND	0.04
Total Xylenes	ug/g	ND	ND	ND	0.04	ND	0.04	ND	0.04	ND	0.04	ND	ND	ND	ND	ND	0.04
F1 (C6-C10)	ug/g	ND	ND	ND	10	ND	10	ND	10	ND	10	ND	ND	ND	ND	ND	10
F1 (C6-C10) - BTEX	ug/g	ND	ND	ND	10	ND	10	ND	10	ND	10	ND	ND	ND	ND	ND	10
TPH COMPOUNDS																	
F2 (C10-C16 Hydrocarbons)	ug/g	52	170	81	10	ND	20	ND	10	ND	20	140	41	220	260	150	10
F3 (C16-C34 Hydrocarbons)	ug/g	980	3200	1600	10	110	10	33	10	270	10	2100	830	3300	3300	3900	10
F4 (C34-C50 Hydrocarbons)	ug/g	680	3000	980	10	27	10	ND	10	97	10	1500	1000	2700	3000	4400	10
Reached Baseline at C50	ug/g	NO	NO	NO	N/A	YES	N/A	YES	N/A	YES	N/A	NO	NO	NO	NO	NO	N/A
F4G (Hydrocarbons Gravimetric)	ug/g	3300	9300	4600	100	-	100	-	100	-	100	7000	4000	11000	10000	15000	100
Total PHCs		**4332**	**12670**	**6281**		**137**		**33**		**367**		**9240**	**4871**	**14520**	**13560**	**19050**	

	Units	M201	M52(479)	DL	M52(741)	M52(1090)	M52(1535)	M122	M126-1	M126-2	M126-3	M240	M241	M242	M243	M244
Petroleum Hydro. - CCME																
Benzene	ug/g	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Toluene	ug/g	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylbenzene	ug/g	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
o-Xylene	ug/g	ND	ND	0.02	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
p+m-Xylene	ug/g	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total Xylenes	ug/g	ND	ND	0.04	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
F1 (C6-C10)	ug/g	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
F1 (C6-C10) - BTEX	ug/g	ND	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TPH COMPOUNDS																
F2 (C10-C16 Hydrocarbons)	ug/g	ND	ND	25	ND	ND	ND	ND	ND	ND	ND	12	ND	ND	ND	ND
F3 (C16-C34 Hydrocarbons)	ug/g	240	270	10	53	43	17	ND	23	26	31	210	150	300	39	16
F4 (C34-C50 Hydrocarbons)	ug/g	75	71	10	23	ND	ND	ND	ND	ND	ND	29	46	75	ND	ND
Reached Baseline at C50	ug/g	YES	YES	N/A	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
F4G (Hydrocarbons Gravimetric)	ug/g	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total PHCs		**315**	**341**		**76**	**43**	**17**	**ND**	**23**	**26**	**31**	**251**	**196**	**375**	**39**	**16**

	Units	M245	M170	M172	DL	M175	DL	M176-1	M176-2	M176-3	M182	M192	M196-1	M196-2	M196-3	DL
Petroleum Hydro. - CCME																
Benzene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	ND	ND	0.68	0.29	ND	ND	ND	0.02
Toluene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	ND	ND	0.39	0.17	ND	ND	ND	0.02
Ethylbenzene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	ND	ND	0.13	0.05	ND	ND	ND	0.02
o-Xylene	ug/g	ND	ND	ND	0.02	ND	0.02	ND	ND	ND	0.12	0.04	ND	ND	ND	0.02
p+m-Xylene	ug/g	ND	ND	ND	0.04	ND	0.04	ND	ND	ND	0.39	0.15	ND	ND	ND	0.04
Total Xylenes	ug/g	ND	ND	ND	0.04	ND	0.04	ND	ND	ND	0.52	0.19	ND	ND	ND	0.04
F1 (C6-C10)	ug/g	ND	ND	ND	10	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	10
F1 (C6-C10) - BTEX	ug/g	ND	ND	ND	10	ND	10	ND	ND	ND	ND	ND	ND	ND	ND	10
TPH COMPOUNDS																
F2 (C10-C16 Hydrocarbons)	ug/g	ND	ND	63	10	ND	20	25	21	20	160	32	ND	ND	ND	10
F3 (C16-C34 Hydrocarbons)	ug/g	24	32	1900	10	930	10	920	840	880	2100	520	550	590	670	10
F4 (C34-C50 Hydrocarbons)	ug/g	ND	ND	960	10	700	10	450	410	410	590	170	210	220	250	10
Reached Baseline at C50	ug/g	YES	YES	NO	N/A	NO	N/A	NO	NO	NO	NO	NO	NO	NO	NO	N/A
F4G (Hydrocarbons Gravimetric)	ug/g	-	-	5600	100	4000	100	3600	2800	3500	4000	2300	2300	2400	2800	100
Total PHCs		**24**	**32**	**7563**		**4930**		**4545**	**3661**	**4400**	**6260**	**2852**	**2850**	**2990**	**3470**	

ND = Not detected
N/A = Not Applicable

Table A3.   Polycyclic aromatic hydrocarbons (PAHs) (µg/g) in St. Marys River sediments.

SEMI-VOLATILE ORGANICS BY GC-MS (SOLID)

PAHs	Units	6900	6901	6902	6903	6904	6981	6983	6984	6991	6992	6986	M201	M52(479)	M52(741)	M52(1090)
Naphthalene	ug/Kg	132	115	85.6	ND	ND	1510	1090	131	917	2340	101	ND	ND	ND	ND
Acenaphthylene	ug/Kg	50	32	32	ND	ND	79.2	36.9	27.3	109	46.9	63.9	ND	ND	ND	ND
Acenaphthene	ug/Kg	14	19	ND	ND	ND	47	30	27	51	37	14	ND	ND	ND	ND
Fluorene	ug/Kg	19.4	20.4	11.2	ND	ND	60	39	42.9	51.3	39.5	20.5	ND	ND	ND	ND
Phenanthrene	ug/Kg	181	166	101	ND	ND	543	324	292	459	283	195	15.1	14.6	ND	7
Anthracene	ug/Kg	73.6	46.6	37.6	ND	ND	178	87.2	163	172	107	69.9	ND	ND	ND	ND
Fluoranthene	ug/Kg	390	288	201	8	ND	870	408	352	873	462	381	15.8	20	ND	9
Pyrene	ug/Kg	337	250	173	7	ND	691	325	275	755	377	327	12.9	13.8	ND	6
Benzo(a)anthracene	ug/Kg	247	150	122	ND	ND	486	244	160	478	236	234	ND	ND	ND	ND
Chrysene	ug/Kg	219	133	116	ND	ND	441	294	153	432	219	211	ND	ND	ND	ND
Benzo(b)fluoranthene	ug/Kg	265	167	148	ND	ND	492	279	149	528	251	259	ND	ND	ND	ND
Benzo(k)fluoranthene	ug/Kg	137	88	70	ND	ND	254	138	77	274	122	142	ND	ND	ND	ND
Benzo(a)pyrene	ug/Kg	319	207	168	ND	ND	614	319	183	676	291	324	9	7	ND	ND
Indeno(1,2,3-cd)pyrene	ug/Kg	201	134	118	ND	ND	383	191	116	449	189	231	ND	ND	ND	ND
Dibenzo(a,h)anthracene	ug/Kg	48	ND	30	ND	ND	93	48	25	105	ND	57	ND	ND	ND	ND
Benzo(ghi)perylene	ug/Kg	169	117	101	ND	ND	306	148	99	376	157	193	ND	ND	ND	ND
TOTAL PAHs	**ug/Kg**	**2802**	**1933**	**1514**	**15**	**ND**	**7047**	**4001**	**2272**	**6705**	**5157**	**2823**	**53**	**55**	**ND**	**22**

PAHs	Units	M52(1535)	M122	M126-1	M126-2	M126-3	DL	M240	DL	M241	M242	M243	M244	M245	M170
Naphthalene	ug/Kg	ND	74.3	ND	ND	ND	5	347	5	140	1040	ND	ND	ND	51.2
Acenaphthylene	ug/Kg	ND	46.7	ND	ND	ND	5	282	5	15.1	61.2	ND	ND	ND	6
Acenaphthene	ug/Kg	ND	31	ND	ND	ND	10	463	10	30	284	ND	ND	ND	ND
Fluorene	ug/Kg	ND	47.6	ND	ND	ND	5	813	5	49.7	353	ND	ND	ND	12
Phenanthrene	ug/Kg	ND	335	ND	ND	ND	5	3840	50	213	1290	ND	ND	ND	88
Anthracene	ug/Kg	ND	120	ND	ND	ND	5	1530	5	70.8	343	ND	ND	ND	31.3
Fluoranthene	ug/Kg	ND	384	ND	ND	ND	5	4740	50	320	1660	ND	ND	ND	128
Pyrene	ug/Kg	ND	286	ND	ND	ND	5	3220	50	261	1160	ND	ND	ND	112
Benzo(a)anthracene	ug/Kg	ND	187	ND	ND	ND	10	1980	100	212	804	ND	ND	ND	67
Chrysene	ug/Kg	ND	143	ND	ND	ND	10	1430	10	165	590	ND	ND	ND	61
Benzo(b)fluoranthene	ug/Kg	ND	152	ND	ND	ND	10	1080	10	183	431	ND	ND	ND	46
Benzo(k)fluoranthene	ug/Kg	ND	77	ND	ND	ND	10	413	10	79	221	ND	ND	ND	17
Benzo(a)pyrene	ug/Kg	ND	182	ND	ND	ND	5	1360	5	221	513	ND	ND	ND	48.8
Indeno(1,2,3-cd)pyrene	ug/Kg	ND	121	ND	ND	ND	20	782	20	160	283	ND	ND	ND	25
Dibenzo(a,h)anthracene	ug/Kg	ND	28	ND	ND	ND	20	178	20	35	65	ND	ND	ND	ND
Benzo(ghi)perylene	ug/Kg	ND	98	ND	ND	ND	20	574	20	137	207	ND	ND	ND	ND
TOTAL PAHs	**ug/Kg**	**ND**	**2313**	**ND**	**ND**	**ND**		**23032**		**2292**	**9305**	**ND**	**ND**	**ND**	**693**

PAHs	Units	M172	M175	M176-1	M176-2	M176-3	DL	M182	DL	M192	M196-1	DL	M196-2	M196-3	DL
Naphthalene	ug/Kg	125	481	176	109	138	5	22500	250	5290	842	25	557	500	5
Acenaphthylene	ug/Kg	20.2	33.1	48.7	25	39.6	5	1230	25	238	104	25	66.9	42.9	5
Acenaphthene	ug/Kg	13	27	12	ND	ND	10	5920	50	979	199	50	132	96	10
Fluorene	ug/Kg	20.2	33.9	22	11.5	17.4	5	28200	250	1690	345	25	214	152	5
Phenanthrene	ug/Kg	126	213	115	61.5	96	5	136000	2500	8300	1450	25	1050	734	5
Anthracene	ug/Kg	45.5	83.9	53.3	34.5	45.6	5	36900	250	2040	551	25	366	248	5
Fluoranthene	ug/Kg	269	398	303	155	252	5	63200	250	10500	2220	25	1730	1110	5
Pyrene	ug/Kg	215	320	251	130	221	5	40300	250	7700	1660	25	1290	827	5
Benzo(a)anthracene	ug/Kg	166	261	223	102	178	10	15400	500	3360	1170	50	844	547	10
Chrysene	ug/Kg	159	247	207	107	154	10	18300	500	3020	1010	50	885	491	10
Benzo(b)fluoranthene	ug/Kg	112	177	144	73	133	10	6520	50	1550	690	50	582	326	10
Benzo(k)fluoranthene	ug/Kg	67	83	79	37	66	10	2820	50	617	370	50	204	124	10
Benzo(a)pyrene	ug/Kg	140	206	171	91.2	138	5	5900	25	1660	820	25	572	327	5
Indeno(1,2,3-cd)pyrene	ug/Kg	95	123	94	54	78	20	3040	100	1050	494	100	341	193	20
Dibenzo(a,h)anthracene	ug/Kg	24	35	27	ND	20	20	761	100	283	133	100	92	53	20
Benzo(ghi)perylene	ug/Kg	73	90	66	40	57	20	2290	100	837	408	100	274	164	20
TOTAL PAHs	**ug/Kg**	**1670**	**2812**	**1992**	**1031**	**1634**		**389281**		**49114**	**12466**		**9200**	**5935**	

APPENDIX B   **Invertebrate Family Counts**

Table B1.　Invertebrate family counts for St. Marys River sites (per 33 cm^2).

