LABORATORY SEDIMENT

TOXICITY TEST REPORT ON

LAKE GEORGE AND LITTLE LAKE GEORGE – ST. MARY'S RIVER AREA OF CONCERN

2005

Technical Memorandum

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SUMMARY

Lake George and Little Lake George sediments (St. Mary's Area of Concern (AOC)), collected in 2005, were assessed in the laboratory for toxicity to *Hyalella azteca, Chironomus tentans,* and *Hexagenia spp.* This was done as a follow up to previous studies done by the Ontario Ministry of the Environment and Environment Canada which revealed toxicity in exposures to sediment from this AOC.

Provincial sediment quality guideline (PSQGs) lowest effect levels (LELs) were exceeded for some metals (cadmium, chromium, copper, iron, nickel, lead, zinc and/or manganese) in all of the Lake George and Little Lake George sediments with the exception of Mid-Lake George (LG248). Upper Lake George (LG231) had the highest concentrations. The LELs for the polycyclic aromatic hydrocarbons (PAH) benzo(g,h,i)perylene and ideno(1,2,3-c,d)pyrene were exceeded in Upper (LG231) and Lower (LG249) Lake George. Growth of *H. azteca* exposed to Upper Lake George (LG231) sediments had significantly reduced survival however; the cause of this reduction is not clear since there was no significant correlation between *H. azteca* growth and contaminant concentrations. The average survival of *C. tentans* was impaired in this sediment as well and the correlation between *C. tentans* survival and oils and greases in the sediment (F3 fraction) was significant. However, due to variability across replicates it is difficult to interpret these results. The average wet weight of *Hexagenia spp.* exposed to Lower Lake George (LG249) was significantly lower than those exposed to the control sediment and there was a strong negative correlation between *Hexagenia spp.* growth and sediment lead concentration.

Results of laboratory tests should always be compared to field studies for full assessment of sediment impairment.

ACKNOWLEDGEMENTS

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1.0 INTRODUCTION

Lake George and Little Lake George are part of the St. Mary's Area of Concern (AOC) downstream of Sault Ste. Marie, Ontario. The lakes are depositional areas and receive contaminants from municipal and major industrial sources (including Algoma Steel and St. Marys Paper) located on the St. Mary's River (George, 2005). Historically Lake George and Little Lake George sediments were contaminated with iron, zinc, lead, manganese, cadmium, nickel, copper, chromium, arsenic, PCBs and oil and grease (George 2005). A sediment and benthic study by Krauss and Nettleton (2000) demonstrated a decreasing trend (1985, 1987 and 1989 collections) in sediment contamination in both lakes. In addition, laboratory toxicity studies were performed on St. Mary's River sediments in 1992 and 1995 and revealed some toxicity due to total petroleum hydrocarbon sediment concentrations and in some cases, unsuitable habitat due to wood fibres (Bedard and Petro 1997). However Milani and Grapentine (2002) conducted a study in 2002 and found that the Ontario Provincial Sediment Quality Guideline (PSQG) Severe Effect Level (SEL) (Persaud *et al*. 1993) was exceeded for iron and manganese at the mouth of Little Lake George and for nickel at the Little Lake George outlet. Milani and Grapentine's (2002) study did not find Little Lake George sediment (mouth and outlet) to be toxic.

The purpose of the study presented here (2005) was to assess the toxicity of Lake George/Little Lake George sediments to benthic invertebrates tested in the laboratory. The results of this study will be used in conjunction with sediment quality and invertebrate community information, to compare the current conditions of Lake George and Little Lake George to historical data and determine the extent of recovery within these sites (George 2005). A battery of sediment toxicity and bioaccumulation tests were performed using organisms representing different trophic levels in order to measure differences in sediment quality. Whole-sediment toxicity tests were performed using the juvenile amphipod, *Hyalella azteca* (14-day exposure, survival and growth), the mayfly nymph, *Hexagenia* spp. (21-day exposure, survival and growth), and the midge, *Chironomus tentans* (14-day exposure, survival and growth). This report presents the results of toxicity tests performed by the MOE's Laboratory Services Branch (LaSB), Aquatic Toxicology Unit (ATU).

2.0 MATERIALS AND METHODS

2.1 Sediment Collection and Storage

Five sediment samples were collected on August 11, 2005 (Figure 1 and Appendix 1). The stations, in order of least to most contaminated (based on source inputs and historical contamination), were as follows: Goulais Bay (LG 292 reference station), Lower Lake George (LG 249), Mid-Lake George (LG 248), Upper Lake George (LG 231) and Little Lake George (LG 87) (George 2005). A total of approximately 10 L of sediment per site was composited, placed into a plastic pail, lined with a food-grade polyethylene bag, and transported to the ATU at the Ontario Ministry of the Environment (MOE) LaSB in Etobicoke, Ontario.

Figure 1. St. Mary's AOC Lake George and Little Lake George Location. Sediment collected on August 11, 2005. Map obtained from; http://www.on.ec.gc.ca/water/raps/map_e.html. × denotes sample location.

Previously collected sediment from Lake Erie served as the negative control sediment. The negative control sediment is relatively uncontaminated sediment, known to support organism survival and growth in the laboratory and provides a measure of organism health and test system integrity. The negative control sediment provides a basis for comparing the biological responses in the test sediments (ASTM, 2000).

Once the sediment samples were received at the testing facility, each sediment bucket was thoroughly homogenized with a stainless steel spoon and any large indigenous organisms or debris were removed. The sediments were stored at 4 ± 2 °C without headspace in the dark for up to 40 days before testing. Storage time was not longer than the 6 weeks suggested by Environment Canada's protocol for invertebrate sediment testing (EC 1997a & b). Research has shown that longer storage times do not alter toxicity response (acute or chronic) for as long as 6 months (Reynoldson *et al.* 1991).

2.2 Physical/ Chemical Analysis of Sediment

Homogenized sediment samples were analysed for particle size, nutrient content (total Kjeldahl nitrogen (TKN), total phosphorus (TP), total organic carbon (TOC) and loss on ignition), as well as metals (including mercury and arsenic), and polycyclic aromatic hydrocarbons (PAH), decommissioning petroleum hydrocarbon and solvent extractables (oil and grease). Analyses were performed at the MOE - LaSB according to MOE standard methods (C129221 and C131066).

2.3 Biological Tests

2.3.1 MOE Standard Sediment Toxicity Test Methods

All sediment toxicity testing and all species culturing were conducted with dechlorinated city of Toronto tap water (Appendix 3). Culture methods for all species are outlined in their respective MOE ATU Section Standard Operating Procedure (SOP) (*H. azteca* culturing MOE 2004a; *Hexagenia* spp. culturing Bedard *et al.* 1992and MOE 2004b; C. *tentans* culturing MOE 2004c). Biological tests were initiated in September 2005. The amphipod test was performed according to the Environment Canada standard method (EC 1997a) with modifications as detailed in Appendix 2a. The mayfly (*Hexagenia* spp.) test was performed according to the MOE's testing protocol (Bedard *et al*., 1992) outlined in Appendix 2b. The chironomid (C. *tentans*) test was performed according to the Environment Canada standard method (EC 1997b) with modifications as detailed in Appendix 2c. It should be noted that a morphological comparison of populations of *Chironomus tentans* (Fabricius) in Europe, Asia and North America has revealed two distinct species under this name. The North American populations constitute a new species described under the name *Chironomus dilutus* (Shobanov *et al*. 1999). For the purposes of this document we will continue to use the name *Chironomus tentans*.

For each test, a sediment sample was placed into three replicate containers in a 1:4 ratio of sediment to water. Vessels were then aerated overnight before test organisms were introduced. During testing, the vessels were maintained at 23 ± 2ºC. Vessels were continuously aerated and exposed to a 16:8 hour light:dark photoperiod. At the start, middle and end of each test, sub-samples of overlying water were collected from the test vessels and monitored for pH, conductivity, ammonia and dissolved oxygen. Temperature and organism health were monitored daily. If observed, dead organisms were removed immediately. Any changes in the appearance of the sediment or overlying water were noted. Water levels were replenished as needed with deionized or reverse osmosis (RO) water.

2.3.2 *Hyalella azteca* (Freshwater Amphipod) Survival and Growth Test

On September 13, 2008 a 14-day survival and growth test using *H. azteca* (4-8 days old) was initiated with each sample. On the day of test initiation, 10 *H. azteca* were added to each test vessel. The amphipods used for testing were maintained in a continuous culture at the MOE laboratory (EC 1997a; MOE 2004a).

2.3.3 *Hexagenia* spp. (Mayfly Nymphs) Survival and Growth Test

On September 7, 2005 a 21-day survival and growth test with *Hexagenia* spp. was initiated with each sample. On the day of test initiation, 10 *Hexagenia* spp. (average wet weight; 4.04±1.88 mg) were added to each test vessel. The *Hexagenia* spp. used for testing were obtained as eggs from the University of Windsor and cultured to testing size at the MOE laboratory (Bedard *et al*. 1992; MOE 2004b).

2.3.4 *Chironomus tentans* (Midge Larvae) Survival and Growth Test

On September 20, 2005 a 10-day survival and growth test with *C. tentans*. was initiated with each sample. On the day of test initiation, 10 *C. tentans* (average head capsule width 0.35±0.06 mm) were added to each test vessel. The *C. tentans* used for testing were maintained in a continuous culture at the MOE laboratory (EC, 1997b; MOE 2004c).

2.4 Chemical Analysis of Overlying Water

In all sediment tests, dechlorinated city of Toronto tap water was used as overlying water (pH 7.6-8.2, hardness 122 mg/L as $CaCO_3$, alkalinity 82-83 mg/L as $CaCO_3$)(Appendix 3). Due to bioturbation of the sediment by the organisms contaminants from the sediment can often end up in the overlying water. Overlying water from the 14-Day *H. azteca* test, the 21-Day *Hexagenia* spp. test and the 10-day *C. tentans* test were collected from all replicates at time of test termination. Replicates were composited and sent to LSB for analysis of metals, anions, dissolved carbon and silicate, pH, alkalinity and conductivity, dissolved nutrients and cations for all tests (*H. azteca* C130595 Appendix 8a; *Hexagenia* spp. C130599 Appendix 8b; and *C. tentans* C132116 Appendix 8c). Conductivity, dissolved oxygen, pH and ammonia were measured using specific ion meters in the ATU laboratory. The measurement of contaminants of the overlying water can provide an indication of contaminant mobility and was assessed as a possible predictor of toxicity to the exposed organisms. These values were compared to Provincial Water Quality Objectives (PWQO) (MOE 1999).

2.5 Data Analysis

Data were analyzed using the Systat 11.0 software package (SYSTAT Systems Inc, 2004). Single composite samples were taken at each site with no replication and were compared to the control sediment. Using guidance from the Environment Canada's statistical guidance document (EC 2005) quantal effects (e.g., mortality) were compared to the control site using Fisher's exact test. Qualitative effects (e.g., growth) could not be assessed using statistical methods due to the lack of field replication, but a biologically significant reduction in growth was determined as a > 60 % reduction in growth relative to the control organisms based on informed opinion of the researcher. A Pearson correlation matrix of the sediment chemistry and toxicity endpoints (log transformed and standardized) was created to examine the relationship between toxicity and elevated levels of contaminants present in the test sediments.

3.0 RESULTS AND DISCUSSION

Refer to Table 2 for an overall summary of the results.

3.1 Sediment Analysis

The Provincial Sediment Quality Guidelines (PSQGs) identify the Lowest Effect Level (LEL) and the Severe Effect Level (SEL) for sediment nutrient, metal, and PAH concentrations. The LEL is the sediment concentration that can be tolerated by most benthic species and the SEL is defined as the sediment chemical concentration that could be detrimental to the majority of macrobenthos (Persaud *et al.* 1993). Sediment concentrations of contaminants measured from sediment collected from Lake George sample sites were compared to these values to assess the potential impact of individual contaminants on impairment.