					Upstream					
Family	243	244	245	6903	52-1535	52-1090	52-741	52-479	126	6904
Ancylidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anisitsiellidae	0.00	0.15	0.00	1.80	0.03	0.06	0.06	0.00	0.06	0.12
Asellidae	0.00	0.12	1.28	4.20	0.15	3.72	0.95	5.20	0.00	1.25
Aturidae	0.00	0.00	0.03	0.00	0.06	0.00	0.30	0.20	0.53	0.00
Caenidae	0.03	0.06	0.00	0.20	0.00	0.18	0.06	1.20	0.09	0.00
Calohypsbiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cambaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Candoniidae	6.51	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceratopogonidae	1.63	1.01	1.01	2.20	1.55	1.40	1.01	2.40	0.95	1.58
Ceropagidae	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.03
Chironomidae	126.93	111.57	82.97	60.00	81.87	56.79	25.12	44.80	41.20	80.57
Chydoridae	7.34	2.32	3.80	1.60	1.28	2.29	1.28	3.80	6.00	1.04
Corixidae	0.00	0.03	0.06	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyclocyprididae	0.39	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprididae	2.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daphnidae	0.57	0.48	0.00	0.40	0.45	0.00	0.03	1.20	0.00	0.06
Dipseudopsidae	0.00	0.00	0.00	0.00	0.03	0.12	0.00	0.00	0.00	0.00
Dreissenidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dugesiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Empididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Enchytraeidae	0.33	4.55	4.47	1.00	3.06	0.52	0.11	0.60	0.22	0.22
Ephemerellidae	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Ephemeridae	2.84	7.25	2.65	9.20	6.81	5.53	1.58	4.00	3.15	6.54
Erpobdellidae	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Feltridae	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00
Gammaridae	0.17	0.06	0.24	0.00	0.03	0.00	0.30	0.40	0.01	0.00
Glossiphoniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
Halicaridae	1.13	0.62	2.35	0.20	1.10	0.98	0.51	0.60	1.00	0.06
Haustoriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Holopedidae	0.00	0.00	0.00	0.00	0.03	0.06	0.03	0.00	0.05	0.00
Hyalellidae	0.17	0.65	0.77	0.00	2.44	2.44	0.15	0.00	0.00	2.11
Hydridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrobiidae	1.05	0.42	0.45	0.00	0.59	0.18	0.06	0.40	0.46	0.00
Hydroptilidae	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00
Hygrobatidae	0.03	0.00	0.00	0.00	0.18	0.03	0.03	0.20	0.08	0.09
Isotomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lebertiidae	0.00	0.24	0.09	0.20	0.18	0.09	0.06	0.00	0.31	0.00
Leptoceridae	0.00	0.18	0.24	0.00	0.03	0.15	0.09	0.00	0.03	0.03
Leptophlebiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnesiidae	0.00	0.00	0.00	0.00	0.03	0.03	0.03	0.00	0.00	0.03
Limnocytheridae	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lumbriculidae	0.25	5.18	10.48	0.00	3.77	0.15	0.00	0.00	0.14	0.00
Lymnaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macrothricidae	0.92	0.06	0.59	4.20	0.92	1.22	0.92	6.00	0.74	1.55
Molannidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naididae	2.85	1.45	1.49	0.80	1.04	2.68	0.67	3.40	0.85	1.38
Oxidae	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.12
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phrygaenidae	0.00	0.00	0.00	0.00	0.06	0.00	0.00	0.00	0.00	0.00
Physidae	0.00	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pionidae	0.37	0.00	0.15	0.40	0.15	0.15	0.09	0.00	0.25	0.00
Plagiostomidae	0.66	0.06	0.18	0.40	0.12	0.39	0.03	0.00	0.16	0.09
Planariidae	0.00	0.00	0.12	0.00	0.00	0.00	0.18	0.00	0.00	0.00
Planorbidae	0.06	0.00	0.15	0.20	0.03	0.27	0.00	0.00	0.00	0.12
Polycentropodidae	0.10	0.15	0.12	0.00	0.33	0.24	0.09	0.00	0.00	0.15
Pyralidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sabellidae	7.30	0.09	17.59	0.00	0.03	1.07	0.00	0.00	3.56	0.12
Sialidae	0.27	0.00	0.03	0.00	0.00	0.00	0.00	0.20	0.03	0.00
Sididae	0.00	0.21	1.34	0.00	0.00	0.15	0.53	0.00	0.00	1.13
Sphaeriidae	0.36	2.02	1.12	3.60	2.43	3.20	0.52	1.40	1.62	0.63
Spongillidae	0.00	0.00	0.00	0.00	0.18	0.27	0.09	1.00	0.00	0.18
Tetrastemmatidae	0.00	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Torrenticolidae	0.00	0.03	0.00	0.00	0.33	0.09	0.03	0.20	0.02	0.00
Trhypachthoniidae	0.00	6.15	23.45	0.00	10.22	0.24	0.06	0.00	0.00	0.03
Tubificidae	21.15	28.90	22.26	41.40	27.63	5.63	3.62	6.80	7.21	57.61
Unionicolidae	0.00	0.00	0.12	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Valvatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Family	Slag Dump						Algoma Slip	
	240	122	201	241	196	242	182	192
Ancylidae	0.06	0.00	0.62	0.00	0.00	0.00	0.00	0.00
Anisitsiellidae	0.00	0.15	0.00	0.06	0.33	0.00	0.00	0.03
Asellidae	1.69	0.03	32.91	0.03	0.00	0.95	0.00	0.03
Aturidae	0.03	0.00	0.00	0.00	0.20	0.06	0.00	0.00
Caenidae	0.03	0.03	0.00	0.06	0.00	0.03	0.00	0.00
Calohypsbiidae	0.00	0.00	0.00	0.00	1.07	0.06	0.00	0.00
Cambaridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Candoniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ceratopogonidae	0.80	0.98	0.56	0.95	1.07	1.63	0.00	0.12
Ceropagidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chironomidae	70.47	53.67	63.40	46.69	53.13	54.46	1.60	2.29
Chydoridae	0.45	1.55	4.40	0.24	5.07	10.19	0.00	0.03
Corixidae	0.03	0.00	0.18	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Cyclocyprididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyprididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Daphnidae	0.15	0.00	2.01	0.00	0.00	0.36	0.00	0.00
Dipseudopsidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dreissenidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.09
Dugesiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Empididae	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Enchytraeidae	0.15	0.00	0.36	0.00	0.00	0.00	0.00	0.00
Ephemerellidae	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00
Ephemeridae	3.18	1.99	0.25	2.44	3.33	1.37	0.20	0.12
Erpobdellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feltridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gammaridae	0.09	0.03	0.95	0.00	0.00	0.48	0.00	0.03
Glossiphoniidae	0.00	0.06	0.00	0.00	0.13	0.00	0.00	0.00
Halicaridae	0.80	0.03	3.92	0.06	0.20	0.00	0.20	0.00
Haustoriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Holopedidae	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Hyalellidae	0.65	0.00	5.60	0.00	0.00	0.00	0.00	0.00
Hydridae	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Hydrobiidae	0.21	0.77	1.10	0.00	0.13	0.21	0.00	0.00
Hydroptilidae	0.12	0.00	0.26	0.00	0.00	0.21	0.00	0.00
Hygrobatidae	0.30	0.00	1.39	0.00	0.13	0.68	0.00	0.00
Isotomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Lebertiidae	0.03	0.06	0.14	0.00	0.27	0.06	0.00	0.00
Leptoceridae	0.03	0.00	1.16	0.00	0.00	0.18	0.00	0.00
Leptophlebiidae	0.09	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnesiidae	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Limnocytheridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lumbriculidae	0.00	0.04	0.00	0.00	0.00	0.00	0.00	0.00
Lymnaeidae	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Macrothricidae	1.81	0.45	11.54	0.74	12.13	10.76	1.20	3.00
Molannidae	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00
Naididae	2.20	0.56	0.26	0.15	16.40	1.42	0.00	0.75
Oxidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Phrygaenidae	0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Physidae	0.15	0.00	0.18	0.00	0.00	0.24	0.00	0.00
Pionidae	0.09	0.12	1.28	0.06	0.20	1.58	0.00	0.03
Plagiostomidae	0.71	0.21	1.67	0.86	1.27	1.63	0.00	0.00
Planariidae	0.62	0.00	3.88	0.00	0.00	0.21	0.00	0.00
Planorbidae	0.03	0.03	0.78	0.00	0.07	0.51	0.00	0.00
Polycentropodidae	0.03	0.00	0.09	0.00	0.00	0.00	0.00	0.00
Pyralidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sabellidae	0.00	0.03	0.00	0.00	8.60	0.59	0.00	0.03
Sialidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sididae	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.00
Sphaeriidae	1.39	3.69	0.03	0.30	0.73	0.60	0.00	0.00
Spongillidae	0.39	0.15	1.16	0.48	0.07	0.00	0.00	0.00
Tetrastemmatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Torrenticolidae	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Trhypachthoniidae	0.03	0.00	0.84	0.00	0.13	0.03	1.20	0.03
Tubificidae	18.61	14.21	30.22	8.31	55.73	56.79	5.00	5.29
Unionicolidae	0.00	0.00	0.00	0.06	0.00	0.06	0.00	0.00
Valvatidae	0.00	0.15	0.06	0.00	0.00	0.00	0.00	0.00

Table B1.   Continued.

Family	Bellevue Marine Park						Lake George Channel					Little Lake George	
	6981	6983	6984	6986	6991	6992	170	172	175	176	6900	6901	6902
Ancylidae	0.20	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Anisitsiellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.00	0.00
Asellidae	44.00	9.80	80.40	3.40	3.40	16.40	1.20	2.25	2.40	0.07	0.00	24.20	0.40
Aturidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Caenidae	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.20	0.07	0.00	0.00	0.00
Calohypsbiidae	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.53	0.00	0.00	1.40
Cambaridae	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Candoniidae	2.00	3.20	12.40	0.00	0.60	0.00	4.80	0.00	1.40	2.60	1.20	0.00	0.00
Ceratopogonidae	0.00	0.00	1.60	0.00	0.00	0.00	3.00	0.00	1.60	4.40	2.40	0.00	1.20
Ceropagidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chironomidae	14.00	26.20	22.00	7.00	27.80	31.80	19.20	9.50	29.00	42.67	56.40	89.00	54.00
Chydoridae	2.80	0.00	3.60	0.40	1.60	3.20	41.80	32.75	3.40	3.60	0.20	5.20	4.20
Corixidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Curculionidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cyclocyprididae	4.40	6.00	14.00	0.00	1.60	1.00	0.40	6.00	0.40	0.80	0.20	2.80	0.00
Cyprididae	2.20	3.20	1.40	0.00	0.00	0.20	0.40	0.50	2.20	0.53	0.00	2.80	0.00
Daphnidae	0.00	0.00	0.00	0.20	0.00	0.00	0.00	2.50	0.00	0.00	0.00	0.20	0.00
Dipseudopsidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dreissenidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dugesiidae	6.00	0.00	0.00	0.00	0.00	3.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Elmidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00
Empididae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Enchytraeidae	0.00	0.00	0.20	0.00	0.00	0.00	0.20	0.00	0.00	0.20	0.00	0.00	0.00
Ephemerellidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ephemeridae	0.00	0.00	0.60	0.00	3.00	0.20	7.00	0.00	14.60	6.00	3.20	0.20	4.00
Erpobdellidae	0.00	0.00	1.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feltridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Gammaridae	0.80	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Glossiphoniidae	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00	0.00	0.07	0.00	0.60	0.00
Halicaridae	0.20	0.20	0.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00
Haustoriidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Heptageniidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Holopedidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hyalellidae	2.60	0.00	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Hydridae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hydrobiidae	9.40	1.80	16.60	1.60	0.00	3.80	0.20	0.00	0.00	0.80	0.80	5.40	3.60
Hydroptilidae	0.00	0.00	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.40	0.00
Hygrobatidae	3.20	0.40	3.60	0.00	0.20	0.20	0.60	0.00	0.00	0.07	0.40	0.00	0.40
Isotomidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lebertiidae	0.20	0.00	0.60	0.00	0.00	0.20	0.20	0.00	0.00	0.13	0.00	0.00	0.00
Leptoceridae	2.40	0.00	0.40	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	2.00	0.00
Leptophlebiidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limnesiidae	0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Limnocytheridae	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lumbriculidae	0.80	0.00	1.80	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00	0.00
Lymnaeidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Macrothricidae	2.00	2.60	4.60	0.00	1.00	4.60	0.00	0.25	0.40	2.47	0.80	5.80	0.40
Molannidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Naididae	0.80	0.60	0.60	2.80	1.20	9.40	0.20	10.75	0.80	7.53	1.00	0.00	1.80
Oxidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Perlodidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Phrygaenidae	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Physidae	0.00	0.40	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Pionidae	0.80	1.00	0.20	4.40	0.20	1.00	0.80	2.50	0.40	0.67	0.00	4.00	0.00
Plagiostomidae	1.60	1.40	2.00	0.00	0.40	5.40	0.00	1.25	0.80	0.33	0.00	1.20	0.00
Planariidae	0.00	1.80	0.20	0.80	0.00	0.00	0.00	1.00	0.00	0.00	0.00	4.40	0.00
Planorbidae	0.40	0.00	1.20	0.20	0.00	2.20	0.00	10.50	0.00	0.00	0.00	1.60	0.00
Polycentropodidae	0.00	0.00	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.00
Pyralidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.00	0.00
Sabellidae	0.20	0.00	38.60	0.00	1.00	1.40	0.00	0.25	2.00	0.67	25.80	0.20	14.40
Sialidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sididae	0.00	0.00	0.00	0.20	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sphaeriidae	3.80	3.00	2.40	2.20	4.60	3.40	7.00	0.25	8.40	3.93	1.40	16.80	2.40
Spongillidae	0.00	1.60	0.00	0.00	0.20	0.20	0.00	0.00	0.80	0.07	5.80	1.00	0.00
Tetrastemmatidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.00	0.00	0.00
Torrenticolidae	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Trhypachthoniidae	0.20	0.60	0.20	0.20	0.00	0.40	0.20	0.00	0.20	0.07	0.00	0.00	0.00
Tubificidae	65.20	72.20	37.60	7.80	45.00	82.00	111.40	23.50	32.60	61.20	30.60	52.80	55.20
Unionicolidae	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Valvatidae	0.20	0.00	0.40	0.00	0.00	2.40	0.00	0.00	0.00	0.07	0.00	0.20	0.20

APPENDIX C   BEAST Community Structure Ordinations

Figure C1.   Ordination of a subset of test sites using benthic community data (family level), summarized on axes 1 and 2, with 90%, 99%, and 99.9% probability ellipses around reference sites (not shown) indicated. Maximally correlated families are shown with an arrow. Stress = 0.162.