3.1.1 Sediment Characterization

Particles were classified into three size classes; clay, less than <2.63 µm; silt, 2.63 to < 62 µm; and sand, 62 to <1000 µm. Silt dominated all treatment sediments except for sediment from station LG292 where sand and silt were present in approximately equal amounts (Figure 2). Contaminants are most often associated with fine sediments because higher surface-to-volume ratios of smaller particles increase the absorptive capacity for contaminants and the majority of organic carbon is in the "fine" fraction (Power and Chapman, 1992 as cited in Ingersoll, 1995). The clay (smallest particle size) content ranged between 11 and 31% in all test sediments.

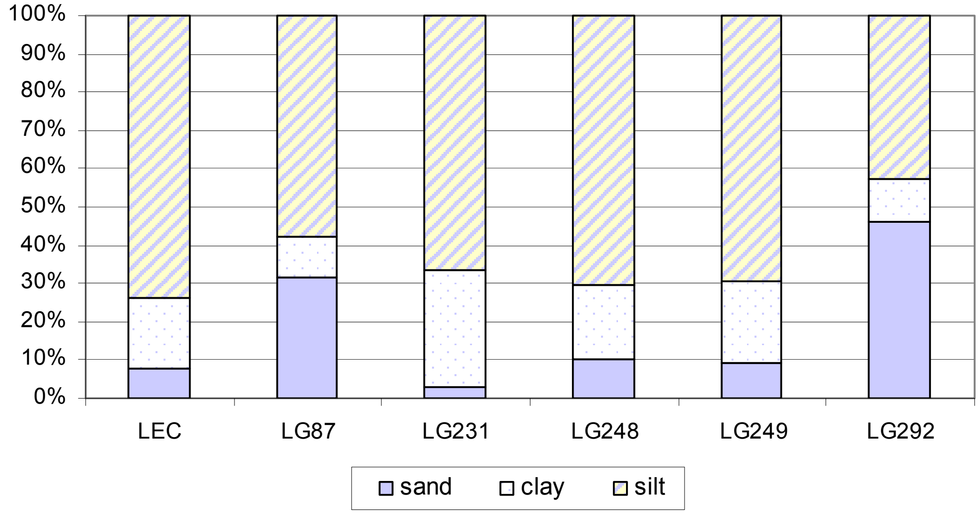

Figure 2. Particle size distribution in Lake George and Little Lake George sediments.

Bioavailability of contaminants in sediment is heavily influenced by natural organic material, which is represented by total organic carbon (TOC) measurements. Total organic carbon may bind to contaminants, rendering them unavailable for uptake by benthic organisms or fish (Spacie *et al*., 1995). The control sediment (LEC) had the lowest TOC (0.5%); treatment sediments ranged from 0.5% to 2.6% TOC (Table 1). Loss on ignition (LOI) is an estimate of the amount of organic and carbonates in the sediment (Heiri et al. 2001). Sediment collected from station LG248 and the control (LEC) sediment had the lowest LOI (13 and 14 mg/g, respectively) and the treatment sediments ranged from 26 to 51 mg/g.

Table 1. Total organic carbon (TOC) of Lake George and Little Lake George sediments. Italicized values exceed the PSQG (Provincial Sediment Quality Guidelines) LELs (Lowest Effect Level) and bolded values exceed the PSQG SELs (Severe Effect Level) (Persaud et al. 1993). See Appendix 4a for particle size, TKN and TP.

Parameter	**Units**	**LEL**	**SEL**	**LEC**	**LG87**	**LG231**	**LG248**	**LG249**	**LG292**
Total organic carbon	%	1	50	0.5	*1.5*	*2.3*	0.5	*2.6*	*1.6*
Solids; total, loss on ignition	mg/g dry			14	26	46	13	51	38

LEC and LG sediments were sub-sampled for chemistry August 23, 2005.

3.1.2 Metals

Bulk sediment samples were analyzed for 12 trace metals and concentrations were compared to PSQGs (Appendix 4b) (Persaud et al. 1993). None of the sediments exceeded SELs for the metals measured. The LEL for Cd (0.6 µg/g) and Cu (16 µg/g) were exceeded in sediment collected from Little Lake George (LG87), however Cd was measured below trace levels and both of these metals were found in lower concentrations than was measured in the Goulais Bay reference site (LG292) sediment. Upper Lake George (LG231) exceeded the LEL for Cu (38 µg/g), Cr (46 µg/g), Fe (31000 µg/g) and Ni (30 µg/g) by 2.4, 1.7, 1.6 and 1.9 times, respectively. Mid-Lake George (LG248) did not exceed the LEL in any of the metals measured. Lower Lake George (LG249) exceeded the LEL for 8 metals, however only Cr (2.1x the LEL), Cu (2.8x the LEL) and Ni (2.2x the LEL) were at concentrations greater than that seen in the reference sediment.

3.1.3 Organic Chemicals

None of the test sediments exceeded the SEL for any of the measured PAHs for which PSQGs are available (Appendix 4c). However the LEL was exceeded for Benzo(g,h,i)perylene and Indeno(1,2,3-c,d)pyrene in sediment from Upper (LG231) and Lower (LG249) Lake George. Naphthalene at the Little (LG87), Upper (LG231) and Lower (LG249) Lake George sites was found to be 14 to 16 times higher than that measured in the reference site sediment (LG292). Petroleum hydrocarbons (F1-F4G), solvent extractable oils and greases were analyzed, as these can often cause toxicity (Appendix 4d). It was identified that Upper Lake George (LG231) has been impacted by mineral petroleum oils (F4G = 420 mg/kg). However, a higher concentration of mineral petroleum (F4G = 460 mg/kg) was measured the reference sediment in which no toxicity was observed].

3.2 Biological Analysis

3.2.1 *Hyalella azteca* (Amphipod) Survival and Growth Test

A - Test Validity and Control Group Comparisons

A toxicity test is considered acceptable if *H. azteca* survival ≥ 80% in control sediments and individual weights are at least 0.1 mg (EC 1997a). *H. azteca* mean survival following exposure to control (LEC) and reference (LG 292) sediments was 97 and 87% and dry weight was 0.09 mg and 0.07 mg (Appendix 5a), respectively. Survival and dry weight of organisms exposed to the control (LEC) and reference (LG292) sediments both met the test criteria. Also, the results from reference toxicant testing confirmed the integrity of the test system, good organism health, and technician proficiency (Appendix 5a). For the duration of the test, pH, DO, conductivity, ammonia and temperature in water overlying Lake Erie control and the reference sediment were at acceptable levels and did not contribute to the observed toxicity (Appendix 5b).

B - Survival

All test sediments had reduced survival relative to the survival in the control sediment but only Little Lake George (LG 87), Upper Lake George (LG 231) had reduced survival when compared to amphipods exposed to the Goulais Bay reference sediment (Appendix 5a, Figure 3). The only sediment that had significantly lower survival than the control ($p \leq 0.05$) was Little Lake George (LG 87) (79% of control). However, this was not significantly different from the survival seen in the reference (88% of reference). Results of the 14-day amphipod test are presented in Appendix 5a (Figure 3). There was no significant correlations between sediment metals, PAHs, nutrients or oils and greases and *H. azteca* survival (Appendix 9).

C - Growth

All test sediments showed impaired growth relative to the control sediment. There was a gradient of impact from highest to lowest being Upper Lake George (LG 231) > Little Lake George (LG 87) > Mid-Lake George (LG 248) (54%, 79%, 92% of reference, respectively)(Appendix 5a, Figure 3). Growth impairment is considered to be biologically significant when growth is less than 60% of that observed in the reference exposed organisms. Upper Lake George (LG 231) was the only sediment with biologically significant growth impairment in the exposed *H. azteca*. There was no significant correlations between sediment metals, PAHs, nutrients or oils and greases and *Hyalella* growth (Appendix 9).

D – Water Quality

For the duration of the test, pH, DO, ammonia and temperature in water overlying the test sediments were at levels unlikely to impair *Hyalella azteca* (Appendix 5b). Water overlying the sediment were pooled from all replicates for each test sediment and submitted to the Ministry of the Environment's Laboratory Services Branch for chemical analysis (Appendix 8a). Impaired amphipod growth in Little Lake George (LG 231) could not be explained by the overlying water chemistry (Appendix 8a). Although the PWQO in water overlying LG231 sediment was exceeded for cadmium, cobalt, copper and zinc (0.375, 0.641, 5.01 and 24.7 ug/L, respectively), concentrations of these metals were higher in the overlying water of other sediments that did not have impaired amphipod survival.

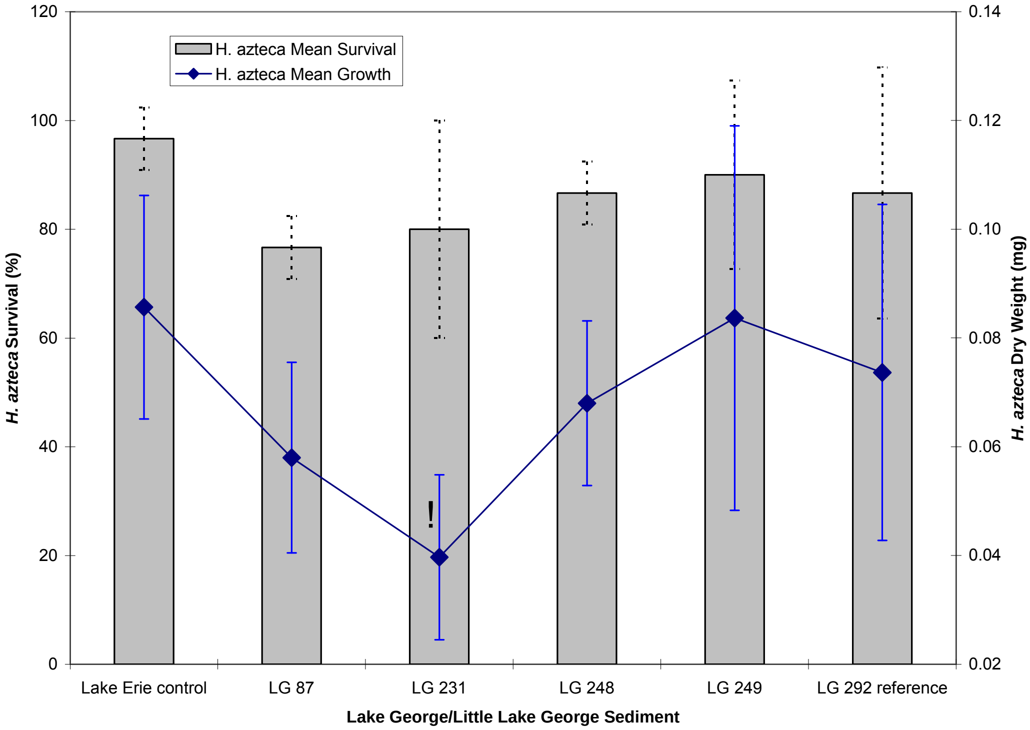

Figure 3. Mean percent survival and mean dry weight (mg) (± standard deviation) of *Hyalella azteca* after a 14 day exposure to Lake George and Little Lake George sediments and Lake Erie control sediment. There was no significant difference of percent survival from the reference sediment exposures (Fisher exact test, p = 0.005). ! indicates survival impairment to less than 60% of the growth seen in the reference exposed organisms.

3.2.2 *Hexagenia* spp. (Mayfly) Survival and Growth Test

A - Test Validity and Control Group Comparisons

Hexagenia spp. survival following exposure to the control (Lake Erie) and reference (LG 292) sediments was 97% and 93%, respectively (Appendix 6a). A toxicity test is considered acceptable if *Hexagenia* survival ≥ 80% in control sediments therefore this test is valid. Results from reference toxicant testing confirmed the integrity of the test system, good organism health and technician proficiency. Initial *Hexagenia spp.* weight was 4.04 ± 1.88 mg (Appendix 6a) and at test termination, mayflies should be ≥ 2 times their initial weight. Mean individual *Hexagenia spp.* wet weight at test termination following exposure to Lake Erie control and the reference sediment was 13.8 mg and 17.86 mg, respectively. Therefore growth in the control and reference was acceptable. Also, measurements of D.O., pH, ammonia, conductivity and temperature in water overlying Lake Erie control sediment at test initiation (day 0), mid-way, and at test termination (day 21) (Appendix 6b) were all within acceptable test limits.