Figure C2. Ordination of a subset of test sites using benthic community data (family level), summarized on axes 1 and 3, with 90%, 99%, and 99.9% probability ellipses around reference sites (not shown) indicated. Invertebrate families and environmental variables are not highly correlated to axes ($r^2 \leq 0.276$ and $r^2 \leq 0.146$, respectively). Stress = 0.158.
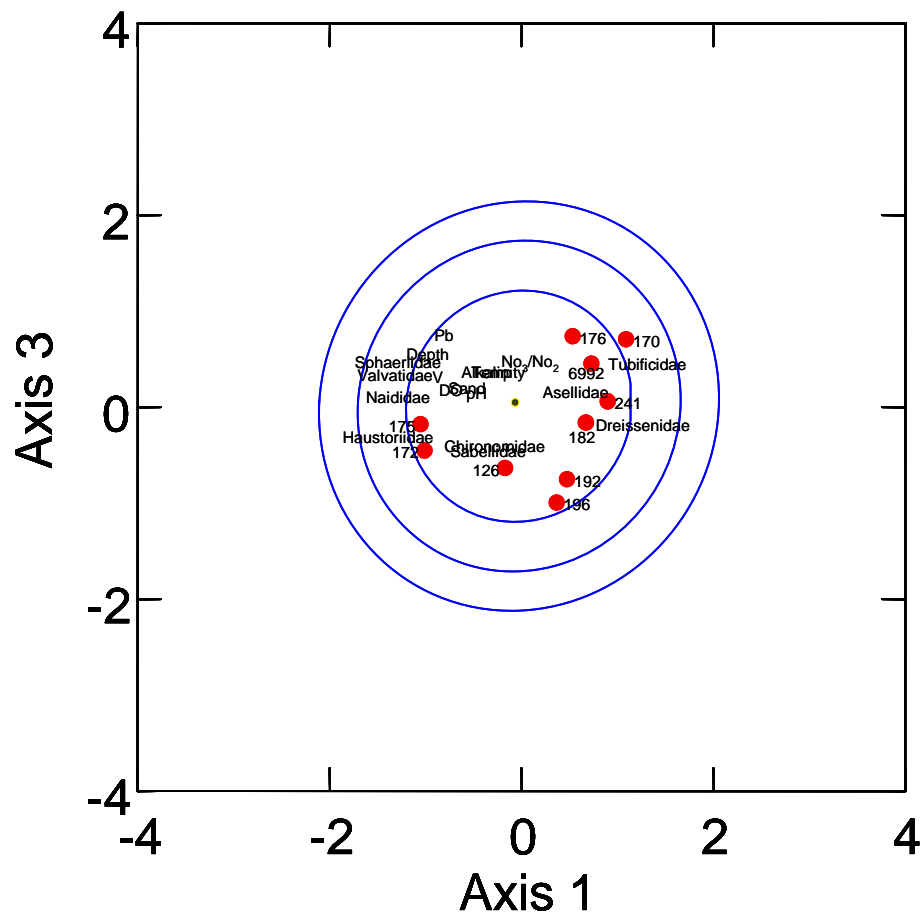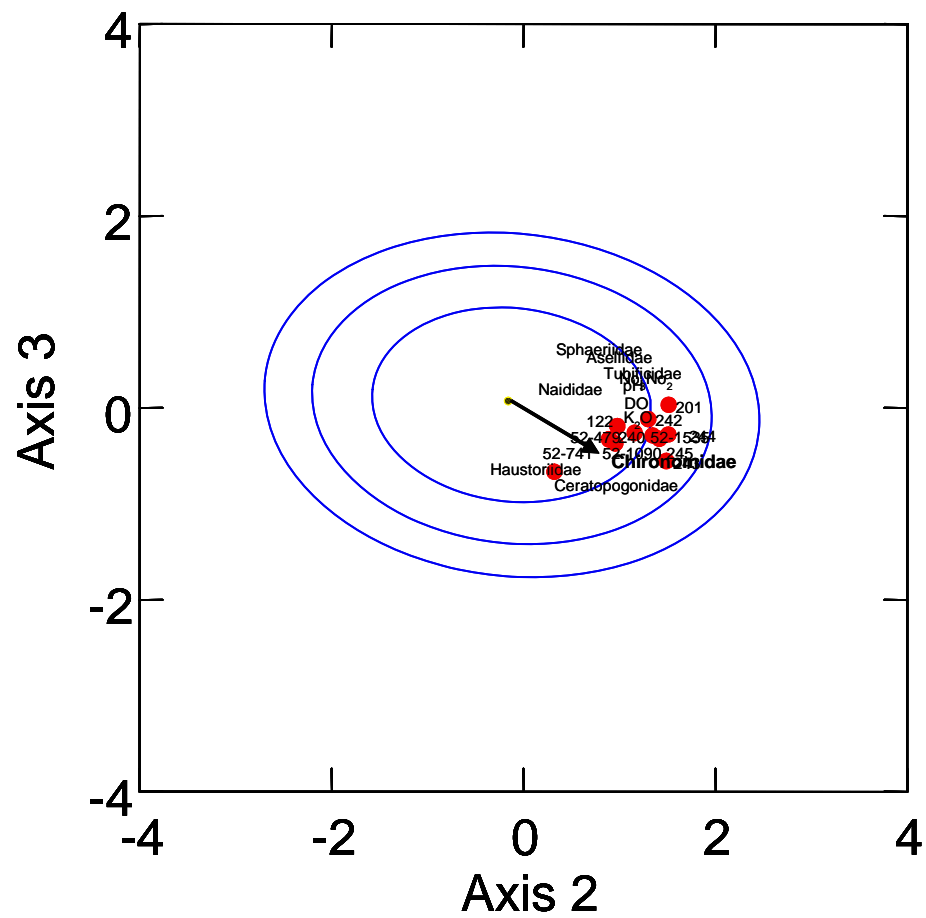
Figure C3. Ordination of a subset of test sites using benthic community data (family level), summarized on axes 1 and 2, with 90%, 99%, and 99.9% probability ellipses around reference sites (not shown) indicated. Stress = 0.161.

APPENDIX D   Toxicity Test Water Quality Parameters

Table D1.   Water quality parameter measurements in toxicity tests.

	Chironomus riparius									
	Day 0					**Day 10**				
Site	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L
69M126	8.2	196-262	22.2-22.4	7.8-8.0	0	8.1-8.4	210-264	23.0-23.1	7.9-8.1	0
69M52 (479)	8.1-8.3	140-227	22.1	7.8-8.0	0	7.9-8.1	160-246	22.8-23.0	7.9-8.0	0
69M52 (741)	8.0-8.1	138-215	21.9-22.1	7.9-8.0	0	8.0-8.1	129-219	22.7-22.8	8.0-8.2	0
69M52 (1090)	8.1-8.4	279-351	21.8-22.3	7.9-8.0	0	8.0-8.2	254-307	22.9-23.0	7.9-8.2	0
69M52 (1535)	8.4	246-321	22.0-22.1	7.5-7.7	0	7.9-8.2	239-287	22.9-23.0	8.0	0
6900	8.3	201-233	23.6-23.7	7.6-7.9	0	8.2-8.3	203-223	23.3-23.5	8.1-8.2	0
6901	8.1-8.2	210-242	23.7	7.6-7.9	0	7.9-8.0	242-304	23.6-23.9	7.9-8.1	0
6902	8.1-8.2	184-231	23.6-24.1	7.6-7.9	0	8.0-8.1	196-241	23.6-23.9	8.0-8.4	0
6903	8.0-8.1	198-235	23.6-23.7	7.7-7.9	0	7.9-8.0	221-275	23.6-23.9	8.0-8.2	0
6904	8.0-8.1	209-257	23.6-23.8	7.8	0	8.0-8.1	224-264	23.8	8.0-8.2	0
69M122	8.5-8.6	284-397	23.6-23.7	6.7-6.8	0	8.2-8.3	280-360	22.2-22.6	8.0-8.4	0
69M170	8.4-8.5	231-276	23.6-23.7	6.5-6.7	0	8.4-8.5	201-268	22.6-22.9	8.3-8.5	0
69M172	8.1-8.2	244-398	23.6-23.7	6.5-6.6	0	8.4	230-332	22.7-22.8	7.8-8.0	0
69M175	8.1-8.2	194-250	23.6-23.7	6.3-6.5	0	8.3	189-235	22.4-22.8	7.7-7.8	0
69M176	8.1-8.2	203-236	23.4-23.5	6.7-6.8	rep1:5-6	8.2-8.3	204-251	22.6	7.5-7.7	0
69M182	8.1-8.3	370-485	21.3-21.4	7.4-7.7	0	7.9-8.4	394-465	23.5-23.7	7.9-8.0	0
69M192	8.3-8.4	394-454	21.2-21.5	7.6-7.8	0	8.3-8.5	360-414	23.5-23.8	7.9-8.0	0
69M196	8.7	197-250	21.2-21.3	7.8-7.9	0	8.4-8.6	188-244	23.6-23.8	7.9-8.1	0
69M201	8.3-8.5	303-462	21.3-21.4	7.6-8.1	0	7.9-8.0	342-573	23.3-23.5	8.1-8.2	0
69M240	8.4-8.5	202-289	21.0-21.5	7.7-8.1	0	8.1-8.3	205-269	23.4-23.5	8.1-8.2	0
69M241	8.3-8.4	283-329	21.4	7.6-7.9	0	8.0-8.1	267-324	23.4-23.6	7.9-8.1	0
69M242	8.0-8.2	330-377	23.2-23.4	7.6-7.7	0	8.7	335-416	22.4-22.6	7.7-7.8	0
69M243	8.3-8.4	218-229	23.4-23.5	8.1-8.3	0	8.5-8.8	215-241	22.6	7.7-7.9	0
69M244	8.1-8.2	253-347	23.2-23.4	8.1-8.4	0	8.4-8.5	236-328	22.4-22.7	7.6-7.8	0
69M245	8.1-8.2	294-342	23.2-23.3	8.1-8.2	0	8.4-8.5	265-343	22.5-22.6	7.8-8.1	0
6981	8.3-8.5	215-313	23.3-23.4	8.0-8.3	0	8.4-8.5	252-368	22.4-22.6	7.7-8.0	0
6983	8.0-8.3	187-243	22.2-22.4	8.0-8.2	0	8.4-8.5	171-234	22.8	8.0-8.2	0
6984	8.6	275-317	22.2-22.4	7.7-8.1	0	8.2-8.4	271-348	22.2-22.3	8.1-8.3	0
6986	7.9	180-227	22.1-22.4	8.1-8.2	0	8.3-8.4	160-251	22.8-22.9	7.8-8.0	0
6991	7.8-7.9	159-207	22.1-22.3	8.2-8.4	0	8.3-8.4	160-200	22.8-23.0	7.8-7.9	0
6992	8.3	n/a	23.0-23.2	8.2-8.4	0	8.3-8.5	243-310	23.3-23.6	7.9-8.0	0