B - Survival

There was no apparent impact of sediment on survival of mayflies. Survival at all sites was greater than 80% and no sites were significantly different than the control or reference sediments (Appendix 6a, Figure 4). *Hexagenia* spp. in all treatments ranged in survival from 80% to 100%. The Pearson correlation matrix of the toxicity endpoints with sediment chemistry did not reveal any significant negative correlations between sediment metals, PAHs, nutrients or oils and greases and *Hexagenia* survival.

C - Growth

The growth response of *Hexagenia* to the test sediments also appeared to follow a gradual gradient of impact with the highest to lowest impact sediments (and their individual mean wet weight) being as follows: LG 249 (7.78 mg) > LG 231 (8.62 mg) > LG 248 (8.91 mg) > Lake Erie Control (13.18 mg) > LG 87 (16.75 mg) > LG 292 (reference) (17.86 mg) (Appendix 6a). However, with the exception of Lower Lake George (LG 249), growth more than doubled over the duration of the test and therefore met the minimum requirement indicating healthy organisms. The observed impairment in the growth of mayflies exposed to Lower Lake George (LG 249) sediment is considered to be biologically significant because these organisms were more than 60% smaller than those exposed to the Goulais Bay reference sediment. A Pearson correlation matrix of the toxicity endpoints with sediment chemistry did not reveal any significant negative correlations between sediment metals, PAHs, nutrients or oils and greases and *Hexagenia* growth.

D – Water Quality

Test solutions were monitored for dissolved oxygen, pH, conductivity and ammonia at the beginning, day 8, and end of testing (Appendix 6b). All parameters measured were within acceptable levels for organism health. Water overlying the sediment were pooled from all replicates for each test sediment and submitted to the Ministry of the Environment's Laboratory Services Branch for chemical analysis (Appendix 8b). Aluminum concentrations in the overlying water exceeded the PWQO for all sites, and this was the only PWQO exceedence in Lower Lake George (LG 249). Overlying water chemistry did not reveal any metals or nutrients that may have contributed to the impaired *Hexagenia spp.* growth in Lower Lake George (LG 249).

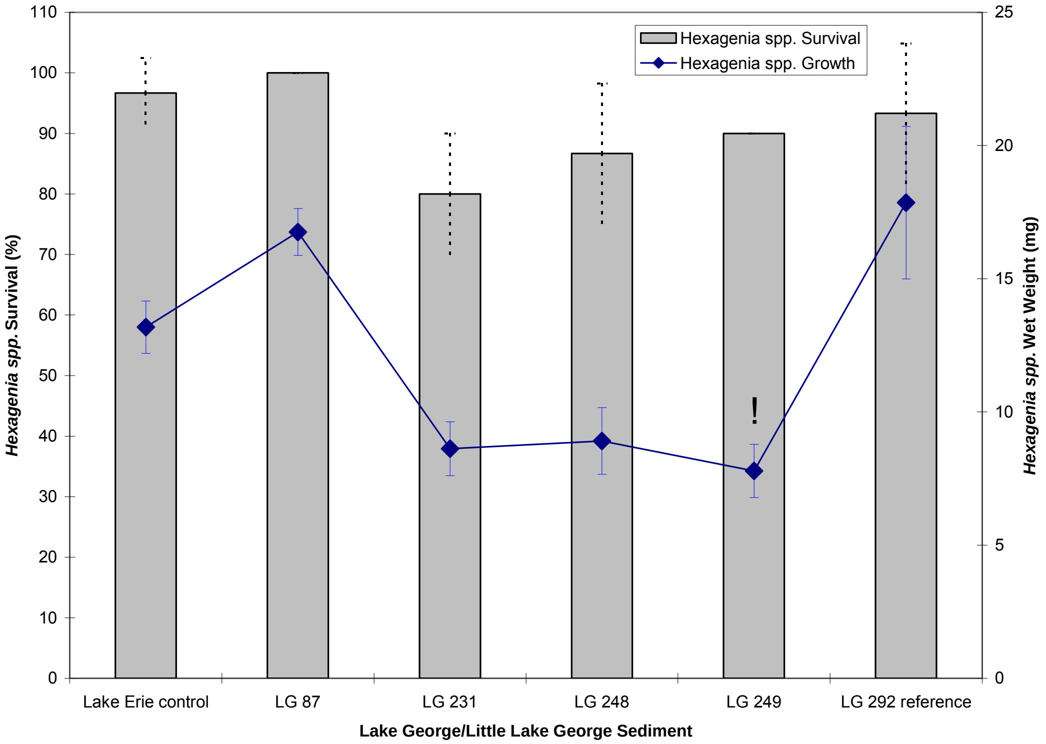

Figure 4. Mean percent survival and mean wet weight (mg) (± standard deviation) of *Hexagenia* spp. after a 21 day exposure to Lake George/Little Lake George sediments and Lake Erie control sediment. ! indicates growth impairment, wet weight less than 60% of organisms exposed to the reference sediment.

3.2.3 *Chironomus tentans* (Midge) Survival and Growth Test

A - Test Validity and Control Group Comparisons

Chironomus tentans mean survival following exposure to Lake Erie control and Goulais Bay reference (LG 292) sediments was 97 and 77% respectively (Appendix 7a). A toxicity test is considered acceptable if *C. tentans* survival is ≥ 70% in control sediments. It should be noted that survival in the reference sediment was variable (CV = 42%) and was impacted by one replicate with only 40% survival. It is unclear why this replicate had reduced survival. Results from reference toxicant testing confirmed the integrity of the test system, good organism health as well as technician proficiency (Appendix 7a). The mean individual midge wet weight following exposure to Lake Erie control sediment was 12.35 mg (Appendix 7a). When the wet weight is multiplied by the conversion factor of 0.129 (Watson-Leung, unpublished data) the approximate dry weight of these organisms is 1.59 mg. This is more than double the minimum acceptable value of 0.6 mg (EC 1997a). Midges exposed to the reference sediment had a mean individual wet weight of 13.95 mg (~1.80 mg dry weight) at test termination. Measurements of pH, DO, conductivity, ammonia and temperature were not at levels which may cause toxicity (Appendix 7b).

B - Survival

With the exception of Upper Lake George (LG 231), there was little difference in midge survival in the test sediments (LG 87, 248 and 249) compared with Lake Erie control and reference (LG 292) sediments (Appendix 7a Figure 5). The mean survival of midges exposed to the Upper Lake George (LG 231) sediment was 47%. This was the only sediment that had survival that was significantly lower than both the control and reference sediments using Fisher's Exact test ($\alpha = 0.05$). It should be noted that survival was highly variable (CV=65%) in this sediment and ranged from 20-80% which may indicate contaminant patchiness. The organisms exposed to Lake Erie control and Mid-Lake George (LG 248) had significantly greater survival than those exposed to the reference sediment, likely due to the low survival in one replicate of the reference sediment. A Pearson correlation matrix of the toxicity endpoints with sediment chemistry did not reveal any significant negative correlations between sediment metals, PAHs, or nutrients and *Chironomus* survival. However, *Chironomus* survival was negatively correlated with solvent extractable oils and greases (SXT – includes plant based polar hydrocarbons) and petroleum hydrocarbons from oils, grease and lubricants (F3 fractions) (R^2=-064 and -0.75, respectively). These correlations are likely driven by the high concentrations of oils and grease being detected only in the Upper Lake George (LG 231) and reference (LG 292) sediments where the survival was lowest. Survival was variable in these sediments however and may not be due to toxicity from these contaminants.

C – Growth

With the exception of Upper Lake George (LG231) growth of midges in all sediments was less than seen in the Goulais Bay reference sediment organisms (Appendix 7a). Average growth in midges exposed to Upper Lake George (LG 231) sediment was greater than seen in reference sediment exposed organisms (124% of reference). This was influenced by the extra large size obtained by the two organisms remaining alive in replicate A, likely due to reduced competition. Due to this mortality induced elevated average growth in Upper Lake George sediment the Pearson correlation matrix revealed significant positive correlations between sediment Al (R^2=0.84), Cr (R^2=0.78), Cu (R^2=0.80), Fe (R^2=0.75), Ni (R^2=0.82) and Perylene (R^2=0.83) and midge growth.

D – Water Quality

Test solutions were monitored for dissolved oxygen, pH, conductivity and ammonia at the beginning, day 5 and at the end of testing (Appendix 7b). Measurements of pH, conductivity, ammonia and temperature were not at levels which may impair *Chironomus tentans*. The overlying water iron (500 µg/L) and copper (7.59 µg/L) concentrations measured for Upper Lake George (LG 231), in which midge survival was impaired, exceeded PWQOs, however these concentrations were lower than measured in water overlying sediments that did not show midge impairment (Appendix 8c).

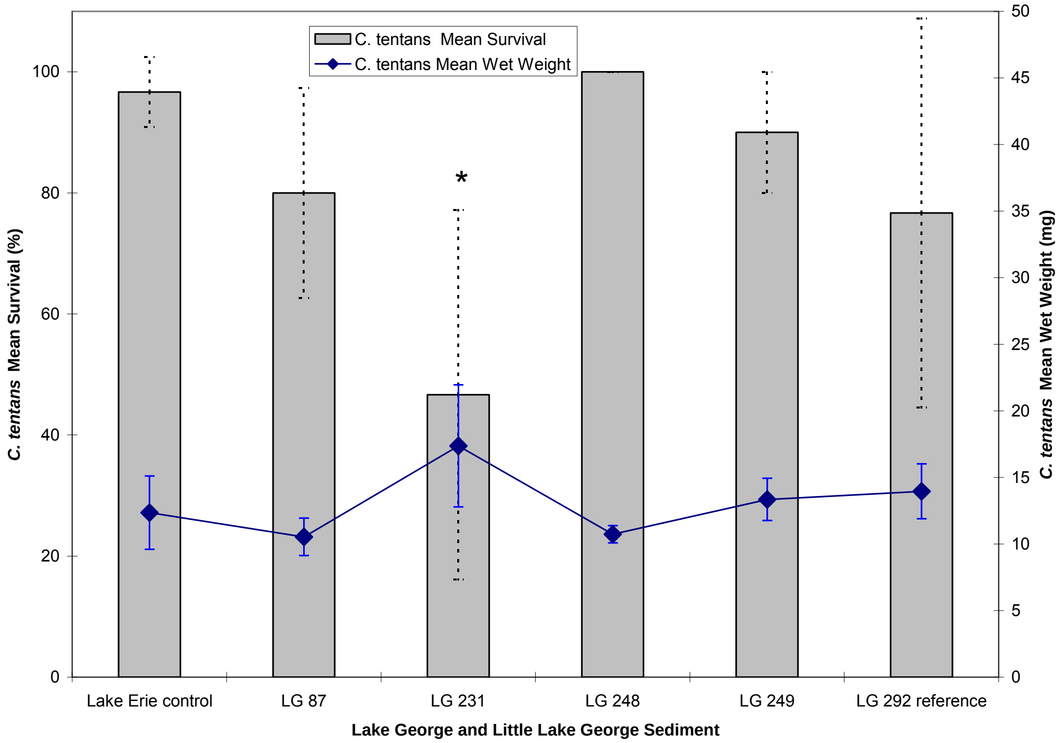

Figure 5. Mean percent survival and mean wet weight (± standard deviation) of *Chironomus tentans* after a 10 day exposure to Lake George/Little Lake George sediment and Lake Erie control sediment. * indicates a significant reduction in survival relative to survival in the LG 292 reference sediment, as determined using a Fisher's exact test (α=0.05)

4.0 SUMMARY / CONCLUSIONS

Historical contamination of Lake George and Little Lake George sediments with iron, zinc, lead, manganese, cadmium, nickel, copper, chromium, arsenic, PCBs and oil and grease has been decreasing over time. In contrast to the 2002 BEAST (Milani and Grapentine 2002) study, metal concentrations in the Lake George and Little Lake George sediments collected in 2005 did not exceed severe effect levels, although lowest effect levels were exceeded for iron, zinc, lead, manganese, cadmium, chromium, copper and nickel. There was very little impairment observed in the sediment toxicity test organisms exposed to Lake George and Little Lake George (Table 2).

Biologically significant growth impairment in the *Hyalella azteca* exposed to Upper Lake George (LG 231) sediment was not explained by any of the measured sediment or water contaminant concentrations and may be due to an un-measured co-contaminant.

Hexagenia spp. growth was impaired in Upper Lake George (LG231), Mid-Lake George (LG248) and Lower Lake George (LG249) when compared to the mayflies exposed to the Goulais Bay reference sediment. However, relative to the Lake Erie control sediment growth was only significantly impaired in Lower Lake George sediment (59% of control). The mayflies were not fed during the toxicity test and rely heavily on nutrients in the sediment for their nutrition. It is not clear from the sediment particle size, total organic carbon, why the mayflies grew better in the Goulais Bay sediment than the Lake George sediments. It may be that the organic carbon was more nutritionally valuable in the Goulais Bay reference sediment. In addition, nickel, manganese, lead and zinc were highest in the Lower Lake George sediment which may have impaired *Hexagenia spp.* growth.

Using the Fisher's exact test survival of the *Chironomus tentans* exposed to test sediments was deemed significantly impaired only in the Upper Lake George (LG231) sediment. This statistical test requires the data from all lab replicates to be pooled and variability across replicates is not taken into consideration. When the variance in survival across replicates of *C. tentans* in Upper Lake George and Goulais Bay sediments were compared using an F-test, it was deemed that the standard deviations were equal ($F_{0.025(2,2)} = 39$). The variability in organism response makes it difficult to interpret these results, however *C. tentans* survival was negatively correlated with the concentration of the F3 fraction petroleum hydrocarbons (lube oil, motor oil, fuel oil and/or grease) in the sediment.

Results of laboratory tests should always be compared to field studies for full assessment of sediment impairment.

Table 2: Summary of Organism Response after exposure to Lake George and Little Lake George Sediments in Toxicity Tests. Elevated negative correlations from the Pearson Correlation matrix and water and sediment quality guideline exceedences are shown.

(PWQO = Provincial Water Quality Objectives; PSQG = Provincial Sediment Quality Guidelines).

🟨 no significant impairment ▨ significant impairment

	Species	*Hexagenia spp.*			*Hyalella azteca*			*Chironomus tentans*			**PSQG EXCEEDENCES** (LEL italics, SEL bold)
	Endpoint	**SURVIVAL**	**GROWTH**	**PWQO EXCEEDENCES**	**SURVIVAL**	**GROWTH**	**PWQO EXCEEDENCES**	**SURVIVAL**	**GROWTH**	**PWQO EXCEEDENCES**	
Sediment	**LG87**	🟨	🟨	Al, Fe, Cr*	🟨	🟨	Al, Zn	🟨	🟨	Al, Co, Cu, Zn, (Fe in rep B only)	*TOC, Cd, Cr, Cu*
	LG231	🟨	🟨	Al, Fe	🟨	▨	Cd, Co, Cu, Zn	▨	🟨	Al, Co, Cu, Fe, Zn	*TOC, TKN, TP, Cd, Cr, Fe, Ni, Cu, Benzo(g,h,i) Ideno*
	LG248	🟨	🟨	Al, Fe	🟨	🟨	Zn	🟨	🟨	Al, Cu, Fe, Zn	none
	LG249	🟨	▨	Al, Fe, Co, Cr*	🟨	🟨	Al, Cd, Cu, Fe, Zn	🟨	🟨	Al, Cu, Fe, Zn	*TOC, TKN, TP, Cd, Cr, Cu, Fe, Pb, Mn, Ni, Zn, Benzo(g,h,i) Ideno*
	LG292	n/a		Al, Fe, Co, Cr*, Cu	n/a		Cd, Cu, Zn	n/a		Al, Cd, Cu, Fe, Zn	*TOC, TKN, TP, Cd, Cr, Fe*
Negative Correlations (>-0.7) with Sediment Chemistry		none	Pb (R^2=-0.82)		none	none		F3 (R^2=-0.75)	none		

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Appendix 1: Lake George and Little Lake George sediment sample information and description

Sample Information

Submitted by: Tara George, Environmental Monitoring and Reporting Branch, OMOE
Location: Lake George
No. of Samples: 5 (plus Lake Erie control sediment)

Name of Samples	ATU Sample No.	Lab Code Name	LIMS No[1].
Lake Erie Control	n/a	Lake Erie **control**	n/a
Stn. 13 02 0087 - Little Lake George	1050355	LG 87	C128849-0007
Stn. 13 02 0231 - Upper Lake George (Index Station)	01050356	LG 231	C128850-0001
Stn. 13 02 0246 - Mid-Lake George	01050353	LG 248	C128849-0002
Stn. 13 02 0247 - Lower Lake George	01050354	LG 249	C128849-0004
Stn. 01 01 0292 - Goulais Bay Index Station	01050357	LG 292 **reference**	C128853-0002

[1] LIMS number which refers to requested toxicity test product codes

Unless otherwise noted all of the above samples were:

Sampled by: Tara George
Sample Method:
Date Sampled: Aug.11.05
Date Received: Aug.15.05
Received by: Trudy Watson-Leung
Condition on Receipt: seals intact, bags in tact with the exception of TAL 8
Storage: 4^{o}C in laboratory cooler
Tests performed: 10-day *Chironomus riparius* growth and survival test (SOP CT2.v2)
14-day *Hyalella azteca* growth and survival test (SOP HA2.v2)
21-day *Hexagenia sp.* growth and survival test (SOP HX2.v1)

Sediment Description:

Name of Samples	colour	odour	soil type	Other
LG 87 - Little Lake George	dark brown	earthy	sand / clay	Sieved sample because there was a lot of rocks. Large Hexagenia were visible. Sample was homogenized by hand. Upon test take down, the surface of sediment had a rusty colouration.
LG 231	brown	none	sand / clay	Sieved sample because there was a lot of rocks. Homogenized by hand.
LG 248	red / brown	earthy	clay / silt	Sample was sieved and homogenized by hand.
LG 249	brown	none	sand / clay	Sample was sieved and homogenized by hand.
LG 292	brown	none	clay / silt	Sample was sieved and homogenized by hand.

Appendix 2: Toxicity Test Method Summaries

Appendix 2a:

Hyalella azteca **Test for Survival and Growth in Sediment: Summary**
(from Bedard *et al.* , 1992 and Environment Canada 1997; with in-lab refinement)

Test Type and Duration	Static Non-Renewal, 14 days
Photoperiod; Light Intensity	16 hr light, 8 hr darkness; 500 - 1000 lux
Temperature	23°C ± 2°C
Dilution Water	Dechlorinated Toronto tap water
Renewal of Test Solutions	Replenish water loss due to evaporation as needed
Organism Age	2 to 9 days old
Test Chambers and Sediment to Water Ratio *	7 cm diameter (>500 mL) glass vessels with 400 mL of dechlorinated water and 100 mL sediment
Organisms/Concentration	10 organisms per replicate. Minimum of 3 replicates.
Feeding Regime *	3 times per week 2 mg of ground fish flake food (NutraFin®)
Test Solution Aeration	Aerate a minimum of 1 hour prior to adding organisms and gently aerate for the duration of the test.
Endpoints	Mortality, growth.
Time to Test Initiation	Test preferably within 2 weeks, must within 6 weeks of sample collection.
Sample Volume Required	5 to 10 L

* denotes differences from Environment Canada 1997

Appendix 2b:

Hexagenia **spp. Test for Survival and Growth in Sediment: Summary**
(from Bedard *et al.* , 1992; with in-lab refinement)

Test Type and Duration	Static Non-Renewal, 21 days
Photoperiod; Light Intensity	16 hr light, 8 hr darkness; 500 - 1000 lux
Temperature	23°C ± 2°C
Dilution Water	Dechlorinated Toronto tap water
Renewal of Test Solutions	Replenish water loss due to evaporation as needed
Organism Age	3 to 4 month old nymphs, average weight 5 mg.
Test Chambers	1.8 L glass vessels with 1300 mL of dechlorinated water and 325 mL sediment
Organisms/Concentration	10 organisms per replicate for a test density 0.08 nymphs per cm^2. Minimum of 3 replicates.
Feeding Regime	Animals are not fed during the test.
Test Solution Aeration	Aerate a minimum of 1 hour prior to adding organisms and gently aerate for the duration of the test.
Endpoints	Mortality, growth.
Time to Test Initiation	Test preferably within 2 weeks, must test within 6 weeks of sample collection.
Sample Volume Required	5 to 10 L

Appendix 2c:

Chironomus tentans Test for Survival and Growth in Sediment: Summary (from Bedard et al., 1992 and Environment Canada 1997; with in-lab refinement)

Test Type and Duration	Static Non-Renewal, 10 days
Photoperiod, Light Intensity	16 hr light, 8 hr darkness; 500 - 1000 lux
Temperature	23°C ± 2°C
Dilution Water	Dechlorinated Toronto tap water
Renewal of Test Solutions	Replenish water loss due to evaporation as needed
Organism Age	>50% sub-sampled organisms head capsule width within 0.33-0.45 12 days old; 2nd or 3rd instar)
Test Chambers and Sediment to Water Ratio*	7 cm diameter (>500 mL) glass vessels with 400 mL of dechlorinate and 100 mL sediment
Organisms/Concentration	10 organisms per replicate . Minimum of 3 replicates.
Feeding Regime	Daily feed a 1.5 mL aliquot of 6 mg (d.w.) or 4 times during test feed of 15 mg (d.w.) of a 3:2 mixture of Cerophyll®:Tetra Conditioning
Test Solution Aeration	Aerate a minimum of 1 hour prior to adding organisms and gently ae the duration of the test.
Endpoints	Mortality, growth.
Time to Test Initiation	Test preferably within 2 weeks, must within 6 weeks of sample coll
Sample Volume Required	5 to 10 L

* denotes a difference from Environment Canada (1997) method

Appendix 3: Chemistry of Lab Dilution Water

Chemistry of dechlorinated City of Toronto tap water used in sediment toxicity testing during the period of testing with Lake George and Little Lake George sediment (C129987).

Parameter Name	units	Hot		Cold	
Calcium	mg/L	34.8		34.5	
Hardness	mg/L	122		122	
Magnesium	mg/L	8.58		8.62	
Potassium	mg/L	1.56		1.56	
Sodium	mg/L	12.7		12.6	
Sulphate	mg/L	30.7		31.6	
Magnesium	mg/L	8.5761		n/a	
Potassium	mg/L	1.559		n/a	
Sodium	mg/L	12.7014		n/a	
Alkalinity; total fixed endpt	mg/L $CaCO_3$	83.2		82.4	
Conductivity	uS/cm	305		303	
pH	none	8.2		7.61	
Nitrogen; ammonia+ammonium	mg/L	0.002	<=W	0.002	<=W
Nitrogen; nitrate+nitrite	mg/L	0.628		0.69	
Nitrogen; nitrite	mg/L	0.001	<=W	0.001	<=W
Phosphorus; phosphate	mg/L	0.0005	<=W	0.0009	<T
Aluminum	ug/L	30.9	+/-3	19.3	+/-3
Barium	ug/L	23.1	+/-1.6	23.1	+/-1.6
Beryllium	ug/L	0.0134	+/-0.02	0.0169	+/-0.02
Cadmium	mg/L	0.114	+/-0.8	-0.0477	+/-0.8
Calcium	ug/L	33.4	+/-4.01	33.4	+/-4.00
Chromium	ug/L	-0.876	+/-1.0	-0.245	+/-1.0
Cobalt	ug/L	-0.316	+/-1.5	-0.00835	+/-1.5
Copper	ug/L	14.1	+/-1.5	0.275	+/-0.8
Iron	ug/L	16	+/-1.5	14.3	+/-1.5
Lead	ug/L	0.541	+/-11	-0.177	+/-11
Magnesium	mg/L	8.65	+/-0.95	8.65	+/-0.95
Manganese	ug/L	0.15	+/-0.2	-0.00279	+/-0.2
Molybdenum	ug/L	1.32	+/-1.5	0.645	+/-1.5
Nickel	ug/L	0.351	+/-1.5	0.268	+/-1.5
Strontium	ug/L	183	+/-14.6	182	+/-14.6
Titanium	ug/L	-0.288	+/-0.3	-0.397	+/-0.3
Vanadium	ug/L	-0.0282	+/-1.0	-0.199	+/-1.0
Zinc	ug/L	2.38	+/-0.7	-0.0378	+/-0.7
Carbon; dissolved inorganic	mg/L	n/a		19	
Carbon; dissolved organic	mg/L	n/a		0.6	
Silicon; reactive silicate	mg/L	n/a		0.42	

<=W = less than minimum detection limit (MDL); <T = a measureable trace amount, interpret with caution.