	Hyalella azteca									
	Day 0					**Day 28**				
Site	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L
69M126	8	225-269	19.9-20.0	8.4-8.5	0	8.4-8.6	240-252	22.1-22.4	7.8-8.2	0
69M52 (479)	8.1	195-228	19.8-20.1	8.4-8.5	0	8.4-8.5	218-262	22.2-22.3	8.1-8.3	0
69M52 (741)	8.0-8.1	210-227	19.8-20.1	8.3-8.4	0	8.3-8.4	196-237	22.3	8.1-8.2	0
69M52 (1090)	7.9-8.0	267-303	19.8-20.1	8.1-8.3	0	8.2-8.3	255-331	21.9-22.0	7.9-8.1	0
69M52 (1535)	8.1-8.3	268-374	21.6-22.0	7.8-7.9	rep4&5: 5	8.2-8.4	199-302	20.8-20.9	8.9	0
6900	8.4-8.5	204-232	21.7-21.8	7.7-8.2	0	8.2-8.5	209-238	23.4-23.6	7.2-7.3	0
6901	8.1-8.2	2.2-269	21.7-21.9	7.9-8.2	0	8.1-8.2	247-330	23.5-23.6	7.0-7.1	0
6902	7.8-7.9	204-216	21.7	7.6-8.0	0	8.0-8.1	212-260	23.2-23.5	6.8-7.0	0
6903	7.8-7.9	214-244	21.6-21.7	7.6-8.2	0	8.0-8.3	242-342	23.2-23.4	6.8-7.2	0
6904	7.8-7.9	204-249	21.7-21.9	7.7-7.8	0	8.2-8.3	218-280	23.1-23.2	6.9-7.1	0
69M122	8.5-8.6	314-407	22.4-22.5	7.5-7.9	0	8.3-8.5	324-372	23.1-23.3	8.4-8.6	0
69M170	8.1-8.4	261-321	21.4-22.4	7.4-7.9	0	8.3-8.5	236-309	23.2-23.4	8.1-8.4	0
69M172	7.8-8.2	278-408	22.4-22.5	7.1-7.6	0	8.3-8.4	265-350	23.2	8.1-8.4	0
69M175	7.7-8.0	229-263	22.2-22.4	7.2-7.5	0	8.2	197-277	23.1-23.2	8.0-81	0
69M176	7.9-8.2	236-277	21.9-22.2	7.2-7.6	rep5: 5-6	8.0-8.1	224-267	23.2-23.3	7.9-8.1	0
69M182	7.9-8.2	400-436	22.5-22.7	7.7-7.9	0	8.1	317-414	22.8-23.0	7.8-8.3	0
69M192	8.2-8.3	358-454	22.8-23.0	7.6-7.7	0	8.2-8.3	264-409	22.8-23.0	7.6-8.0	0
69M196	8.5-8.6	187-275	22.7-23.1	7.9-8.0	0	8.5-8.6	239-263	22.7-22.8	7.6-7.8	0
69M201	8.1-8.3	287-458	22.8-23.0	7.6-7.7	0	8.3-8.5	308-474	22.6-22.9	7.5-7.7	0
69M240	8.2-8.3	201-252	22.6-22.9	7.7-8.2	0	8.3-8.5	186-245	22.0-22.1	7.8-8.0	0
69M241	8.0-8.1	251-337	22.4-22.9	8.1-8.2	0	8.2-8.3	257-347	22.0-22.2	7.5-7.8	0
69M242	7.7-7.9	330-436	23.0-23.4	7.7-8.2	0	8.4-8.5	282-423	23.0-23.4	8.2-8.5	0
69M243	8.1	236-257	23.0-23.7	8.0-8.2	0	8.4-8.5	212-255	23.0-23.4	7.8-8.1	0
69M244	7.7-8.0	292-388	23.0-23.6	8.0-8.2	0	8.3-8.4	270-332	22.8-23.1	7.9-8.0	0
69M245	8.0-8.2	382-393	22.9-23.3	7.8-8.0	0	8.3-8.5	258-337	22.5-22.9	7.8-8.5	0
6981	8.3-8.4	254-339	23.0-23.6	7.8-8.0	0	8.3-8.5	236-348	22.6-22.8	7.7-8.1	0
6983	8.4-8.5	179-250	22.5-22.7	7.5-7.6	0	8.5-8.7	159-295	22.0-22.8	8.1-8.2	0
6984	8.4	411-453	23.0-23.5	8.3-8.7	0	8.4-8.5	363-414	21.5-21.8	7.8-8.3	0
6986	8.3-8.4	201-228	22.3-22.6	7.2-7.3	0	8.4-8.6	98-299	22.3-22.5	8.1-8.2	0
6991	8.2-8.3	170-230	22.4-22.7	7.1-7.2	0	8.3-8.4	179-272	22.3-22.4	7.9-8.1	0
6992	8.1-8.2	203-239	22.6-22.7	6.8-7.1	0	8.1-8.2	169-269	22.2-22.3	8.1-8.2	0

Table D1.   Continued.

	Hexagenia spp.									
	Day 0					Day 21				
Site	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L
69M126	8.1-8.2	300-350	23.1-23.2	8.1-8.3	0	8.3	310-370	23.3	8.4-8.5	0
69M52 (479)	8.2	270-310	23.1-23.3	8.1-8.4	0	8.2-8.3	300-420	23.3	8.3-8.5	0
69M52 (741)	8.1-8.2	300-320	22.9-23.1	8.3-8.4	0	8.2	290-370	23.0-23.1	8.3-8.6	0
69M52 (1090)	8.1-8.2	310-340	22.7-23.3	7.5-8.3	0	8.2	290-360	23.2-23.3	8.4-8.5	0
69M52 (1535)	8.1-8.2	340-360	23.0-23.1	8.2-8.4	0	8.1-8.2	360-390	22.9-23.1	8.2-8.3	0
6900	7.8-7.9	241-273	22.8-23.0	7.8	0	7.9-8.0	252-274	22.3-22.4	8.0-8.1	0
6901	8.5-8.6	298-370	22.8-23.1	8.4-8.5	0	8.1	300-357	23.0-23.1	7.9-8.2	0
6902	8.5-8.6	276-306	22.9-23.1	8.3-8.4	0	8.1	276-301	22.9-23.3	7.5-8.1	0
6903	8.4-8.5	248-348	22.8-23.0	8.1-8.4	0	8.1	236-362	22.9-23.2	7.8-8.0	0
6904	8.3-8.4	272-306	22.5-22.9	8.0-8.4	0	8	263-292	23.0-23.1	7.9-8.2	0
69M122	8.4-8.6	338-442	22.8-23.1	8.7-8.9	0	8.2-8.4	192-226	23.0-23.1	7.9-8.1	0
69M170	8.4-8.6	262-318	22.7-22.9	8.7-8.9	0	8.3-8.5	178-194	22.7-22.9	7.7-8.2	0
69M172	8.3-8.4	326-473	22.4-22.8	8.7-8.8	0	8.3-8.4	218-487	22.4-22.8	7.5-7.9	0
69M175	8.2-8.3	234-338	22.3-22.6	8.7-8.8	0	8.2-8.3	177-200	22.5-22.6	7.9-8.0	0
69M176	8.4-8.6	290-349	22.7-23.0	8.3-8.4	0	8.4-8.5	297-348	21.9-22.3	7.8-8.0	0
69M182	8.3-8.7	442-544	22.9-23.2	8.0-8.3	0	8.0-8.4	472-625	21.5-22.4	7.9-8.0	0
69M192	8.6-8.7	405-437	22.7-22.9	8.1-8.3	0	8.6	442-491	22.2-22.4	8.0-8.2	0
69M196	8.4-8.8	282-382	22.6-22.7	8.2-8.5	0	8.7-8.9	281-390	22.1-22.2	7.9-8.2	0
69M201	7.7-8.3	531-791	22.5-22.7	8.3-8.5	0	8.0-8.3	568-937	22.2-22.4	7.9-8.2	0
69M240	8.0-8.3	295-346	22.7-22.8	8.3-8.5	0	8.1	291-301	22.5-22.9	6.8-8.2	0
69M241	8.0-8.3	318-405	22.5-22.7	8.3-8.4	0	8.0-8.1	298-350	22.6-22.9	8.0-8.3	0
69M242	8.2	n/a	22.5-22.2	8.5-8.6	0	8.1-8.2	450-490	23.0-23.2	8.1-8.3	0
69M243	8.0-8.1	n/a	23.1-23.2	8.3-8.5	0	8.3	330-350	23.0-23.2	7.9-8.4	0
69M244	7.9-8.1	n/a	23.1-23.3	8.5-8.6	0	8.2-8.3	340-410	22.9-23.2	8.0-8.3	0
69M245	8.0-8.1	n/a	22.9-23.2	8.5-8.6	0	8.2	340-400	23.0-23.3	7.9-8.2	0
6981	7.9-8.0	n/a	22.9-23.2	8.2-8.6	0	8.1-8.3	410-550	22.9-23.2	7.7-8.3	0
6983	7.9	224-254	22.6-22.9	7.6-7.9	0	7.8-8.0	322-396	22.5-22.7	7.9-8.2	0
6984	8.6-8.7	235-261	22.9-23.1	8.2-8.4	0	8.2-8.3	252-273	22.9-23.1	7.8-8.0	0
6986	7.6-7.9	226-245	22.7-23.0	7.6-7.9	0	7.8	252-293	22.4-22.5	8.0-8.1	0
6991	7.6-7.8	199-217	22.6-22.9	7.6-7.7	0	7.9	219-238	22.4-22.5	8.2-8.3	0
6992	7.8	223-226	22.5-22.7	7.5-7.7	0	8.1-8.3	216-260	22.3-22.4	7.9-8.0	0

	Tubifex tubifex									
	Day 0					Day 28				
Site	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L	pH	Conductivity (µS/cm)	Temperature (°C)	Dissolved O$_2$ mg/L	Ammonia mg/L
69M126	8.1-8.2	290-364	21.7-21.8	7.6-7.7	0	8.1-8.2	196-265	21.2-21.4	7.8-8.0	0
69M52 (479)	7.8-7.9	230-269	21.7-22.8	7.5-7.7	0	8.1-8.3	109-236	21.2-21.3	8.2-8.8	0
69M52 (741)	7.7-7.8	121-278	21.5-21.6	7.7-7.9	0	7.9-8.2	73-262	21.1-21.3	8.4-8.9	0
69M52 (1090)	8.1-8.2	202-359	21.6-21.9	7.5-7.7	0	7.8-8.2	92-355	21.1	8.2-8.4	0
69M52 (1535)	8.3-8.4	261-380	22.4	7.7-8.1	0	n/a	n/a	n/a	n/a	0
6900	8.1	241-274	21.7-21.8	7.8-8.4	0	8.1-8.2	151-223	21.6-21.9	7.8-7.9	0
6901	7.9-8.0	220-288	21.7-21.8	8.0-8.3	0	7.9-8.0	198-358	21.8-22.1	7.8	0
6902	7.9-8.1	220-259	21.6-22.1	7.8-8.0	0	8.0-8.1	137-285	21.7-22.0	7.7-7.9	0
6903	7.9-8.0	247-276	21.7-21.9	7.9-8.1	0	7.9-8.0	175-232	21.6-22.0	7.8-7.9	0
6904	7.9-8.0	228-292	21.4-21.7	7.6-7.9	rep 1: 7+	7.9	198-224	21.7-21.9	7.7-7.9	0
69M122	8.2-8.4	333-480	21.9-22.0	7.3-7.6	0	8.1-8.2	281-412	23.0-23.1	7.6-7.7	0
69M170	8.3-8.5	151-316	22.0-22.1	8.1-8.3	0	8.4-8.6	124-292	23.0-23.2	7.8-8.0	0
69M172	8.2-8.3	238-459	22.1-22.4	7.5-8.1	0	8.2-8.5	185-290	23.1-23.2	7.5-7.5	0
69M175	8.2-8.3	189-282	22.0-22.1	7.8-7.9	0	8.2-8.4	171-340	23.0-23.2	7.7-7.8	0
69M176	8.1-8.2	209-300	22.0-22.1	7.8-7.9	0	8.2-8.3	168-225	23.1-23.2	7.1-7.4	0
69M182	8.0-8.2	502-593	21.1-21.2	7.8-8.0	0	8.6-8.7	360-489	21.8-22.0	8.1-8.2	0
69M192	8.2-8.3	434-492	21.2-21.3	7.6-7.9	0	8.5-8.6	290-437	21.9-22.0	8.1-8.3	0
69M196	8.3-8.6	286-363	21.0-21.1	7.6-7.7	0	7.8	94-239	21.7-22.0	8.0-8.3	0
69M201	8.1-8.2	426-551	20.9-21.0	7.5-7.8	0	7.4-7.7	220-689	22.0-22.1	7.8-8.3	0
69M240	8.1-8.3	255-419	20.8-20.9	7.4-7.6	0	7.8-7.9	156-187	21.9-22.2	7.6-7.7	0
69M241	8.1-8.3	310-412	20.9-21.1	7.3-7.6	0	8.2-8.5	158-354	22.0-22.1	8.1-8.2	0
69M242	8.0-8.4	341-448	22.7-23.0	7.7-8.0	0	8.1-8.2	366-398	21.7-21.8	7.2-7.6	0
69M243	8.4-8.5	266-328	22.6-22.7	7.9-8.1	0	8.3-8.4	216-297	21.7-21.9	7.5-7.7	0
69M244	8.2-8.3	231-363	22.5-22.6	7.9-8.2	0	8.1-8.2	261-310	21.7-22.0	7.6-7.7	0
69M245	8.1-8.2	372-403	22.6-22.7	7.8-8.0	0	8.1-8.2	212-293	21.4-21.8	7.6-7.8	0
6981	8.4-8.5	260-345	22.6-22.7	7.7-7.8	0	8.0-8.3	178-317	21.6-21.9	7.0-7.4	0
6983	8.5-8.6	336-389	22.0-22.3	7.9-8.1	0	8.1	211-270	21.7-21.8	7.9-8.1	0
6984	7.7-7.9	241-306	22.0-22.5	7.3-7.4	0	7.9-8.1	125-314	22.6-22.9	7.6-7.9	0
6986	7.3-7.9	168-349	21.8-22.1	7.3-7.5	0	8.0-8.2	69-342	22.3-22.6	8.0-8.4	0
6991	7.3-7.7	209-293	21.6-21.8	7.3-7.6	0	7.9-8.0	69-181	22.3-22.5	7.9-8.1	0
6992	7.4-7.6	191-295	21.3-21.7	7.2-7.4	0	7.9-8.0	131-214	22.1-22.4	7.8-8.0	0