Appendix 4: Lake George and Little Lake George Sediment Chemistry

Appendix 4a: Total organic carbon (TOC), total Kjeldahl nitrogen (TKN), total phosphorus (TP), total solids - loss on ignition (LOI) and particle size of Lake George and Little Lake George sediments. Underlined values exceed the PSQG (Provincial Sediment Quality Guidelines) LELs (Lowest Effect Level) and bolded values exceed the PSQG SELs (Severe Effect Level, Persaud et al. 1993). (C129221 and C131066)

Parameter	LEL	SEL	LEC^	LG 87	LG231	LG 248	LG 249	LG 292
TOC (%)	1	10	0.5	1.5	2.3	0.5	2.6	1.6
TKN (mg/g dw)*	0.55	4.8	0.5	0.4 (<T)	1.4	0.4 (<T)	1.4	1
TP (mg/g dw)*	0.68	2	0.68	0.46	0.86	0.5	0.98	0.79
solids, total, LOI (mg/g dw)			14	26	46	13	51	38
particle size (%): <1000 >62 mm sand			8	32	3 (<T)	10	9	46
<62 >2.63 silt			74	58	67	70	69	43
<2.63 clay			18.4	10.7	30.8	19.3	21.3	11.2

* parameters were measured on sediment subsampled October 13, 2005 (C131066) all other parameters were measured on sediment subsampled on August 23, 2005.

^ LEC sediment subsampled for chemistry July 25, 2005 (C128168); LG sediments subsampled for chemistry Aug.23.2005 (C129221) and Oct.13.2005 (C131066).

Appendix 4b: Metal concentrations (µg/g) of sediment collected from Lake George and Little Lake George. Underlined values exceed the PSQG (Provincial Sediment Quality Guidelines) LELs (Lowest Effect Level) and bolded values exceed the PSQG SELs (Severe Effect Level).

Parameter (µg/g dw)	LEL	SEL	LEC^	LG 87	LG231	LG 248	LG 249	LG 292
arsenic			4	2.4	5.7	1.6	10	4.9
mercury	0.2	2	0.01	0.04 (<T)	0.08	0.02 (<T)	0.1	0.04 (<T)
aluminum			9700	7500	17000	6900	19000	16000
cadmium	0.6	10	0.6 (<T)	0.7 (<T)	0.6 (<T)	<=W	0.7 (<T)	0.8 (<T)
chromium	26	110	16	26	46	19	54	39
copper	16	110	17	17	38	10	44	32
iron	20000	40000	16000	17000	31000	13000	39000	24000
lead	31	250	9 (<T)	9 (<T)	21	12	32	10
manganese	460	1100	600	200	390	210	740	420
nickel	16	75	17	14	30	11	35	26
zinc	120	820	44	60	110	43	150	73

^ LEC sediment subsampled for chemistry July 25, 2005 (C128168); Lake George/Little Lake George sediments subsampled for chemistry August 23, 2005.

Appendix 4c: PAH concentrations (ng/g) of sediment collected from Lake George and Little Lake George. Underlined values exceed the PSQG (Provincial Sediment Quality Guidelines) LELs (Lowest Effect Level) and bolded values exceed the PSQG SELs (Severe Effect Level). (C129221)

Parameter	LEL	SEL*	LEC	LG 87	LG231	LG 248	LG 249	LG 292
PAHs (ng/g dw)								
Acenaphthene			<=W	18 (<T)	16 (<T)	<=W	17 (<T)	<=W
Acenaphthylene			<=W	27	42	3.3 (<T)	42	<=W
Anthracene	220	370000	<=W	45	46	4.8 (<T)	52	<=W
Benzo(a)anthracene	320	1480000	5 (<T)	140	150	17 (<T)	170	6.8 (<T)
Benzo(a)pyrene	370	1440000	6 (<T)	160	190	20	220	6.4 (<T)
Benzo(b)fluoranthene			17 (<T)	220	280	35	330	19 (<T)
Benzo(e)pyrene			13 (<T)	140	200	22	220	11 (<T)
Benzo(g,h,i)perylene	170	320000	13 (<T)	130	180	23	250	12 (<T)
Benzo(k)fluoranthene	240	1340000	5.5 (<T)	120	130	16 (<T)	150	7.1 (<T)
Chrysene	340	460000	22	190	220	28	260	15 (<T)
Dibenzo(a,h)anthracene	60	130000	<=W	26	32	3.4 (<T)	39	2.3 (<T)
Fluoranthene	750	1020000	19 (<T)	280	330	42	380	23
Fluorene	190	160000	4.1 (<T)	23	33	3 (<T)	34	3.1 (<T)
Indeno(1,2,3-c,d)pyrene	200	320000	16 (<T)	200	270	36	330	17 (<T)
Naphthalene			8.5 (<T)	270	310	28	300	19 (<T)
Perylene			19 (<T)	70	210	23	160	160
Phenanthrene	560	950000	19 (<T)	160	210	25	230	19 (<T)
Pyrene	490	850000	15 (<T)	230	260	33	320	16 (<T)
% Recovery								
d10-acenaphthene			100	85	87	100	100	91
d10-anthracene			110	92	55	96	140	110
d10-fluoranthene			110	110	110	110	110	110
d10-fluorene			110	96	98	110	110	100
d10-phenanthrene			110	99	100	110	110	100
d10-pyrene			110	110	110	110	110	110
d12-benz(a)anthracene			110	110	120	120	120	120
d12-benzo(a)pyrene			160	150	150	170	170	130
d12-benzo(b)fluoranthene			110	110	120	110	110	120
d12-benzo(ghi)perylene			81	74	73	82	73	78
d12-benzo(k)fluoranthene			95	96	100	100	98	110
d12-chrysene			97	96	100	100	99	100
d12-indeno(123-cd)pyrene			68	60	62	71	68	64
d14-dibenz(ah)anthracene			90	80	83	93	89	85
d8-acenaphthylene			97	66	65	100	98	72
d8-naphthalene			95	74	74	95	92	86

<=W = less than minimum detection limit (MDL); <T = a measurable trace amount, interpret with caution

* for SEL, multiply value by TOC of sediment

Appendix 4d: Oils and Grease concentrations (mg/kg) of sediment collected from Lake George and Little Lake George (C131066).

Parameter	Units	LEC		LG 87		LG231		LG 248		LG 249		LG 292	
Benzene	mg/kg	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL
Ethylbenzene	mg/kg	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL
F1 (C6 - C10)	mg/kg	10	<MDL	10	<MDL	10	<MDL	10	<MDL	10	<MDL	10	<MDL
F2 (C10 - C16)	mg/kg	14		10	<MDL	10	<MDL	10	<MDL	10	<MDL	10	<MDL
F3 (C16 - C34)	mg/kg	78		92		240		50	<MDL	50	<MDL	300	<MDL
F4 (C34 - C50)	mg/kg	50	<MDL	50	<MDL	57		50	<MDL	50	<MDL	100	
F4G (gravimetric)	mg/kg		NDND		NDND	420			NDND		NDND	460	
m/p-xylene	mg/kg	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL
o-xylene	mg/kg	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	<MDL
Toluene	mg/kg	0.1	<MDL	1		0.1	<MDL	0.1	<MDL	0.1	<MDL	0.1	NDST*
Solvent extractable	mg/kg	130		320		430		80		190		650	

*GC/FID analysis combined PT/GC/FID analysis identified a partially resolved complex mixture of hydrocarbons (RCM) primarily in the c12 to >c50 carbon range.

<MDL = Less than method detection limit; NDST = No Data, see textual information; NDND = No Data: Not analyzed.

Appendix 5: *Hyalella azteca* Test Results

Appendix 5a*: Hyalella azteca* 14 – day test for survival and growth toxicity summary

TEST METHOD ***Based on:***

Environment Canada. Biological Test Method: Test for Survival and Growth in Sediment Using the Freshwater Amphipod *Hyalella azteca* . EPS 1/RM/33. December 1997.

TEST SYSTEM:

Sediment volume:	100 mL	**Test containers:**	700 mL glass jars	**Feeding:**	2 mg TetraMin 3 times per week
Water volume:	400 mL	**Test water source:**	dechlor. Toronto Tap	**Test Option:**	static, aerated
No. animals/replicate:	10	**No. replicates:**	3		

CULTURE INFORMATION:

QA/QC DATA (a reference toxicant test was performed using the same culture)**:**

Batch No.:	Sept 9/05	**Reference test date:** Sept.08.05	**Historical Mean (mg/L):** 307
Age Range, at time 0:	4-8 days	**ATU Sample No.:** 01050425	**Historical Warning**
		96-hr LC50 (mg/L KCl): 379	**Limits (mg/L):** 204 - 409
		95% confidence limits (mg/L): 332 - 432	

RESULTS:

Date Test Initiated:	Sept.13.05	**Initiated by:** Trudy Watson-Leung, Kim Hunter
Date Test Terminated:	Sept.27.05	**Terminated by:** Trudy Watson-Leung, Richard Chong-Kit, Kim Hunter, Marcie Chaudet
Statistical Software:	TOXSTAT 3.5	

1) Survival Effects (≥ 80% required in the control)

Sediment	**Percentage Survival** (n = 10 per replicate)			**Mean Survival per sediment (%)**	**Percent Survival**		**Coefficient of Variation (%)**
	rep. A	**rep. B**	**rep. C**		**of control**	**of reference**	
Lake Erie **control**	100	90	100	97	n/a	112	6
LG 87	70	80	80	77	79*	88	8
LG 231	100	80	60	80	83	92	25
LG 248	90	80	90	87	90	100	7
LG 249	100	100	70	90	93	104	19
LG 292 **reference**	100	100	60	87	90	100	27

* significantly different than survival in the control sediment using Fisher's Exact test (α = 0.05)

2) Growth Effects (dry weight measured, ≥ 0.1 mg required in the control)

Sediment	**Dry weight per organism** (mg)			**Mean Dry Weight per sediment (mg)**	**Percent Growth**		**Coefficient of Variation (%)**
	rep. A	**rep. B**	**rep. C**		**of control**	**of reference**	
Lake Erie **control**	0.11	0.08	0.07	0.09	n/a	116	24
LG 87	0.06	0.08	0.04	0.06	68	79	30
LG 231	0.06	0.03	0.04	0.04	**! 46**	**! 54**	38
LG 248	0.05	0.08	0.07	0.07	79	92	22
LG 249	0.11	0.04	0.10	0.08	98	114	42
LG 292 **reference**	0.09	0.04	0.09	0.07	86	n/a	42

! biologically significant impairment in growth relative to the control and/or reference sediment.

Appendix 5b: *Hyalella azteca* 14 – day test for survival and growth water quality parameters

DAY 0						**Ammonia**	**Unionized Ammonia**
Sample Name	**Replicate**	**pH**	**DO**	**Conductivity**	**Temperature**	**NH_3 + NH_4**	**NH_3**
			mg/L	**µS/cm**	**°C**	**mg/L**	**mg/L**
Lake Erie **control**	A-C*	8.1	8.6	379	21.1	2.0	0.1
LG 87	A-C*	8.1	8.8	294	21.1	1.0	0.1
LG 231	A-C*	7.6	8.5	266	21.1	0.6	<0.1
LG 248	A-C*	8.1	8.4	321	21.4	0.7	<0.1
LG 249	A-C*	8.0	8.8	272	21.0	0.1	<0.1
LG 292 **reference**	A-C*	8.0	8.7	268	21.2	0.4	<0.1

A-C* = A:40 mL; B:40 mL; C:20 mL

DAY 7						**Ammonia**	**Unionized Ammonia**
Sample Name	**Replicate**	**pH**	**DO**	**Conductivity**	**Temperature**	**NH_3 + NH_4**	**NH_3**
			mg/L	**µS/cm**	**°C**	**mg/L**	**mg/L**
Lake Erie **control**	A-C+	8.1	8.1	454	22.3	<0.1	<0.1
LG 87	A-C^+	8.1	8.4	261	22.2	0.1	<0.1
LG 231	A-C^+	7.6	8.3	217	22.1	0.1	<0.1
LG 248	A-C^+	7.9	8.0	323	22.4	0.2	<0.1
LG 249	A-C^+	8.2	8.4	251	22.4	0.1	<0.1
LG 292 **reference**	A-C^+	7.8	8.4	231	22.4	0.1	<0.1

A-C^+ = A:20 mL; B:40 mL; C:40 mL

DAY 14						**Ammonia**	**Unionized Ammonia**
Sample Name	**Replicate**	**pH**	**DO**	**Conductivity**	**Temperature**	**NH_3 + NH_4**	**NH_3**
			mg/L	**µS/cm**	**°C**	**mg/L**	**mg/L**
Lake Erie **control**	A	8.0	8.5	459	22.5	0.4	<0.1
LG 87	A	7.8	8.7	272	22.8	<0.1	<0.1
LG 231	A	7.3	8.5	210	22.5	0.1	<0.1
LG 248	A	8.0	8.8	360	22.6	0.4	<0.1
LG 249	A	7.8	8.9	244	22.9	<0.1	<0.1
LG 292 **reference**	A	7.5	8.6	226	23.0	0.2	<0.1

Appendix 6: *Hexagenia* spp. Test Results

Appendix 6a: *Hexagenia* spp.21 – day test for survival and growth toxicity summary

TEST METHOD *Based on:*

Bedard D, A Hayton & D Persaud. 1992. *Ontario Ministry of the Environment Laboratory Sediment Biological Testing Protocol,* Ontario Ministry of the Environment, Toronto, ON. 23 p.

American Society for Testing and Materials. 2000. *Test Method for Measuring the Toxicity of Sediment-Associated Contaminants with* Freshwater Invertebrates. E 1706-00. Annual Book of ASTM Standards, Vol 11.05. pp 1109-1223.

TEST SYSTEM:

Sediment volume:	325	**Test containers:**	1.8 L glass jars	**Feeding:**	none
Water volume:	1300 mL	**Test water source:**	dechlor. Toronto Tap		
No. animals/replicate:	10	**No. replicates:**	3	**Test Option:**	static, aerated

CULTURE INFORMATION: **QA/QC DATA** (a reference toxicant test was performed using the same culture)**:**

Batch No.:	LEC 50 & 54	**Reference test date:**	Aug.19.2005	**Historical Mean:**	3.2 mg/L KCl
Average wet weight:	4.04 (±1.88)	**ATU Sample No.:**	01050377	**Historical Warning Limits (mg/L KCl):**	1.4 - 5.1
		96-hr LC50 (mg/L KCl):	2.91		
		95% confidence limits:	2.01 - 4.24 mg/L		

RESULTS:

Date Test Initiated: Sept.07.05 **Initiated by:** Trudy Watson-Leung and Kim Hunter
Date Test Terminated: Spet.28.05 **Terminated by:** Trudy Watson-Leung, Kim Hunter and Marcie Chaudet
Statistical Software: TOXSTAT

1) Survival Effects (≥ 80% required in the control)

Sediment	**Percentage Survival** (n = 10 per replicate)			**Mean Survival**	**Percent Survival**		**Coefficient of**
	rep. A	**rep. B**	**rep. C**	**per sediment (%)**	**of control**	**of reference**	**Variation (%)**
Lake Erie **control**	90	100	100	97	n/a	104	6
LG 87	100	100	100	100	103	107	0
LG 231	90	70	80	80	83	86	13
LG 248	80	100	80	87	90	93	13
LG 249	90	90	90	90	93	96	0
LG 292 **reference**	80	100	100	93	97	n/a	12

* no sediments were significantly different than survival in the control or reference sediment using Fisher's Exact test ($\alpha = 0.05$)

2) Growth Effects (wet weight measured; 2x initial weight required in control)

Sediment	**Wet weight per organism** (mg)			**Mean Wet Weight**	**Percent Growth**		**Coefficient of**
	rep. A	**rep. B**	**rep. C**	**per sediment (mg)**	**of control**	**of reference**	**Variation (%)**
Lake Erie **control**	14.27	12.37	12.90	13.18	n/a	74	7
LG 87	15.74	17.22	17.30	16.75	127	94	5
LG 231	7.62	8.58	9.65	8.62	65	! 48	12
LG 248	8.07	8.30	10.35	8.91	68	! 50	14
LG 249	7.76	8.79	6.80	7.78	! 59	! 44	13
LG 292 **reference**	16.08	21.16	16.33	17.86	135	n/a	16

! biologically significant impairment in growth relative to the control and/or reference

Appendix 6b: *Hexagenia* spp.21 – day test for survival and growth water quality parameters

DAY 0

Sample Name	Replicate	pH	DO mg/L	Conductivity µS/cm	Temperature °C	Ammonia $NH_3 + NH_4$ mg/L	Unionized Ammonia NH_3 mg/L
Lake Erie **control**	A	8.1	8.8	369	23.0	2.0	0.1
LG 87	A	7.8	8.7	299	22.7	0.8	<0.1
LG 231	A	7.6	8.6	269	23.1	0.5	<0.1
LG 248	A	8.1	8.9	315	22.9	0.4	<0.1
LG 249	A	7.9	8.8	285	23.0	<0.1	<0.1
LG 292 **reference**	A	7.8	9.0	276	23.0	0.2	<0.1

DAY 8

Sample Name	Replicate	pH	DO mg/L	Conductivity µS/cm	Temperature °C	Ammonia $NH_3 + NH_4$ mg/L	Unionized Ammonia NH_3 mg/L
Lake Erie **control**	B	8.1	8.4	443	21.5	<0.1	<0.1
LG 87	B	7.7	8.4	246	21.5	0.1	<0.1
LG 231	B	7.4	9.0	192	21.6	<0.1	<0.1
LG 248	B	8.2	8.7	394	21.6	<0.1	<0.1
LG 249	B	7.8	8.9	230	21.6	<0.1	<0.1
LG 292 **reference**	B	7.5	8.5	203	21.5	<0.1	<0.1

DAY 21

Sample Name	Replicate	pH	DO mg/L	Conductivity µS/cm	Temperature °C	Ammonia $NH_3 + NH_4$ mg/L	Unionized Ammonia NH_3 mg/L
Lake Erie **control**	C	8.1	8.6	405	22.7	0.3	<0.1
LG 87	C	7.4	8.1	226	22.6	<0.2	<0.1
LG 231	C	7.2	8.5	173	22.7	<0.2	<0.1
LG 248	C	8.2	8.8	324	22.8	<0.2	<0.1
LG 249	C	7.9	8.9	220	23.0	<0.2	<0.1
LG 292 **reference**	C	7.1	8.5	176	23.1	<0.2	<0.1

Appendix 7: *Chironomus tentans* Test Results

Appendix 7a: *Chironomus tentans* – 14-day test for growth and survival toxicity summary

TEST METHOD: (modified based on the following 2 methods)

Environment Canada. Biological Test Method: Test for Survival and Growth in Sediment Using the Larvae of Freshwater Midges (*Chironomus tentans* or *Chironomus riparius*). EPS 1/RM/32. December 1997.

and

Bedard, D., A. Hayton and D. Persaud. 1992. Ontario Ministry of the Environment Laboratory Sediment Biological Testing Protocol, Ontario Ministry of the Environment, Water Resources Branch, ISBN 0-7729-9924-4, Toronto, Ontario. 23 p.

TEST SYSTEM:

Sediment volume: 100 mL
Water volume: 400 mL
No. animals/replicate: 10

Test containers: 700 mL glass jars
Test water source: dechlor. Toronto Tap
No. replicates: 3

Feeding: 2 mL (1.5 mg d.w./100 mL) of 3:2 cereal leaves (Cerophyll®): Fish food flake (Spirulina®) mixture; 4 times on non-consecutive day
Test Option: static, aerated

CULTURE INFORMATION:

Tank No./source: Tray 60 and 61
Date of Hatch out: Sept.5/6.05
Mean Head Capsule Width (mm ± s.d.) at t=0: 0.35 ± 0.06

QA/QC DATA (a KCl reference toxicant test was performed using the same culture)**:**

Reference test date: Sept.20.2005
ATU Sample No.: 01050447
96-hr LC50 (g/L KCl): 3.12
95% confidence limits (g/L): 2.87 - 3.38

Historical Mean (g/L): 5.05
Historical Warning Limits (g/L): 2.04 - 8.06

RESULTS:

Date Test Initiated: Sept.20.05
Date Test Terminated: Sept.30.05
Statistical Software: TOXSTAT 3.5

Initiated by: Trudy Watson-Leung, Kim Hunter
Terminated by: Kim Hunter, Marcie Chaudet, Richard Chong-Kit

1) Survival Effects (? 70% required in the control)

Sediment	**Percentage Survival** (n = 10 per replicate)			**Mean Survival per sediment (%)**	**Percent Survival**		**Coefficient of Variation (%)**
	rep. A	**rep. B**	**rep. C**		**of control**	**of reference**	
Lake Erie **control**	100	100	90	97	n/a	126	6
LG 87	70	100	70	80	83	104	22
LG 231	20	80	40	47	48*	61*	65
LG 248	100	100	100	100	103	130	0
LG 249	80	100	90	90	93	117	11
LG 292 **reference**	90	40	100	77	79	n/a	42

* significantly less survival than in the control or reference sediment using Fisher's Exact test ($\alpha = 0.05$)

2) Growth Effects (wet weight measured; ? 5.0 mg per organism (average) required in control)

Sediment	**Wet weight per organism** (mg)			**Mean Dry Weight per sediment (mg)**	**Percent Growth**		**Coefficient of Variation (%)**
	rep. A	**rep. B**	**rep. C**		**of control**	**of reference**	
Lake Erie **control**	12.00	9.79	15.26	12.35	n/a	89	22
LG 87	11.12	11.55	8.93	10.53	85	75	13
LG 231	22.66	14.70	14.72	17.36	141	124	26
LG 248	10.87	11.30	10.01	10.73	87	77	6
LG 249	12.76	15.15	12.13	13.35	108	96	12
LG 292 **reference**	12.07	16.15	13.64	13.95	113	n/a	15

Appendix 7b: *Chironomus tentans* – 14-day test for growth and survival water quality parameters

DAY 0

Sample Name	Replicate	pH	DO mg/L	Conductivity µS/cm	Temperature °C	Ammonia $NH_3 + NH_4$ mg/L	Unionized Ammonia NH_3 mg/L
Lake Erie **control**	A-C*	8.2	8.3	370	22.0	2.0	0.1
LG 87	A-C*	8.1	8.4	273	22.0	0.8	<0.1
LG 231	A-C*	7.8	8.3	256	22.2	0.4	<0.1
LG 248	A-C*	8.1	8.3	303	22.1	0.7	<0.1
LG 249	A-C*	7.9	8.4	261	22.1	<0.1	<0.1
LG 292 **reference**	A-C*	8.0	8.5	247	22.1	0.3	<0.1

* 40 mL A, 40 mL B and 20 mL C

DAY 5

Sample Name	Replicate	pH	DO mg/L	Conductivity µS/cm	Temperature °C	Ammonia $NH_3 + NH_4$ mg/L	Unionized Ammonia NH_3 mg/L
Lake Erie **control**	A-C*	8.3	7.9	447	23.1	<0.1	<0.1
LG 87	A-C*	8.1	8.1	274	23.3	<0.1	<0.1
LG 231	A-C*	7.6	7.6	221	23.3	0.1	<0.1
LG 248	A-C*	8.1	7.8	344	23.4	<0.1	<0.1
LG 249	A-C*	7.8	8.0	265	23.5	0.2	<0.1
LG 292 **reference**	A-C*	7.8	8.3	241	23.5	0.1	<0.1

DAY 10

Sample Name	Replicate	pH	DO mg/L	Conductivity µS/cm	Temperature °C	Ammonia $NH_3 + NH_4$ mg/L	Unionized Ammonia NH_3 mg/L
Lake Erie **control**	C	7.9	7.4	458	23.0	0.3	<0.1
LG 87	C	8.2	8.5	290	23.2	<0.1	<0.1
LG 231	C	7.7	8.1	216	23.2	0.1	<0.1
LG 248	C	8.0	7.5	350	23.1	<0.1	<0.1
LG 249	C	8.0	8.4	265	23.1	0.1	<0.1
LG 292 **reference**	C	7.6	7.7	237	23.2	0.2	<0.1

Appendix 8: Chemistry of Water Overlying Test Sediments

Appendix 8a: Metal and nutrient concentrations in the overlying water of the 14 – day *Hyalella azteca* toxicity test with Lake George and Little Lake George sediment (C130595). Values in bold text exceed the Provincial Water Quality Objective (PWQO)(MOE 1999).