APPENDIX E   BEAST Toxicity Ordinations

Figure E1.   Ordination of a subset of test sites using 10 toxicity test endpoints summarized on axes 2 and 3, with 90%, 99%, and 99.9% probability ellipses around reference sites (not shown) indicated. The contributions of maximally correlated endpoint and environmental variable are shown with arrows. [*Chironomus* survival and growth (Crsu, Crgw), *Tubifex* survival, %cocoons hatched and reproduction (Ttsu, Ttht, Ttyg), *Hyalella* survival and growth (Hasu, Hagw), *Hexagenia* survival and growth (Hlsu, Hlgw)]. Stress = 0.111. (Note: sites 6900 and 6986 are in bands 2 and 3, respectively, on alternate axes.)
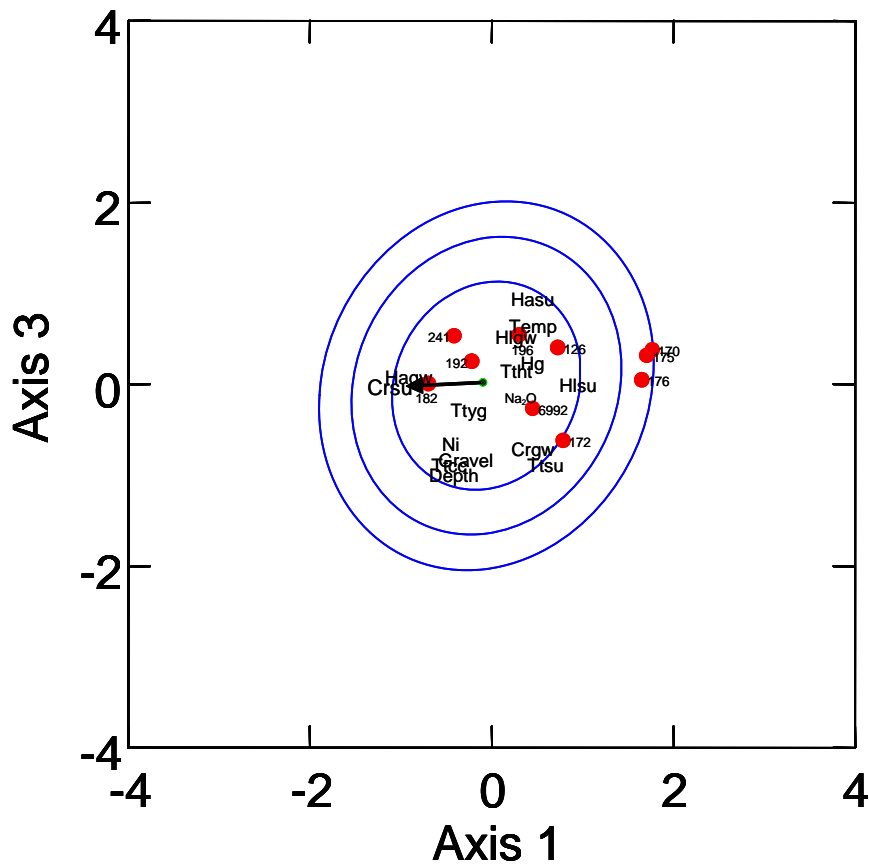
Figure E2.   Ordination of a subset of test sites using 10 toxicity test endpoints summarized on axes 1 and 3, with 90%, 99%, and 99.9% probability ellipses around reference sites (not shown) indicated. The contributions of the maximally correlated endpoint is shown with an arrow. [*Chironomus* survival and growth (Crsu, Crgw), *Tubifex* survival, %cocoons hatched and reproduction (Ttsu, Ttht, Ttyg), *Hyalella* survival and growth (Hasu, Hagw), *Hexagenia* survival and growth (Hlsu, Hlgw)]. Stress = 0.105.
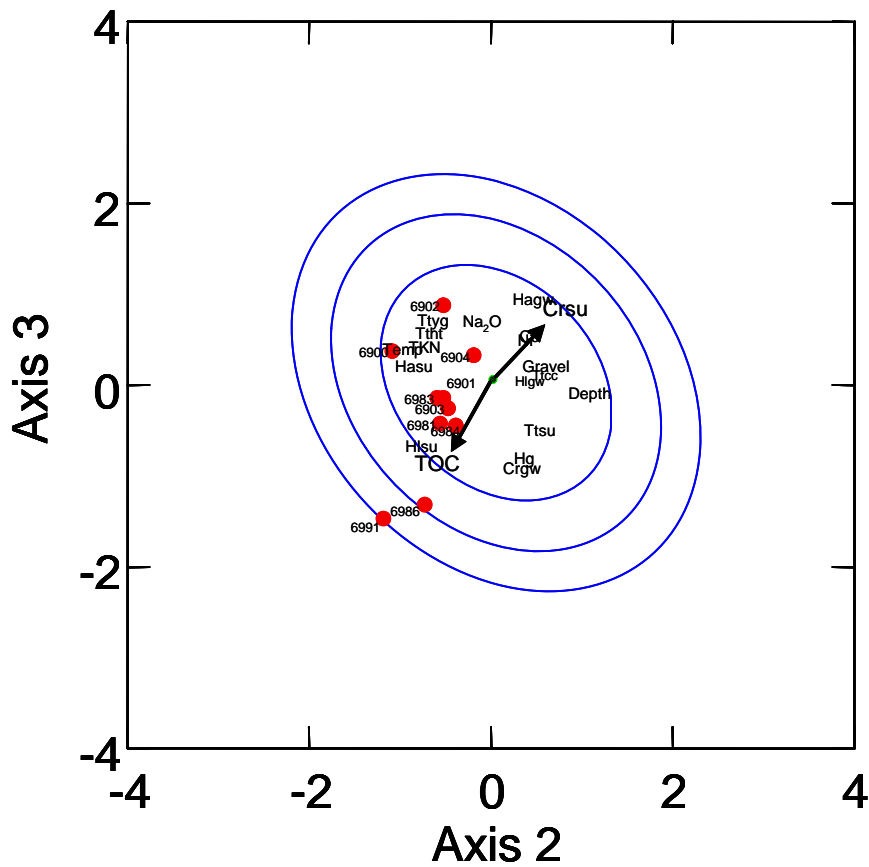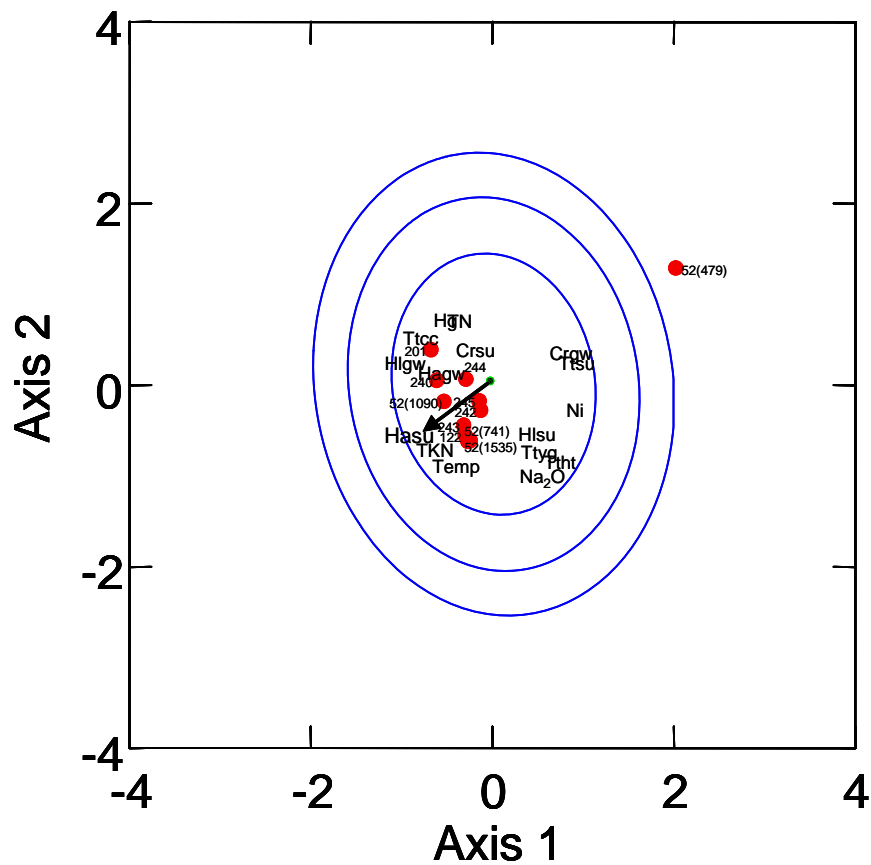
Figure E3.　Ordination of a subset of test sites using 10 toxicity test endpoints summarized on axes 1 and 2, with 90%, 99%, and 99.9% probability ellipses around reference sites (not shown) indicated.　The contributions of maximally correlated endpoints are shown with arrows. [*Chironomus* survival and growth (Crsu, Crgw), *Tubifex* survival, %cocoons hatched and reproduction (Ttsu, Ttht, Ttyg), *Hyalella* survival and growth (Hasu, Hagw), *Hexagenia* survival and growth (Hlsu, Hlgw)]. Stress = 0.105. (Note: sites 52-741 and 52-1535 are located in Band 2 on Axis 3.)