Parameter	UNITS	PWQO	LEC	LG87	LG231	LG248	LG249	LG292 A+B	LG292 C
Calcium	mg/L		60.2	31.1	19.9	45.8	25.9	23.7	24.1
Magnesium	mg/L		11.2	6.84	4.88	8.24	6.1	5.52	5.7
Sodium	mg/L		13.8	12.6	10.4	12.2	11.1	10.4	10.7
Potassium	mg/L		3.22	4.05	1.79	2.32	1.91	1.78	2.09
Hardness	mg/L		197	106	69.8	148	89.8	81.8	83.6
Sulphate	mg/L		47.7	24.4	33.8	27.6	35.8	33.9	32.3
Conductivity	uS/cm		469	295	217	377	263	240	244
pH	none		8.39	8.16	7.58	8.22	7.89	7.76	7.8
Alkalinity; total fixed endpt	mg/L $CaCO_3$		145	76.4	21.4	120	41.5	32.2	33.1
Nitrogen; ammonia+ammonium	mg/L		0.051	0.017	0.146	0.244	0.095	0.196	0.127
Nitrogen; nitrite	mg/L		0.055	0.055	0.041	0.068	0.036	0.063	0.063
Nitrogen; nitrate+nitrite	mg/L		3.21	2.02	1.61	2.39	2.37	2.14	0.02
Phosphorus; phosphate	mg/L		0.0836	0.0255	0.0959	0.0675	0.0824	0.0701	2.84
Carbon; dissolved organic	mg/L		3.1	2.7	2	2.4	2	2.3	2.3
Carbon; dissolved inorganic	mg/L		33.7	17.9	5.1	29	9.8	7.7	7.3
Silicon; reactive silicate	mg/L		9.74	3.6	8.6	7.24	8.92	5.98	5.32
Aluminum	ug/L	75	**131 +/-12**	**78.1 +/-7**	20 +/-3	35.2 +/-3	**655 +/-59**	58.6 +/-5	25.1 +/-3
Barium	ug/L		61.3 +/-4.3	44 +/-3.1	31.7 +/-2.2	44.5 +/-3.1	34.1 +/-2.4	31.3 +/-2.2	32 +/-2.2
Beryllium	ug/L	1100 (hardness >75 mg/L)	0.00638 +/-0.02	-0.00445 +/-0.02	0.00867 +/-0.02	-0.000559 +/-0.02	0.0215 +/-0.02	-0.000832 +/-0.02	0.00375 +/-0.02
Calcium	mg/L		60 +/-7.20	29.5 +/-3.54	18.7 +/-2.25	45.4 +/-5.45	25.8 +/-3.10	22.4 +/-2.69	23 +/-2.76
Cadmium	ug/L	0.1 (hardness 0-100); 0.5 (hardness >100 mg/L)	0.0323 +/-0.8	-0.293 +/-0.8	**0.375 +/-0.8**	0.135 +/-0.8	**0.203 +/-0.8**	**0.751 +/-0.8**	**0.443 +/-0.8**
Cobalt	ug/L	0.6	0.567 +/-1.5	-0.26 +/-1.5	**0.641 +/-1.5**	0.468 +/-1.5	0.579 +/-1.5	-0.506 +/-1.5	0.394 +/-1.5
Chromium	ug/L	Cr VI = 1; Cr III = 8.9	-0.516 +/-1.0	0.195 +/-1.0	-0.00801 +/-1.0	-0.000185 +/-1.0	0.289 +/-1.0	-0.509 +/-1.0	-0.36 +/-1.0
Copper	ug/L	5 (hardness >20)	**6 +/-0.8**	3.49 +/-0.8	**5.01 +/-0.8**	4 +/-0.8	**6.92 +/-0.8**	**6.03 +/-0.8**	**5.09 +/-0.8**
Iron	ug/L	300	205 +/-16.4	164 +/-13.1	48 +/-3.8	50.7 +/-4.1	**978 +/-78.3**	99.6 +/-8.0	38.4 +/-3.1
Magnesium	mg/L		10.9 +/-1.20	7.01 +/-0.77	4.8 +/-0.53	8.09 +/-0.89	6.24 +/-0.69	5.43 +/-0.60	5.63 +/-0.62
Manganese	ug/L		6.12 +/-0.5	4.17 +/-0.3	1.68 +/-0.2	0.932 +/-0.2	52.9 +/-4.2	4.92 +/-0.4	1.38 +/-0.2
Molybdenum	ug/L	40	2.64 +/-1.5	0.653 +/-1.5	0.158 +/-1.5	1.45 +/-1.5	0.0586 +/-1.5	0.0586 +/-1.5	0.455 +/-1.5
Nickel	ug/L	25	1.97 +/-1.5	0.893 +/-1.5	0.485 +/-1.5	0.223 +/-1.5	1.22 +/-1.5	0.387 +/-1.5	1.45 +/-1.5
Lead	ug/L	5 (hardness >80)	1.42 +/-11	-3.78 +/-11	2.58 +/-11	-1.59 +/-11	2.17 +/-11	-1.25 +/-11	-1.11 +/-11
Strontium	ug/L		276 +/-22.1	92.8 +/-7.4	62.2 +/-5.0	108 +/-8.7	74.5 +/-6.0	71.1 +/-5.7	77.2 +/-6.2
Titanium	ug/L		4.05 +/-0.3	3.19 +/-0.3	0.621 +/-0.3	1.55 +/-0.3	22.6 +/-1.8	2.06 +/-0.3	0.636 +/-0.3
Vanadium	ug/L	6	2.48 +/-1.0	1.25 +/-1.0	0.873 +/-1.0	2.62 +/-1.0	3.78 +/-1.0	1.85 +/-1.0	2.03 +/-1.0
Zinc	ug/L	20	19.8 +/-2.0	**21.8 +/-2.2**	**24.7 +/-2.5**	**24.8 +/-2.5**	**30.2 +/-3.0**	**24.6 +/-2.5**	**20.7 +/-2.1**

<=W = No measurable response (zero), < reported value; <T = A measurable trace amount, interpret with caution

Appendix 8b: Metal and nutrient concentrations in the overlying water of the 21 – day *Hexagenia* spp. toxicity test with Lake George/Little Lake George sediment (C130599). Values in bold text exceed the Provincial Water Quality Objective (PWQO) (MOE 1999).

Parameter	Units	PWQO	LEC	LG87	LG231	LG248	LG249	LG292
Calcium	mg/L		59.3	24.0	16.2	43.5	25.3	16.1
Hardness	mg/L		197	83.0	57.8	142	86.4	56.4
Magnesium	mg/L		11.9	5.64	4.2	8.1	5.62	3.94
Potassium	mg/L		2.73	2.74	1.18	1.63	1.49	1.32
Sodium	mg/L		12.9	11.4	9.48	11.3	9.96	9.52
Sulphate	mg/L		55.1	35.7	34.1	25.5	25.4	32.8
Alkalinity; total fixed endpt	mg/L CaCO3		142	36.1	11.1	118	42.3	10.4
Conductivity	uS/cm		449	238	184	347	228	179
pH	none		8.38	7.82	7.31	8.34	7.95	7.28
Nitrogen; ammonia+ammonium	mg/L		0.007	0.014	0.015	0.006	0.006	0.049
Nitrogen; nitrate+nitrite	mg/L		1.01	0.502	0.374	0.55	0.314	0.562
Nitrogen; nitrite	mg/L		0.004	0.01	0.006	0.002	0.008	0.012
Phosphorus; phosphate	mg/L		0.0321	0.0086	0.0109	0.0136	0.0261	0.0116
Carbon; dissolved inorganic	mg/L		33.8	8.8	3.4	24.7	10.2	3.5
Carbon; dissolved organic	mg/L		3	2.6	1.8	2.2	2.2	1.7
Silicon; reactive silicate	mg/L		11.5	4.38	10.6	9.48	10.3	7.88
Aluminum	ug/L	75	**751 +/-68**	**862 +/-78**	**671 +/-60**	**437 +/-39**	**569 +/-51**	**1040 +/-93**
Barium	ug/L		73.3 +/-5.1	51.6 +/-3.6	36.7 +/-2.6	46.8 +/-3.3	32.2 +/-2.3	41.5 +/-2.9
Beryllium	ug/L	1100 (hardness >75 mg/L)	0.0405 +/-0.02	0.0362 +/-0.02	0.0286 +/-0.02	0.0234 +/-0.02	0.0295 +/-0.02	0.0455 +/-0.02
Cadmium	ug/L	0.1 (hardness 0-100); 0.5 (hardness >100 mg/L)	0.101 +/-0.8	0.255 +/-0.8	-0.122 +/-0.8	-0.293 +/-0.8	-0.242 +/-0.8	-0.0362 +/-0.8
Calcium	mg/L		60.8 +/-7.29	22.2 +/-2.67	15.5 +/-1.86	44.9 +/-5.39	23.4 +/-2.81	15.8 +/-1.90
Chromium	ug/L	Cr VI = 1; Cr III = 8.9	0.414 +/-1.0	***2.07** +/-1.0	0.665 +/-1.0	0.751 +/-1.0	**1.02** +/-1.0	**1.56** +/-1.0
Cobalt	ug/L	0.6	0.592 +/-1.5	0.308 +/-1.5	0.369 +/-1.5	0.517 +/-1.5	**0.678** +/-1.5	**0.826** +/-1.5
Copper	ug/L	5 (hardness >20)	4.37 +/-0.8	4.54 +/-0.8	3.99 +/-0.8	2.4 +/-0.8	4.38 +/-0.8	**5.49 +/-0.8**
Iron	ug/L	300	**1350** +/-107.8	**1400** +/-112.3	**958** +/-76.6	**552** +/-44.1	**804** +/-64.3	**1270** +/-101.4
Lead	ug/L	5 (hardness >80)	0.393 +/-11	3.61 +/-11	0.188 +/-11	-0.154 +/-11	2.92 +/-11	-0.564 +/-11
Magnesium	mg/L		11.3 +/-1.24	5.58 +/-0.61	4.16 +/-0.46	7.6 +/-0.84	5.52 +/-0.61	4.11 +/-0.45
Manganese	ug/L		76.3 +/-6.1	62.4 +/-5.0	63 +/-5.0	51.5 +/-4.1	88.8 +/-7.1	191 +/-15.3
Molybdenum	ug/L	40	2.04 +/-1.5	-0.635 +/-1.5	-0.338 +/-1.5	1.64 +/-1.5	-0.0405 +/-1.5	-0.536 +/-1.5
Nickel	ug/L	25	3.64 +/-1.5	2.23 +/-1.5	1.33 +/-1.5	0.615 +/-1.5	0.991 +/-1.5	2.44 +/-1.5
Strontium	ug/L		283 +/-22.7	61.7 +/-4.9	45.3 +/-3.6	93.5 +/-7.5	59 +/-4.7	42.7 +/-3.4
Titanium	ug/L		14.2 +/-1.1	21.6 +/-1.7	16.9 +/-1.4	12.5 +/-1.0	13.3 +/-1.1	21.6 +/-1.7
Vanadium	ug/L	6	4.44 +/-1.0	3.11 +/-1.0	2.38 +/-1.0	4.25 +/-1.0	2.97 +/-1.0	3.28 +/-1.0
Zinc	ug/L	20	5.95 +/-0.7	13.3 +/-1.3	11.8 +/-1.2	4.78 +/-0.7	8.76 +/-0.9	8.81 +/-0.9

<=W = No measurable response (zero), < reported value; <T = A measurable trace amount, interpret with caution

* form of Chromium unknown

Appendix 8c: Metal and nutrient concentrations in the overlying water of the 10 – day *Chironomus tentans* toxicity test with Lake George/Little Lake George sediment (C132116). Values in bold text exceed the Provincial Water Quality Objective (PWQO) (MOE 1999).