APPENDIX F   Toxicity-Contaminant Relationships
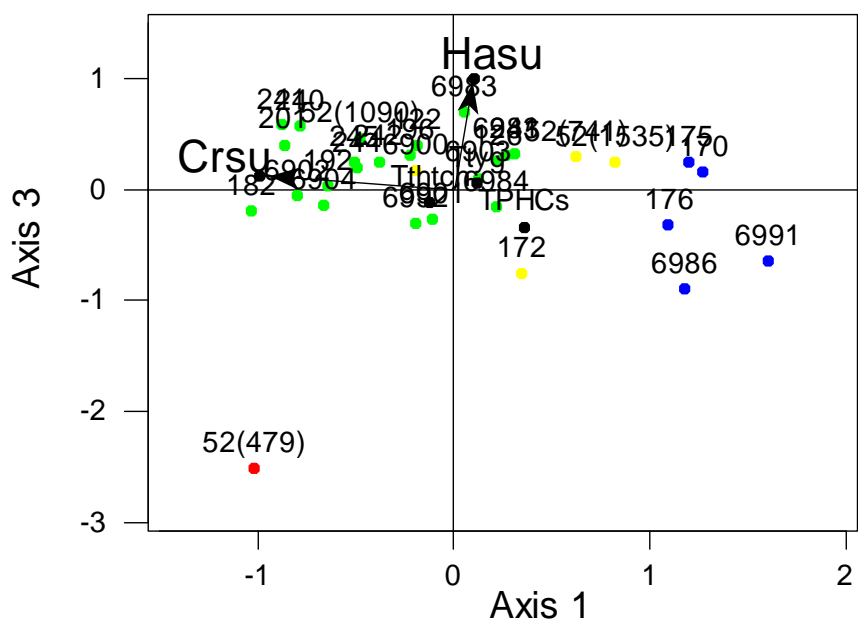
Figure F1.   Toxicological response of St. Marys River sites represented by 3-dimensional HMDS (stress = 0.05). The directions of maximum correlations of endpoints and environmental variables with sites are shown as vectors. Sites are colour-coded by toxicity class as determined by BEAST assessment with reference sites (green = non-toxic, yellow = potentially toxic, blue = toxic, red = severely toxic). [TPHCs = total petroleum hydrocarbons, Crsu = *Chironomus* survival, Hasu = *Hyalella* survival].
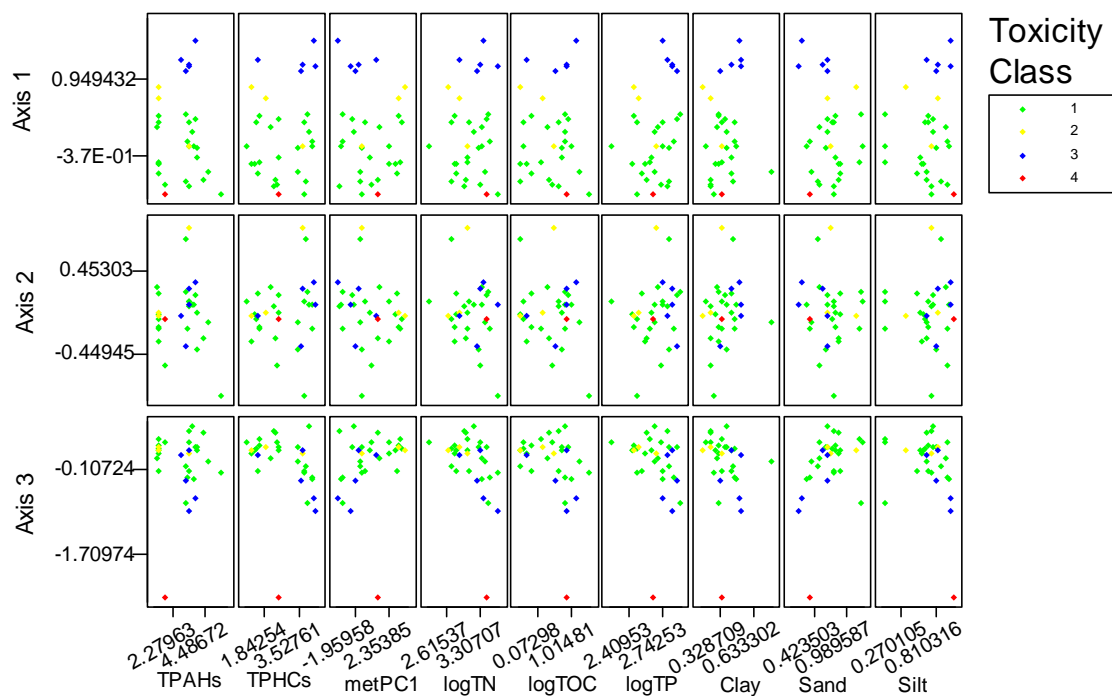
Figure F2.   St. Marys River sediment toxicity relationships to contaminant concentrations based on integrated descriptors. High values for Axis 1 correspond to sites with high relative toxicity to *Chironomus* survival (see text for derivation of variables). Low values for Axis 3 corresponds to sites with high relative toxicity to *Hyalella* survival. Sites are colour-coded by toxicity class as determined by BEAST assessment with reference sites.

Figure F3.   St. Marys River sediment toxicity relationships to contaminant concentrations based on individual toxicity endpoint and integrated metal and organic contaminant descriptors (see text for derivation of variables). Sites are colour-coded by toxicity class as determined by BEAST assessment with reference sites.
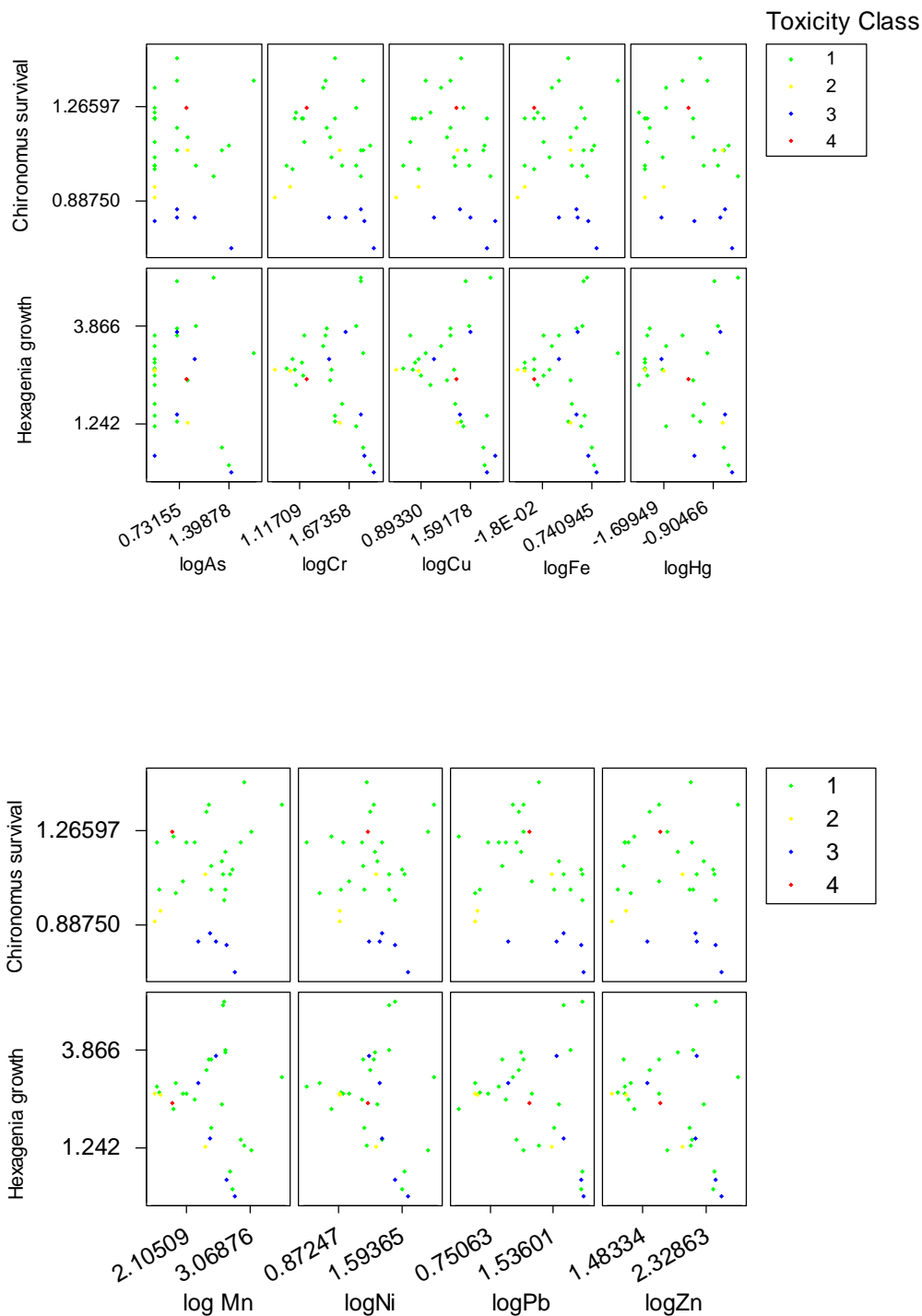
Figure F4.   St. Marys River sediment toxicity relationships to contaminant concentrations based on individual toxicity endpoint and individual metal concentrations (see text for derivation of variables). Sites are colour-coded by toxicity class as determined by BEAST assessment with reference sites.
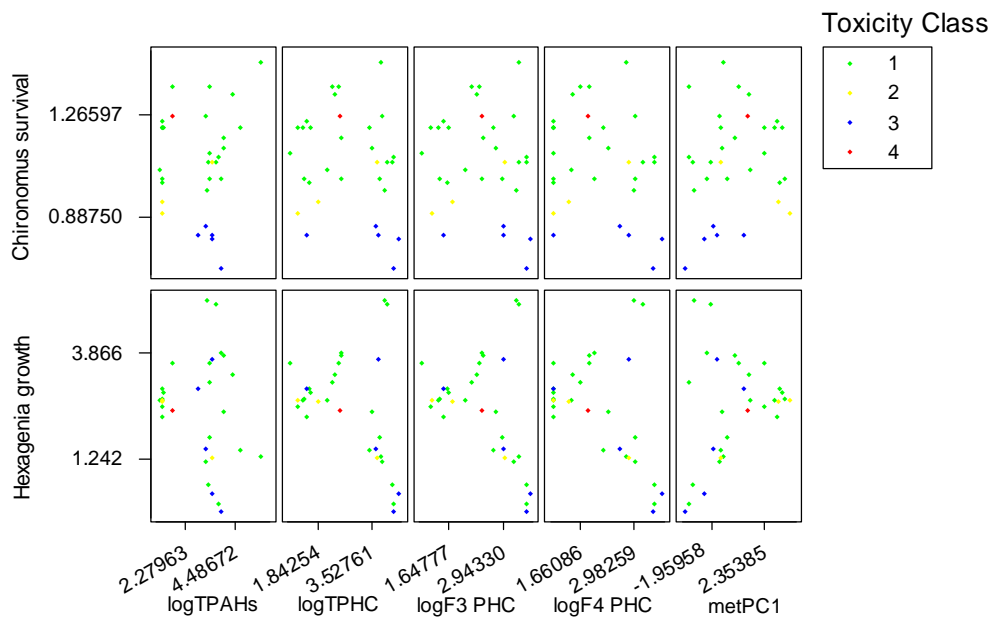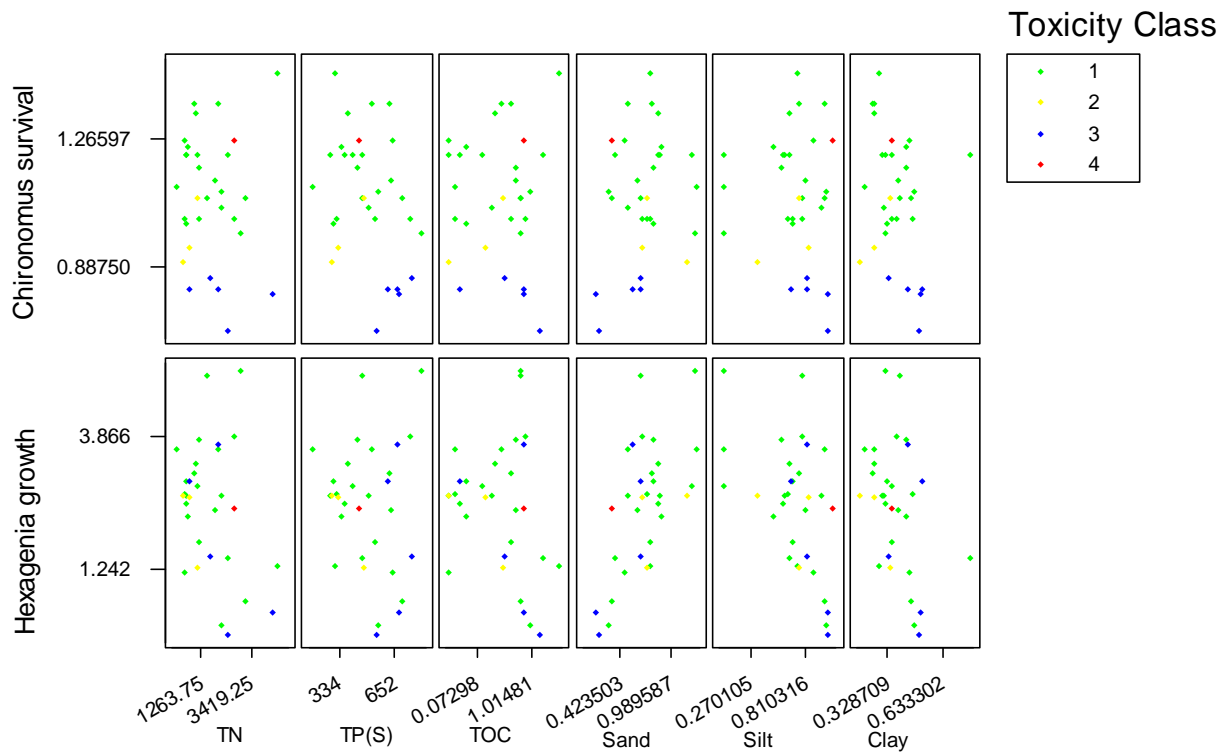
Figure F5.   St. Marys River sediment toxicity relationships to contaminant concentrations based on individual toxicity endpoint and sediment nutrient concentrations and particle size (see text for derivation of variables). Sites are colour-coded by toxicity class as determined by BEAST assessment with reference sites.

APPENDIX G   **Quality Assurance/Quality Control**

Table G1.   Coefficient of variation (%) for measured analytes for field-replicated sites.

Parameter	Coefficient of Variation (%)		
	126	176	196
Al (%)	5.2	1.8	4.4
Al_2O_3 (%)	2.4	0.2	1.7
Alkalinity (mg/L)	0.9	0.7	0.5
Ba (ppm)	5.9	5.6	3.3
BaO (%)	2.7	0.5	1.0
Ca (%)	4.1	8.1	3.5
Clay (%)	92.2	9.6	10.3
Co (ppm)	50.8	21.6	25.7
Cr (ppm)	29.6	12.3	16.0
Cr_2O_3 (%)	66.8	6.6	19.6
Cu (ppm)	5.2	5.1	4.5
Fe (%)	4.7	5.2	3.4
Fe_2O_3 (%)	9.6	1.8	0.2
Hg (ppm)	43.9	16.0	49.3
K (%)	23.7	31.9	24.1
K_2O (%)	7.8	1.6	3.3
Li (ppm)	10.4	18.7	5.1
LOI (%)	3.5	3.6	3.2
Mg (%)	14.4	3.2	2.3
MgO (%)	8.8	0.6	1.7
Mn (ppm)	3.7	4.3	2.0
MnO (%)	4.8	7.4	6.4
Na (%)	15.3	26.9	24.2
Na_2O (%)	3.6	0.6	3.1
NH_3 (mg/L)	35.7	14.9	17.6
Ni (ppm)	18.9	27.4	21.8
No_3/No_2 (mg/L)	2.0	2.0	0.4
P_2O_5 (%)	17.0	3.2	4.5
Pb (ppm)	61.4	6.9	4.9
Sand (%)	67.3	3.0	21.2
Silt (%)	104.5	3.5	8.6
SiO_2 (%)	0.5	1.0	1.0
Sr (ppm)	7.7	6.1	6.5
Ti (ppm)	5.8	3.3	7.7
TiO_2 (%)	10.6	1.7	1.8
Total Kjeldahl N (mg/L)	14.9	3.1	1.2
Total N (ppm)	9.6	14.3	20.4
Total Organic C (%)	20.0	1.6	6.0
Total P(Sediment) (ppm)	5.9	16.3	18.5
Total P(Water) (mg/L)	25.8	10.8	10.5
V (ppm)	2.4	1.6	3.2
Y (ppm)	8.2	2.6	4.6
Zn (ppm)	3.7	3.1	5.3
Mean (%)	**19.6**	**7.5**	**8.9**
Min (%)	**0.5**	**0.2**	**0.2**
Max (%)	**104.5**	**31.9**	**49.3**

Table G2. Relative percent difference for laboratory repeats and percent recovery for reference material.

Laboratory Repeats						
	Site 170			**Site 201**		
Analyte	**Concn 1**	**Concn 2**	**RPD**	**Concn 1**	**Concn 2**	**RPD**
Ag	<0.5	<0.5		<0.5	<0.5	
Al	0.81	0.89	5.9	0.60	0.53	7.8
Al	8122	8869	5.9	6004	5324	7.8
As	9	8	7.3	5	5	0.0
Ba	50	53	4.5	46	43	4.4
Be	0.4	0.4	3.5	0.5	0.4	5.4
Bi	<5	<5		<5	<5	
Ca	0.36	0.38	2.9	0.43	0.37	8.6
Ca	3606	3763	2.9	4275	3748	8.6
Cd	<1	<1		<1	<1	
Co	8	10	15.4	6	<1	
Cr	28	28	0.3	25	22	7.5
Cu	12	12	1.9	21	21	0.4
Fe	1.71	1.76	1.9	1.70	1.55	5.9
Fe	17113	17611	1.9	17001	15543	5.9
K	0.18	0.19	4.6	0.15	0.14	8.0
K	1795	1922	4.6	1533	1357	8.0
Li	10	11	1.4	8	6	17.8
Mg	0.43	0.45	2.9	0.31	0.28	6.6
Mg	4350	4541	2.9	3073	2779	6.6
Mn	187	195	2.8	274	256	4.4
Mo	<1	<1		<1	<1	
Na	0.03	0.03	6.4	0.03	0.03	10.2
Na	279	307	6.4	317	271	10.2
Nb	<5	<5		<5	<5	
Ni	22	23	1.4	19	19	0.1
Pb	9	8	6.3	15	10	26.8
Sb	<5	<5		<5	<5	
Sn	<20	<20		<20	<20	
Sr	12	14	9.5	18	16	7.9
Ti	719	821	9.0	599	508	10.7
V	33	33	0.5	30	26	7.5
W	<20	<20		<20	<20	
Y	8	8	3.0	8	7	4.0
Zn	34	35	1.6	49	47	2.3
Aluminum	9.99	10.43	2.9	8.95	9.20	1.8
Barium	0.062	0.064	1.8	0.060	0.061	0.6
Calcium	1.79	1.74	1.9	1.68	1.73	1.6
Chromium	0.01	0.01	1.3	0.01	0.01	6.9
Iron	3.48	3.48	0.1	3.40	3.55	2.9
Potassium	3.09	3.08	0.2	2.47	2.43	1.0
Magnesium	1.21	1.21	0.5	0.91	0.95	3.2
Manganese	0.04	0.04	2.6	0.05	0.06	3.4
Sodium	1.80	1.96	5.6	1.75	1.86	4.2
Phosphorus	0.20	0.20	1.3	0.21	0.23	5.3
Silicon	74.64	75.30	0.6	74.18	74.83	0.6
Titanium	0.49	0.48	1.7	0.48	0.50	1.7
LOI	3.10	3.06	0.9	7.45	7.55	0.9
Whole Rock	99.84	100.97	0.8	100.62	101.92	0.9

Overall RPD mean   4.9

Laboratory Repeats									
	Site 244			**Site 52(1090)**			**Site 122**		
Analyte	**Concn 1**	**Concn 2**	**RPD**	**Concn 1**	**Concn 2**	**RPD**	**Concn 1**	**Concn 2**	**RPD**
Total P	366	420	9.4	-	-				
Total N	590	652	6.8	-	-				
TOC	-	-		1.5	1.4	4.5	0.50	0.30	30.8

Laboratory Repeats		
	Site 176	
Analyte	**Concn 1**	**Concn 2**	**RPD**
Hg	0.17	0.17	0.0

Reference Material - % Recovery		
Analyte	**LKSD-3/SO-2**	**LKSD-4/SO-2**
As	108	127
Cd	100	100
Co	93	100
Cu	94	90
Fe	89	94
Mn	101	97
Ni	102	
Pb	89	105
V	91	100
Zn	94	96
Aluminum	99	99
Barium	100	100
Calcium	105	101
Chromium	100	100
Iron	100	96
Potassium	98	97
Magnesium	100	97
Manganese	100	111
Sodium	99	98
Phosphorus	111	107
Silicon	98	102
Titanium	94	87
Loss on Ignition	98	98
Mean	**99**	
Range	**89 - 127**	

RPD = Relative Percent Difference

$$RPD = \frac{(x_1 - x_2)}{((x_1 + x_2)/2)} \times 100$$

Table G3. Quality control results for PHC analysis.

QA/QC Batch No.	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
699089	BMO	RPD	Moisture	3/9/2005	1.3		%	50
699250	SR	MATRIX SPIKE	o-Terphenyl	3/10/2005		103	%	65 - 135
			F2 (C10-C16 Hydrocarbons)	3/10/2005		96	%	65 - 135
			F3 (C16-C34 Hydrocarbons)	3/10/2005		96	%	65 - 135
			F4 (C34-C50 Hydrocarbons)	3/10/2005		96	%	65 - 135
			Reached Baseline at C50	3/10/2005		NO	%	N/A
		Spiked Blank	o-Terphenyl	3/10/2005		114	%	65 - 135
			F2 (C10-C16 Hydrocarbons)	3/10/2005		89	%	65 - 135
			F3 (C16-C34 Hydrocarbons)	3/10/2005		89	%	65 - 135
			F4 (C34-C50 Hydrocarbons)	3/10/2005		89	%	65 - 135
			Reached Baseline at C50	3/10/2005		YES	%	N/A
		Method Blank	o-Terphenyl	3/10/2005		117	%	65 - 135
			F2 (C10-C16 Hydrocarbons)	3/10/2005	ND	DL=10	ug/g	
			F3 (C16-C34 Hydrocarbons)	3/10/2005	ND	DL=10	ug/g	
			F4 (C34-C50 Hydrocarbons)	3/10/2005	ND	DL=10	ug/g	
			Reached Baseline at C50	3/10/2005	YES	DL=0	ug/g	
		RPD	F2 (C10-C16 Hydrocarbons)	3/10/2005	9		%	50
			F3 (C16-C34 Hydrocarbons)	3/10/2005	7.3		%	50
			F4 (C34-C50 Hydrocarbons)	3/10/2005	1.1		%	50
			Reached Baseline at C50	3/10/2005	NC		%	50
699251	SR	MATRIX SPIKE	o-Terphenyl	3/10/2005		90	%	65 - 135
			F2 (C10-C16 Hydrocarbons)	3/10/2005		85	%	65 - 135
			F3 (C16-C34 Hydrocarbons)	3/10/2005		85	%	65 - 135
			F4 (C34-C50 Hydrocarbons)	3/10/2005		85	%	65 - 135
			Reached Baseline at C50	3/10/2005		YES	%	N/A
		Spiked Blank	o-Terphenyl	3/10/2005		110	%	65 - 135
			F2 (C10-C16 Hydrocarbons)	3/10/2005		84	%	65 - 135
			F3 (C16-C34 Hydrocarbons)	3/10/2005		84	%	65 - 135
			F4 (C34-C50 Hydrocarbons)	3/10/2005		84	%	65 - 135
			Reached Baseline at C50	3/10/2005		YES	%	N/A
		Method Blank	o-Terphenyl	3/10/2005		113	%	65 - 135
			F2 (C10-C16 Hydrocarbons)	3/10/2005	ND	DL=10	ug/g	
			F3 (C16-C34 Hydrocarbons)	3/10/2005	ND	DL=10	ug/g	
			F4 (C34-C50 Hydrocarbons)	3/10/2005	ND	DL=10	ug/g	
			Reached Baseline at C50	3/10/2005	YES	DL=0	ug/g	
		RPD	F2 (C10-C16 Hydrocarbons)	3/10/2005	NC		%	50
			F3 (C16-C34 Hydrocarbons)	3/10/2005	6.1		%	50
			F4 (C34-C50 Hydrocarbons)	3/10/2005	NC		%	50
			Reached Baseline at C50	3/10/2005	NC		%	50
699276	NGN	MATRIX SPIKE	Benzene	3/9/2005		90	%	80 - 120
			Toluene	3/9/2005		109	%	80 - 120
			Ethylbenzene	3/9/2005		104	%	80 - 120
			o-Xylene	3/9/2005		97	%	80 - 120
			p+m-Xylene	3/9/2005		106	%	80 - 120
			F1 (C6-C10)	3/9/2005		101	%	80 - 120
		Spiked Blank	Benzene	3/9/2005		85	%	65 - 135
			Toluene	3/9/2005		85	%	65 - 135
			Ethylbenzene	3/9/2005		94	%	65 - 135
			o-Xylene	3/9/2005		82	%	65 - 135
			p+m-Xylene	3/9/2005		84	%	65 - 135
			F1 (C6-C10)	3/9/2005		73	%	65 - 135