Parameter	UNITS	PWQO	LEC	LG87 B	LG87 A+C	LG231 B	LG231 A+C	LG248	LG249	LG292 B	LG292 A+C
Calcium	mg/L		58.1	32.3	32	23.9	21.5	46.1	33.5	24.9	25.8
Hardness	mg/L		191	112	110	84	76.4	151	112	86.4	88.2
Magnesium	mg/L		11.2	7.7	7.4	5.94	5.54	8.74	7.02	5.94	5.82
Potassium	mg/L		4.98	5.74	5.49	2.9	2.62	3.32	3.33	3.16	2.97
Sodium	mg/L		14	12.7	12.9	10.9	10.8	12.4	11.1	11.6	11.1
Sulphate	mg/L		46	23.8	28.5	31.2	33.1	26.5	33.1	33.5	32
Alkalinity; total fixed endpt	mg/L CaCO3		146	76.2	68.9	36	27.2	125	58.7	31.1	36.7
Conductivity	uS/cm		466	303	306	239	232	377	286	252	245
pH	none		8.34	8.12	8.1	7.74	7.55	8.29	7.94	7.27	7.19
Nitrogen; ammonia+ammonium	mg/L		0.004 <T	0.004 <T	0.005 <T	0.002 <=W	0.003 <T	0.006 <T	0.003 <T	0.008 <T	0.002 <=W
Nitrogen; nitrite	mg/L		0.006	0.005	0.004 <T	0.003 <T	0.003 <T	0.004 <T	0.003 <T	0.005	0.002 <T
Nitrogen; nitrate+nitrite	mg/L		3.54	2.45	2.56	1.66	2.25	1.88	2.28	3.05	2.12
Phosphorus; phosphate	mg/L		0.227	0.204	0.129	0.236	0.227	0.16	0.21	0.222	0.171
Carbon; dissolved organic	mg/L		4.6	17.5	15.9	8.1	6.5	29	14.1	7.3	9.1
Carbon; dissolved inorganic	mg/L		33.8	3.54	3.36	8.42	8.02	8.66	8.82	5.82	6.12
Silicon; reactive silicate	mg/L		11.1	5.3	4.5	4.5	3.9	4	5	4.7	3.8
Aluminum	ug/L	75	**558 +/-50**	**151 +/-14**	**128 +/-12**	**277 +/-25**	**330 +/-30**	**333 +/-30**	**435 +/-39**	**171 +/-15**	**737 +/-66**
Barium	ug/L		62.1 +/-4.3	49.4 +/-3.5	47.5 +/-3.3	38.1 +/-2.7	36.4 +/-2.6	51.7 +/-3.6	37.8 +/-2.6	35.6 +/-2.5	39.7 +/-2.8
Beryllium	ug/L	1100 (hardness >75 mg/L)	0.0353 +/-0.02	0.00335 +/-0.02	0.00576 +/-0.02	0.0144 +/-0.02	0.0148 +/-0.02	0.0206 +/-0.02	0.0125 +/-0.02	0.000886 +/-0.02	0.0243 +/-0.02
Calcium	mg/L		61.1 +/-7.34	30.4 +/-3.65	28.9 +/-3.46	22.6 +/-2.71	21.2 +/-2.54	47.4 +/-5.69	29.4 +/-3.52	23.6 +/-2.83	24 +/-2.88
Chromium	ug/L	Cr VI = 1; Cr III = 8.9	-0.346 +/-1.0	-0.637 +/-1.0	-0.801 +/-1.0	-0.533 +/-1.0	-0.659 +/-1.0	-0.421 +/-1.0	-0.152 +/-1.0	-0.868 +/-1.0	0.0341 +/-1.0
Cadmium	ug/L	0.1 (hardness 0-100); 0.5 (hardness >100 mg/L)	0.241 +/-0.8	-0.0498 +/-0.8	-0.205 +/-0.8	-0.437 +/-0.8	0.0083 +/-0.8	0.0083 +/-0.8	-0.0498 +/-0.8	0.0858 +/-0.8	**0.183 +/-0.8**
Cobalt	ug/L	0.6	**0.64 +/-1.5**	**1.15 +/-1.5**	**0.627 +/-1.5**	0.234 +/-1.5	**1.05 +/-1.5**	0.0851 +/-1.5	-0.348 +/-1.5	0.126 +/-1.5	0.505 +/-1.5
Copper	ug/L	5 (hardness >20)	**10.2 +/-1.1**	**8.57 +/-0.9**	**7.73 +/-0.9**	**7.59 +/-0.8**	**9.76 +/-1.1**	**8.93 +/-1.0**	**11.3 +/-1.2**	**11 +/-1.2**	**13.2 +/-1.5**
Iron	ug/L	300	**1070 +/-85.7**	**312 +/-24.9**	238 +/-19.0	**500 +/-40.0**	**582 +/-46.6**	**486 +/-38.9**	**782 +/-62.6**	254 +/-20.3	**1090 +/-87.3**
Magnesium	mg/L		10.8 +/-1.19	7.32 +/-0.81	7.09 +/-0.78	5.84 +/-0.64	5.62 +/-0.62	8.34 +/-0.92	6.97 +/-0.77	5.91 +/-0.65	6.05 +/-0.67
Manganese	ug/L		41 +/-3.3	13.8 +/-1.1	6.16 +/-0.5	196 +/-15.7	34.4 +/-2.7	24.5 +/-2.0	68.5 +/-5.5	14.7 +/-1.2	67.5 +/-5.4
Molybdenum	ug/L	40	0.988 +/-1.5	0.573 +/-1.5	0.85 +/-1.5	0.85 +/-1.5	0.573 +/-1.5	2.09 +/-1.5	0.711 +/-1.5	0.988 +/-1.5	-0.119 +/-1.5
Nickel	ug/L	25	4.11 +/-1.5	1.15 +/-1.5	1.66 +/-1.5	1.66 +/-1.5	1.61 +/-1.5	1.61 +/-1.5	1.73 +/-1.5	0.524 +/-1.5	2.03 +/-1.5
Lead	ug/L	5 (hardness >80)	2.74 +/-11	2 +/-11	3.99 +/-11	0.84 +/-11	-0.402 +/-11	0.591 +/-11	4.57 +/-11	-1.64 +/-11	3.49 +/-11
Strontium	ug/L		260 +/-20.8	95.9 +/-7.7	93.3 +/-7.5	72.6 +/-5.8	69.6 +/-5.6	103 +/-8.2	83.5 +/-6.7	73.6 +/-5.9	73.3 +/-5.9
Titanium	ug/L		14.7 +/-1.2	6.38 +/-0.5	5.04 +/-0.4	9.39 +/-0.8	12 +/-1.0	14.3 +/-1.1	15 +/-1.2	6 +/-0.5	28 +/-2.2
Vanadium	ug/L	6	2.04 +/-1.0	0.888 +/-1.0	2.4 +/-1.0	0.337 +/-1.0	0.561 +/-1.0	2.54 +/-1.0	1.58 +/-1.0	1.66 +/-1.0	3.63 +/-1.0
Zinc	ug/L	20	**27.8 +/-2.8**	**32.3 +/-3.2**	**24.2 +/-2.4**	19.2 +/-1.9	**22.6 +/-2.3**	**25.5 +/-2.6**	**33.1 +/-3.3**	**24.2 +/-2.4**	**27.8 +/-2.8**

<=W = No measurable response (zero), < reported value; <T = A measurable trace amount, interpret with caution

Appendix 9: Pearson Correlation of Sediment Chemistry and Toxicity Endpoints

Appendix 9a: Pearson correlations between measured metal, nutrient, PAH and oils and greases concentrations in the sediment and the mean survival and mean wet weight for the exposed *Chironomus tentans*, Hyalella azteca and Hexagenia spp. with Lake George/Little Lake George sediment (C129221 and/or C132116). Values in bold text had a negative correlation greater than 0.7.

	Chironomus tentans		*Hyalella azteca*		Hexagenia spp.	
	Survival	Growth	Survival	Growth	Survival	Growth
Nutrients						
Total Organic Carbon (TOC)	-0.544	0.661	-0.079	-0.078	-0.043	-0.044
Loss on Ignition (LOI)	-0.544	0.755	0.076	-0.011	-0.139	-0.073
Total Kjeldahl Nitrogen (TKN)	-0.542	0.887	0.341	-0.002	-0.514	-0.401
Total Phosphorous (TP)	-0.378	0.804	0.499	0.183	-0.445	-0.405
Metals						
Mercury (Hg)	-0.398	0.638	0.190	0.024	-0.340	-0.526
Aluminum (Al)	-0.467	0.843	0.386	0.114	-0.366	-0.239
Cadmium (Cd)	-0.342	0.392	-0.159	0.076	0.400	0.485
Chromium (Cr)	-0.479	0.783	0.249	0.076	-0.260	-0.233
Copper (Cu)	-0.516	0.799	0.206	0.045	-0.231	-0.152
Iron (Fe)	-0.438	0.753	0.282	0.097	-0.298	-0.339
Lead (Pb)	-0.196	0.532	0.441	0.137	-0.550	**-0.819**
Manganese (Mn)	-0.146	0.620	0.608	0.412	-0.254	-0.371
Nickel (Ni)	-0.478	0.817	0.315	0.093	-0.316	-0.245
Zinc (Zn)	-0.404	0.690	0.245	0.086	-0.292	-0.417
Arsenic (As)	-0.311	0.686	0.401	0.244	-0.231	-0.319
PAHs						
Acenaphthene	-0.474	0.327	-0.450	-0.295	0.078	-0.098
Acenaphthylene	-0.407	0.270	-0.367	-0.344	-0.175	-0.452
Anthracene	-0.346	0.172	-0.413	-0.328	-0.084	-0.395
Benzo(a)anthracene	-0.341	0.171	-0.403	-0.328	-0.101	-0.417
Benzo(a)pyrene	-0.332	0.172	-0.380	-0.324	-0.133	-0.455
Benzo(b)fluoranthene	-0.365	0.232	-0.356	-0.306	-0.132	-0.437
Benzo(e)pyrene	-0.382	0.251	-0.354	-0.322	-0.161	-0.456
Benzo(g,h,i)perylene	-0.340	0.244	-0.292	-0.258	-0.152	-0.478
Benzo(k)fluoranthene	-0.344	0.180	-0.395	-0.321	-0.101	-0.415
Chrysene	-0.357	0.211	-0.375	-0.308	-0.108	-0.417
Dibenzo(a,h)anthracene	-0.383	0.263	-0.352	-0.288	-0.102	-0.394
Fluoranthene	-0.364	0.216	-0.378	-0.314	-0.113	-0.417
Fluorene	-0.461	0.349	-0.363	-0.319	-0.122	-0.356
Indeno(1,2,3-c,d)pyrene	-0.349	0.227	-0.331	-0.296	-0.157	-0.474
Naphthalene	-0.415	0.242	-0.436	-0.357	-0.086	-0.348
Perylene	-0.660	0.827	-0.009	-0.136	-0.179	0.033
Phenanthrene	-0.412	0.285	-0.367	-0.315	-0.120	-0.392
Pyrene	-0.341	0.194	-0.370	-0.301	-0.107	-0.427
Oils and Greases						
Solvent extractable (SXT)	-0.636	0.576	-0.342	-0.289	0.151	0.594
F2 (C10 - C16)	**-0.701**	0.644	-0.370	-0.319	0.089	0.403
F3 (C16 - C34)	**-0.749**	0.639	-0.418	-0.452	0.005	0.539
F4 (C34 - C50)	-0.496	0.542	-0.084	-0.189	-0.003	0.592
Toluene	0.103	-0.574	**-0.758**	-0.213	0.739	0.590