QA/QC Batch No.	Init	QC Type	Parameter	Date Analyzed yyyy/mm/dd	Value	Recovery	Units	QC Limits
		Method Blank	Benzene	3/9/2005	ND	DL=0.02	ug/g	
			Toluene	3/9/2005	ND	DL=0.02	ug/g	
			Ethylbenzene	3/9/2005	ND	DL=0.02	ug/g	
			o-Xylene	3/9/2005	ND	DL=0.02	ug/g	
			p+m-Xylene	3/9/2005	ND	DL=0.04	ug/g	
			Total Xylenes	3/9/2005	ND	DL=0.04	ug/g	
			F1 (C6-C10)	3/9/2005	ND	DL=10	ug/g	
			F1 (C6-C10) - BTEX	3/9/2005	ND	DL=10	ug/g	
		RPD	Benzene	3/9/2005	NC		%	20
			Toluene	3/9/2005	NC		%	20
			Ethylbenzene	3/9/2005	NC		%	20
			o-Xylene	3/9/2005	NC		%	20
			p+m-Xylene	3/9/2005	NC		%	20
			Total Xylenes	3/9/2005	NC		%	N/A
			F1 (C6-C10)	3/9/2005	NC		%	N/A
			F1 (C6-C10) - BTEX	3/9/2005	NC		%	N/A
699587	NGN	MATRIX SPIKE	Benzene	3/12/2005		85	%	80 - 120
			Toluene	3/12/2005		92	%	80 - 120
			Ethylbenzene	3/12/2005		94	%	80 - 120
			o-Xylene	3/12/2005		78	%	80 - 120
			p+m-Xylene	3/12/2005		95	%	80 - 120
			F1 (C6-C10)	3/12/2005		89	%	80 - 120
		Spiked Blank	Benzene	3/12/2005		64	%	65 - 135
			Toluene	3/12/2005		70	%	65 - 135
			Ethylbenzene	3/12/2005		70	%	65 - 135
			o-Xylene	3/12/2005		66	%	65 - 135
			p+m-Xylene	3/12/2005		73	%	65 - 135
			F1 (C6-C10)	3/12/2005		76	%	65 - 135
		Method Blank	Benzene	3/12/2005	ND	DL=0.02	ug/g	
			Toluene	3/12/2005	ND	DL=0.02	ug/g	
			Ethylbenzene	3/12/2005	ND	DL=0.02	ug/g	
			o-Xylene	3/12/2005	ND	DL=0.02	ug/g	
			p+m-Xylene	3/12/2005	ND	DL=0.04	ug/g	
			Total Xylenes	3/12/2005	ND	DL=0.04	ug/g	
			F1 (C6-C10)	3/12/2005	ND	DL=10	ug/g	
			F1 (C6-C10) - BTEX	3/12/2005	ND	DL=10	ug/g	
		RPD	Benzene	3/12/2005	NC		%	20
			Toluene	3/12/2005	NC		%	20
			Ethylbenzene	3/12/2005	NC		%	20
			o-Xylene	3/12/2005	NC		%	20
			p+m-Xylene	3/12/2005	NC		%	20
			Total Xylenes	3/12/2005	NC		%	N/A
			F1 (C6-C10)	3/12/2005	NC		%	N/A
			F1 (C6-C10) - BTEX	3/12/2005	NC		%	N/A
701035	DTI	RPD	F4G (Heavy Hydrocarbons)	3/15/2005	5.4		%	50
		Spiked Blank	F4G (Heavy Hydrocarbons)	3/15/2005		72	%	65 - 135
		Method Blank	F4G (Heavy Hydrocarbons)	3/15/2005	ND	DL=100	ug/g	

ND = Not detected
N/A = Not Applicable
NC = Non-calculable
RPD = Relative Percent Difference
SPIKE = Fortified sample

Table G4.   Quality control results for PAH and TOC analysis.

Batch No.	Init	QC Type	Parameter	Value	Recovery	Units	QC Limits
701554	BMO	RPD	Moisture	2.3		%	50
701957	MGH	QC STANDARD	Total Organic Carbon (TOC)		100	%	85 - 115
		Spiked Blank	Total Organic Carbon (TOC)		100	%	75 - 125
		Method Blank	Total Organic Carbon (TOC)	ND	DL=300	ug/g	
		RPD	Total Organic Carbon (TOC)	1		%	35
701960	MGH	QC STANDARD	Total Organic Carbon (TOC)		102	%	85 - 115
		Spiked Blank	Total Organic Carbon (TOC)		102	%	75 - 125
		Method Blank	Total Organic Carbon (TOC)	ND	DL=300	ug/g	
		RPD	Total Organic Carbon (TOC)	0.06		%	35
701962	MGH	MATRIX SPIKE	Total Organic Carbon (TOC)		NA	%	75 - 125
		QC STANDARD	Total Organic Carbon (TOC)		101	%	85 - 115
		Spiked Blank	Total Organic Carbon (TOC)		101	%	75 - 125
		Method Blank	Total Organic Carbon (TOC)	ND	DL=300	ug/g	
		RPD	Total Organic Carbon (TOC)	1.6		%	35
702122	YZ	MATRIX SPIKE	2-Fluorobiphenyl		59	%	40 - 130
			D14-Terphenyl		83	%	40 - 130
			D5-Nitrobenzene		41	%	40 - 130
			Naphthalene		30	%	40 - 140
			Acenaphthylene		72	%	40 - 140
			Acenaphthene		70	%	40 - 140
			Fluorene		76	%	40 - 140
			Phenanthrene		103	%	40 - 140
			Anthracene		93	%	40 - 140
			Fluoranthene		92	%	40 - 140
			Pyrene		91	%	40 - 140
			Benzo(a)anthracene		92	%	40 - 140
			Chrysene		92	%	40 - 140
			Benzo(b)fluoranthene		89	%	40 - 140
			Benzo(k)fluoranthene		99	%	40 - 140
			Benzo(a)pyrene		88	%	40 - 140
			Indeno(1,2,3-cd)pyrene		89	%	40 - 140
			Dibenzo(a,h)anthracene		85	%	40 - 140
			Benzo(ghi)perylene		90	%	40 - 140
		Spiked Blank	2-Fluorobiphenyl		66	%	40 - 130
			D14-Terphenyl		80	%	40 - 130
			D5-Nitrobenzene		59	%	40 - 130
			Naphthalene		70	%	40 - 140
		RPD	Naphthalene	14.3		%	50
		Spiked Blank	Acenaphthylene		81	%	40 - 140
		RPD	Acenaphthylene	8.3		%	50
		Spiked Blank	Acenaphthene		79	%	40 - 140
		RPD	Acenaphthene	8.8		%	50
		Spiked Blank	Fluorene		85	%	40 - 140
		RPD	Fluorene	6		%	50
		Spiked Blank	Phenanthrene		88	%	40 - 140
		RPD	Phenanthrene	3.8		%	50
		Spiked Blank	Anthracene		89	%	40 - 140
		RPD	Anthracene	4.1		%	50
		Spiked Blank	Fluoranthene		94	%	40 - 140
		RPD	Fluoranthene	4.6		%	50
		Spiked Blank	Pyrene		94	%	40 - 140
		RPD	Pyrene	5		%	50
		Spiked Blank	Benzo(a)anthracene		99	%	40 - 140
		RPD	Benzo(a)anthracene	4.1		%	50
		Spiked Blank	Chrysene		91	%	40 - 140
		RPD	Chrysene	5.1		%	50
		Spiked Blank	Benzo(b)fluoranthene		104	%	40 - 140
		RPD	Benzo(b)fluoranthene	8.6		%	50
		Spiked Blank	Benzo(k)fluoranthene		98	%	40 - 140
		RPD	Benzo(k)fluoranthene	5.6		%	50
		Spiked Blank	Benzo(a)pyrene		102	%	40 - 140
		RPD	Benzo(a)pyrene	6.3		%	50
		Spiked Blank	Indeno(1,2,3-cd)pyrene		95	%	40 - 140
		RPD	Indeno(1,2,3-cd)pyrene	NC		%	50
		Spiked Blank	Dibenzo(a,h)anthracene		109	%	40 - 140
		RPD	Dibenzo(a,h)anthracene	2		%	50
		Spiked Blank	Benzo(ghi)perylene		98	%	40 - 140
		RPD	Benzo(ghi)perylene	NC		%	50
		Method Blank	2-Fluorobiphenyl		70	%	40 - 130
			D14-Terphenyl		78	%	40 - 130
			D5-Nitrobenzene		63	%	40 - 130
			Naphthalene	ND	DL=5	ug/Kg	
			Acenaphthylene	ND	DL=5	ug/Kg	
			Acenaphthene	ND	DL=10	ug/Kg	
			Fluorene	ND	DL=5	ug/Kg	
			Phenanthrene	ND	DL=5	ug/Kg	
			Anthracene	ND	DL=5	ug/Kg	
			Fluoranthene	ND	DL=5	ug/Kg	
			Pyrene	ND	DL=5	ug/Kg	
			Benzo(a)anthracene	ND	DL=10	ug/Kg	
			Chrysene	ND	DL=10	ug/Kg	
			Benzo(b)fluoranthene	ND	DL=10	ug/Kg	
			Benzo(k)fluoranthene	ND	DL=10	ug/Kg	
			Benzo(a)pyrene	ND	DL=5	ug/Kg	
			Indeno(1,2,3-cd)pyrene	ND	DL=20	ug/Kg	
			Dibenzo(a,h)anthracene	ND	DL=20	ug/Kg	
			Benzo(ghi)perylene	ND	DL=20	ug/Kg	
702307	YZ	MATRIX SPIKE	2-Fluorobiphenyl		67	%	40 - 130
			D14-Terphenyl		79	%	40 - 130
			D5-Nitrobenzene		65	%	40 - 130
			Naphthalene		!!31	%	40 - 140
			Acenaphthylene		71	%	40 - 140
			Acenaphthene		67	%	40 - 140
			Fluorene		71	%	40 - 140
			Phenanthrene		!!35	%	40 - 140
			Anthracene		70	%	40 - 140
			Fluoranthene		!!18	%	40 - 140
			Pyrene		!!28	%	40 - 140
			Benzo(a)anthracene		40	%	40 - 140
			Chrysene		49	%	40 - 140
			Benzo(b)fluoranthene		63	%	40 - 140
			Benzo(k)fluoranthene		45	%	40 - 140
			Benzo(a)pyrene		!!34	%	40 - 140
			Indeno(1,2,3-cd)pyrene		49	%	40 - 140
			Dibenzo(a,h)anthracene		62	%	40 - 140
			Benzo(ghi)perylene		44	%	40 - 140
		Spiked Blank	2-Fluorobiphenyl		68	%	40 - 130
			D14-Terphenyl		74	%	40 - 130
			D5-Nitrobenzene		64	%	40 - 130
			Naphthalene		78	%	40 - 140
		RPD	Naphthalene	0.9		%	50
		Spiked Blank	Acenaphthylene		80	%	40 - 140
		RPD	Acenaphthylene	0.7		%	50
		Spiked Blank	Acenaphthene		79	%	40 - 140
		RPD	Acenaphthene	1		%	50
		Spiked Blank	Fluorene		85	%	40 - 140
		RPD	Fluorene	3.9		%	50
		Spiked Blank	Phenanthrene		88	%	40 - 140
		RPD	Phenanthrene	3		%	50
		Spiked Blank	Anthracene		90	%	40 - 140
		RPD	Anthracene	1.8		%	50
		Spiked Blank	Fluoranthene		93	%	40 - 140
		RPD	Fluoranthene	2.3		%	50
		Spiked Blank	Pyrene		90	%	40 - 140
		RPD	Pyrene	5.6		%	50
		Spiked Blank	Benzo(a)anthracene		90	%	40 - 140
		RPD	Benzo(a)anthracene	1.6		%	50
		Spiked Blank	Chrysene		91	%	40 - 140
		RPD	Chrysene	5.8		%	50
		Spiked Blank	Benzo(b)fluoranthene		95	%	40 - 140
		RPD	Benzo(b)fluoranthene	1.2		%	50
		Spiked Blank	Benzo(k)fluoranthene		73	%	40 - 140
		RPD	Benzo(k)fluoranthene	6.8		%	50
		Spiked Blank	Benzo(a)pyrene		91	%	40 - 140
		RPD	Benzo(a)pyrene	3.3		%	50
		Spiked Blank	Indeno(1,2,3-cd)pyrene		97	%	40 - 140
		RPD	Indeno(1,2,3-cd)pyrene	NC		%	50
		Spiked Blank	Dibenzo(a,h)anthracene		93	%	40 - 140
		RPD	Dibenzo(a,h)anthracene	NC		%	50
		Spiked Blank	Benzo(ghi)perylene		88	%	40 - 140
		RPD	Benzo(ghi)perylene	NC		%	50
		Method Blank	2-Fluorobiphenyl		64	%	40 - 130
			D14-Terphenyl		67	%	40 - 130
			D5-Nitrobenzene		60	%	40 - 130
			Naphthalene	ND	DL=5	ug/Kg	
			Acenaphthylene	ND	DL=5	ug/Kg	
			Acenaphthene	ND	DL=10	ug/Kg	
			Fluorene	ND	DL=5	ug/Kg	
			Phenanthrene	ND	DL=5	ug/Kg	
			Anthracene	ND	DL=5	ug/Kg	
			Fluoranthene	ND	DL=5	ug/Kg	
			Pyrene	ND	DL=5	ug/Kg	
			Benzo(a)anthracene	ND	DL=10	ug/Kg	
			Chrysene	ND	DL=10	ug/Kg	
			Benzo(b)fluoranthene	ND	DL=10	ug/Kg	
			Benzo(k)fluoranthene	ND	DL=10	ug/Kg	
			Benzo(a)pyrene	ND	DL=5	ug/Kg	
			Indeno(1,2,3-cd)pyrene	ND	DL=20	ug/Kg	
			Dibenzo(a,h)anthracene	ND	DL=20	ug/Kg	
			Benzo(ghi)perylene	ND	DL=20	ug/Kg	

ND = Not detected
NC = Non-calculable
RPD = Relative Percent Difference
QC Standard = Quality Control Standard
SPIKE = Fortified sample